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Current and Future Industrial Energy Service Characterizations

Volume I

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PREFACE

This three-volume report examines current and future energy demands, end uses, and costs to characterize typical applications and resultant services in the United States and industrial sectors of 15 selected states. It represents the first step of the Industrial Energy Service Characterization, initiated in November 1979, by the Solar Energy Research Institute (SERI) under Task No. 5638.10. This step was (1) to develop adequate and reliable industrial energy use data and (2) using existing data bases and state industrial energy models, to synthesize information on future needs for energy in the industrial sector by 4-digit SIC (Standard Industrial Classification) and state.

Volume I details the activities performed in this effort. Volume II presents data on the U.S. manufacturing subsector energy consumption, intensity, growth rates, and cost for 1971, 1974, and 1976. Volume III contains data on 15 selected states' manufacturing subsector energy consumption, intensity, growth rates, and cost for 1974 and 1976.

To proceed further in this task, the above data, plus data on process level or end-use level energy consumption and distribution of temperature levels for end-use energy requirements by disaggregated geographic areas, should be gathered in FY 1981, to include the states not considered in this report. The analytical methods and supporting data and specifically the energy consumption, intensity, growth rates, and cost data contained in Volumes II and III should be computerized so the results can be easily updated, refined, or expanded. A simple analysis of energy intensity trends will be refined and expanded to the 3-digit level—particularly after the 1977 Census of Manufacturers is published (expected in Fall 1980).

This report was prepared for the Office of Solar Applications for Industry, U.S. Department of Energy (DOE). SERI acknowledges the help of Synergic Resources Corporation who, under subcontract to SERI, prepared the final report on Projection of State Industrial Energy Demand and Prices. Technical advice and support were provided by David Feasby, Kenneth Brown, Michael DeAngelis, and David Roessner.

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SUMMARY

OBJECTIVES

To support and accelerate SERI research on (1) the industrial process heat (IPH) market assessment and development and (2) the comparative evaluation of solar thermal systems for IPH applications, this study examines the current and future energy demand, its end uses, and cost data to characterize typical energy applications and resultant services in the industrial sector and projects state industrial energy demand and prices for 15 selected states.

DISCUSSION

The detailed, accurate, and complete data on industrial end-use energy requirements (by type of heat and temperature range) and cost by disaggregated geographic areas are critical to supporting these objectives.

Existing industrial energy data bases were evaluated to assess their potential for supporting SERI research. The data sources, compilation methods, and degree to which verification and validation were performed; level of detail and disaggregation; and primary sources of information used to estimate end-use energy consumption were examined.

Data on the industrial sector energy demands, their functional uses, and costs in 1971, 1979, and 1976 were developed for the entire United States and 15 selected states (Alabama, California, Illinois, Indiana, Louisiana, Michigan, Missouri, New Jersey, New York, Ohio, Oregon, Pennsylvania, Texas, West Virginia, Wisconsin). These states have the greatest potential for replacing conventional fuel with solar energy.

The energy data developed include fuels and electric energy used for heat and power purchased by the manufacturing subsector and listed by 2-, 3-, and 4-digit SIC, primary fuel, and end use. Practical application of these data is demonstrated in the descriptive analysis of the U.S. manufacturing subsector energy service characterization.

The review of state energy forecasting models was conducted to determine future energy demands, end-uses, and prices in the industrial sector in the 15 selected states.

Also, several national models that forecast energy supply and prices are discussed. The discussion focuses on national energy models in general and the Department of Energy (DOE) Midterm Energy Forecasting System (MEFS) in particular.

Projections of state level energy prices to 1990 are developed and presented. These are based on: (1) state-level energy price data from 1960 to 1978 from the Federal Energy Data System (FEDS) price data base, (2) the 1978 Annual Report to Congress (ARC) regional price forecast, and (3) the world oil price assumptions from the 1979 ARC currently being prepared.

In developing the projections of a state's industrial energy demand the effects of federal and state industrial energy conservation programs were considered. The energy intensity approach, rather than national or regional econometric models, was used to develop projections of state industrial energy demand by 2-, 3-, and 4-digit SICs.

This study approaches existing data bases and data sources by disaggregating projections of energy requirements by 2-digit SICs to projections by end use (and temperature level) and 4-digit SICs. The end-use profiles for each 4-digit SIC industry were grouped as follows:

- hot water
- steam (212° F-300° F, each 100° F interval from 300° F-1000° F, and 1000° F).
- hot air (100° F intervals).

The end-use projections were integrated over the industrial mix in each state to obtain the temperature distribution for industrial energy use at the data level in 1990.

CONCLUSIONS AND RECOMMENDATIONS

The IPH market assessments must have a comprehensive and consistent data base on industrial energy consumption and cost that can be used to evaluate and target specific solar applications. Detailed, accurate, and complete data on current and future industrial end-use energy requirements (by type of heat and temperature range) and cost by disaggregated geographic areas are needed to achieve reliable results with technical performance, economic analysis, and comparative evaluation of solar thermal systems for IPH applications.

A review and evaluation of existing industrial energy data bases, which could be used to study industrial applications of solar energy, led to the following conclusions:

- Although several different data bases on industrial energy end use exist, generally, consistency in the information is lacking.
- With the exception of the Intertechnology Corporation (ITC) and Battelle data bases, which were developed specifically to study solar industrial applications, none of the other data bases provides the information required for evaluating industrial solar energy applications.
- Most data bases that report end-use information by quality and quantity of the energy used represent only hypothetical or reference plants.
- Most data bases that have real plant data do not provide the detail required on the quality and quantity of energy end uses.
- No single data base can be considered uniformly better than any other.
- The Drexel University Process Energy Data Base, which details data on 108 industrial processes and uses ITC and Battelle information, is probably the most detailed data source for end-uses at the 4-digit SIC level.
- The data bases vary significantly, perhaps corresponding to the variant energy consumption patterns throughout the United States. Unfortunately, no one has attempted to provide statistical measures of the actual variation in existing plants.
- Although, considerable time and resources have been expended in developing these various data bases, no effort has been made to verify or validate the data.
- There is a considerable gap between what these data bases claim to provide and what they actually provide.

- Meaningful site-specific detailed energy consumption data are needed. DOE is conducting a large-scale survey to develop such a data base, but it probably will not be available for several years.
- Most existing data bases are very limited in evaluating solar energy applications at a detailed geographic level.

Data from the Drexel University Industrial Process Energy Data Base and the ITC study can be used to develop a profile of industrial energy needs by temperature level for the major energy-consuming industries at the 4-digit level. However, the information from these two sources has significant limitations. The necessary reliance on these data base points out the need for systematically validating the data and modifying, refining, and expanding the data to satisfy SERI's needs.

In reviewing state energy models in 15 selected states, we found that 9 states do not have any documented models for forecasting or evaluating industrial energy use and conservation. The other six states (California, Wisconsin, New York, New Mexico, Texas, Oregon) do have formal models. All the models are primarily econometric and provide no end-use information. Except for the California model, no explicit consideration of conservation or cogeneration is included. The existing models are severely limited in forecasting industrial energy requirements at a level necessary to analyze solar energy potential.

Although several models have been developed at the national level to forecast energy supply and prices, none of the state models addressed forecasts of energy prices (except for electricity), which were generally required as input to the demand models. Most of these models have some disaggregation of fuels, sectors, and geographic regions; however, none provides state-specific output. Thus, none can directly obtain state-specific forecasts. We concluded that national energy models do provide some potential benefits, because the projections can be used at the regional level and simple disaggregation techniques developed to estimate state level data.

A brief review of federal and state industrial energy conservation programs indicated that although many energy periodicals frequently report the results of industrial energy conservation efforts by individual firms, it is difficult to determine the aggregate impacts of such efforts for a state or nation. Even though DOE has a mandatory industrial reporting program for the ten most energy-intensive industries that consume over 90% of the purchased energy used by the nation's manufacturers, it is very difficult to document which measures were actually taken in states and specific companies.

The results of this study indicate several areas of needed research. These are summarized below:

- An effort should be implemented to assemble real data on existing industrial plants initiated by SERI and in cooperation with other DOE laboratories for Industrial Energy Data Collection (IEDC). Such a data base could be used to refine the end-use estimates developed in this study.
- A systematic, statistically-based effort to validate existing industrial data bases should be done.
- An analysis of energy intensity trends should be refined and expanded to the 3-digit level, particularly after the <u>1977 Census of Manufacturers</u> data are published (expected in Fall 1980).

- The analytical methods and supporting data used in this study should be automated so that the results can be easily updated, refined, or expanded to cover additional industries or states.
- For industries likely to be primary candidates for solar energy applications, more detailed energy-use profiles (by end use) should be developed. They should also include information on the major determinants of energy usage patterns to facilitate an analysis of the impact of conservation, cogeneration, and various regulatory/policy options.
- Cooperative research programs should be established with state agencies or other research groups (EPRI, ARI, etc.) to develop innovative research methods.

TABLE OF CONTENTS

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (continued)

TABLE OF CONTENTS (concluded)

LIST OF FIGURES

LIST OF FIGURES (Concluded)

LIST OF TABLES

LIST OF TABLES (Continued)

LIST OF TABLES (Concluded)

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NOMENCLATURE

ABMA	American Boiler Manufacturers Association
AEROS	Aerometric and Emissions Reporting System
ARC	Annual Report to Congress
BESOM	Brookhaven Energy Systems Optimization Model
CEC	California Energy Commission
CES	Capital Energy Substitution
CHRDS	Comprehensive Human Resources Data System
DNR	Department of Natural Resources (Wisconsin)
DOE	Department of Energy
DRI	Data Resources, Inc.
ECDB	Energy Consumption Data Base
ECPA	Energy Conservation and Production Act
EED	Econometric Electrical Demand
EIA	Environmental Impact Assessment
EMS	Energy Management System
EPA	Environmental Protection Agency
EPCA	Energy Policy and Conservation Act
EPRI	Electric Power Research Institute
ERDA	Energy Research and Development Administration
FEA	Federal Energy Administration
FEDS	Federal Energy Data System
FERC	Federal Energy Regulatory Commission
FEUDS	Facility Energy Utilization Data System
FUA	Fuel Use Act
GEA	General Energy Associates
GEAC	Governor's Energy Advisory Council (Texas)
IEA	Institute for Energy Analysis
IEDC	Industrial Energy Data Collection
IEES	International Energy Evaluation System
IPEP	Industrial Plant Energy Profiles
IPH	Industrial Process Heat
IPHDB	Industrial Process Heat Data Base
ISTUM	Industrial Sector Technology Use Model

NOMENCLATURE (Concluded)

ITC	Intertechnology Corporation
LEAP	Long-Term Energy Analysis Package
LPP	Linear Programming Processing Model
MEFS	Midterm Energy Forecasting System
MEMM	Midterm Energy Market Model
MFBI	Major Fuel-Burning Installations
NECPA	National Energy Conservation Policy Act
NEDS	National Emissions Data System
NEPP	Northwest Energy Policy Project
NGPA	Natural Gas Policy Act
NSF	National Science Foundation
ORC	Ohio Revised Code
ORNL	Oak Ridge National Laboratory
PG&E	Pacific Gas and Electric
PIES	Project Independence Evaluation System
PUC	Public Utilities Commission
PURPA	Public Utility Regulatory Policy Act
RPA	Resource Planning Associates
RPMS	Refinery and Petrochemical Modeling System
SERI	Solar Energy Research Institute
SIC	Standard Industrial Classification
SMSA	Standard Metropolitan Statistical Area
SWEEP	Southwest Water, Economy, Energy, and Population Novel
TERA	Total Energy Resource Analysis
USBM	U.S. Bureau of Mines

SECTION 1.0

INTRODUCTION

1.1 BACKGROUND

Studies of the industrial market, solar system configurations, market suitability, and industrial decision-making criteria indicate there are potential industrial applications for solar energy. Applications that maximize the comparative advantages of solar energy relative to other energy forms need to be identified. The Solar Energy Research Institute (SERI) has undertaken several programs to investigate these potential applications. For example, studies of solar industrial process heat (IPH) were initiated at SERI in early 1978. Since that time, studies of the industrial market, solar system configurations, and model development have taken place to assist in evaluating the potential industrial applications for solar energy (Brown 1980).

The potential in the industrial sector depends on several factors including:

- the state's industrial mix,
- air quality regulations,
- fuel consumption patterns,
- conventional fuels and electricity prices,
- state and local incentives for solar energy use and conservation,
- availability of solar energy resources,
- solar systems capital and energy costs, and
- degree of current activity in the state related to solar energy utilization.

The evaluation of solar applications requires information on location, fuel prices and availability, environmental considerations, availability of solar resources, and energy end-use requirements in the industrial plant. Identifying viable solar systems also requires that systems' engineering and design satisfy the requirements of the most appropriate applications and that systems development activities respond to the needs of the marketplace. At SERI, we have attempted to develop a structured program encompassing the various activities related to developing optimum solar systems for industrial needs. These activities include:

- industrial market analysis,
- market development activities,
- case studies of solar energy applications in industry,
- identification of criteria used by industrial decision makers in evaluating energy investments,
- development of performance analysis models for IPH applications, and
- comparative evaluation and systems analysis of solar thermal systems for various industrial applications.

The results of these activities depend on the availability and validity of data on industrial energy demands, functional uses, and cost. These same data are important in characterizing typical energy applications and resultant services in the sector. Industrial data are needed that geographically disaggregates to the state level or below and provides information on energy end use by type and temperature level. For example, market suitability studies and development activities provide information on industrial groups that could be most helpful for solar energy applications. But because of the diversity of the quality and quantity of energy used in different industries, detailed and geographically disaggregated information is required. Similarly, end-use matching studies (Brown et al. 1979) and industrial applications case studies (Hooker, May, and West 1980) require reliable data on energy end uses at the 4-digit SIC (Standard Industrial Classification) or greater level. The analysis of cost and performance goals, which has used available end-use data, needs more accurate and disaggregated information. Finally, the comparative evaluation of solar thermal systems requires end-use data by temperature to help rank solar systems.

SERI has already undertaken several research activities that characterize industrial energy demand, end uses, and cost. Information has been and is being collected on industrial energy utilization through case studies and information gathered from existing data bases. In a related project, a Market Development Directory (Colorado School of Mines 1980) for solar IPH systems has been compiled. This directory identifies industrial plants at the 4-digit SIC level that are considered promising candidates for solar energy use. In another SERI study, End-Use Matching for Solar Industrial Process Heat (Brown et al. 1979), an evaluation of IPH requirements and the matching of specific solar systems was performed for selected industries in six cities. In most of these studies, SERI researchers found several data bases on industrial energy consumption at the national level. However, none of them was specifically designed to satisfy the detailed data requirements for solar energy systems analysis. Also, the information was inconsistent, and none provided information on future industrial energy needs at the end-use level or at the state or substate level.

1.2 OBJECTIVES AND SCOPE

The principal objectives of this study were to:

- examine the current energy demand, its end uses, and cost to characterize typical energy applications and resultant services in the industrial sector;* and
- develop a projection of state industrial energy demand and prices to 1990 for 15 selected states.

Most project research was directed to seven operational objectives that:

- determine requirements for industrial energy data;
- review and evaluate existing data bases on industrial energy consumption at the end-use level;

*Although industry includes agriculture, mining, construction, and manufacturing, this report considered only the manufacturing subsector.

- develop data bases on the quantity and cost of fuels and electric energy used for heat and power by the United States and selected state industrial sectors by 2-, 3-, and 4-digit SICs; primary fuel, and functional use;
- identify and review projections and forecasting models of industrial energy demand and prices at the state level;
- select the most useful models and projection methods;
- review and update the projections of state industrial energy demand and price accounting for effects of industrial conservation; and
- disaggregate projections to the 4-digit level using secondary data sources.

This report details the activities performed in this effort. Section 2.0 discusses the requirements for industrial data based on reviews of past and on-going research to determine potential applications of solar energy in industry. Section 3.0 reviews and evaluates existing data bases on industrial energy end use. Sections 4.0 and 5.0 analyze the quantity and cost of fuels and electric energy used for heat and power by the United States and selected state industrial sectors. The data are broken down by 2-, 3-, and 4-digit SIC, primary fuel, and functional use. Sections 6.0 and 7.0 describe existing state energy models and energy pricing methods, respectively. The federal- and state-supported industrial energy conservation programs and the implications for projecting industrial energy demand and prices are discussed in Sec. 8.0. Section 9.0 describes the approach used in this study to develop projections of state-level industrial energy needs at the 2-digit SIC level. Section 10.0 describes the data sources, procedures, and results of the disaggregation of the 2-digit projections to the 4-digit level. Appendix A reviews selected data bases. Appendix B describes state energy models in California, New Mexico, New York, Oregon, Texas, and Wisconsin. Appendices C and D present federal conservation acts affecting state industrial energy demand and conservation programs in 15 states, respectively. Appendix E has tables showing the results of an analysis of energy intensities.

Volume II contains a summary of the data developed for the current U.S. manufacturing subsector energy service characterization. The disaggregated data required to characterize the state manufacturing subsector energy usage patterns are provided in Volume III.

SECTION 2.0

REQUIREMENTS FOR INDUSTRIAL ENERGY DATA

2.1 INTRODUCTION

This section defines the industrial energy data needs for the various studies being conducted at SERI to evaluate and accelerate the implementation of IPH solar technologies. This information is based on reviews of past and on-going research and interviews with several SERI task leaders and researchers. It is not meant to be a comprehensive list of all SERI's data requirements, but merely an identification of typical information requirements.

The specific projects include:

- market suitability analysis,
- market development,
- end-use matching,
- industrial applications case studies,
- development of cost and performance goals for solar systems, and
- comparative evaluation of solar thermal systems for industry.

A brief description of the industrial energy information needs for these applications follows.

Market Suitability Analysis. The market suitability analysis determines the most suitable geographic locations for solar technologies in the industrial sector. In addition, it attempts to identify those industrial manufacturing groups that could most benefit from solar energy commercialization.

Market Development. Market development at SERI attempts to accelerate the implementation of solar energy in specific industrial groups by identifying the specific applications of solar energy, the potential cost and benefits, and the location and concentration of industries that constitute the near-term market. SERI then can design and develop specific systems to satisfy market requirements in the most cost-effective manner, disseminate information to industrial audiences about solar applications, and influence industry relative to new energy investments.

To accomplish this, market development must have an excellent data base on industrial energy consumption. Current activities include preparing a Market Development Directory (Colorado School of Mines 1980) that identifies industrial plants considered suitable for solar applications. Unfortunately, existing data bases (described in Sec. 3.0) do not provide accurate and reliable information on industrial energy use by end use. The applicability of the data provided on temperature and pressure of steam or temperature of hot air is questionable.

End-Use Matching. End-use matching identifies the optimal match of solar collector technology and industrial process energy needs. Various combinations of solar collectors, industrial processes, and geographic locations are evaluated. The location provides information on available insolation; performance characteristics of various collectors translate this into energy available for industrial process needs; and process information provides data on energy requirements. Evaluating these three areas by using a systems approach provides information to determine which systems will deliver the required energy at the lowest cost; i.e., solar systems designed to operate close to required process temperatures, which minimizes energy waste after collection. Thus, the end-use matching process identifies viable near-term solar applications and compares alternative systems for specific local conditions.

To perform end-use matching, SERI has already developed economic and performance evaluation programs (Brown et al. 1979). The performance program PROSYS and the cost and economic evaluation program ECONOMAT have been developed and used for evaluating collector performance, matching the performance with industrial process needs and the related economics. With these programs, collector performance can be rapidly determined for a specific application under operating conditions. SERI has conducted studies of industrial end-use matching in six U.S. cities. Since detailed process or end-use information was not available, a data base was developed using secondary data sources. Two site-specific industrial case studies also were performed. Interestingly, the case studies indicated that more accurate and complete data on industrial energy consumption were needed to achieve reliable results. The case studies also pointed out differences in data obtained from real site-specific cases and the secondary data, which generally represent hypothetical or reference plants.

Industrial Applications Case Studies. SERI is conducting several industrial case studies to determine the near-term feasibility of industrial use of solar energy and to develop information for end-use matching, research, and commercialization. Information is being obtained through industrial site visits, and suitable solar systems are being designed and evaluated. Industrial plant personnel are being encouraged to participate in evaluating analysis results, and detailed plant-specific information, including opportunities for energy conservation, is being compiled. These case studies have indicated the difficulties and expense of collecting site-specific energy data. In many cases, the information cannot be readily obtained even through site visits without instrumentation to measure actual energy flows and quality of energy used. Again, this can be quite expensive and time consuming.

The preferred approach for developing end-use data for these case studies would be through a site visit, including examining billing records and a walk-through audit, and by using process energy-use data from a secondary data base as a supplement. Therefore, there is a need for accurate and reliable end-use data for the different industry groups.

Development of Cost and Performance Goals for Solar Systems. Identifying cost and performance goals to commercialize solar IPH applications requires characterizing the potential market for solar energy in the industrial sector including the specific criteria, trade-offs, and procedures employed by industrial decision makers in selecting energy supply systems. Studies of this type initially were performed by Intertechnology Corporation (ITC) (1977) and Battelle Columbus Laboratories (1977) for the U.S. Department of

Energy (DOE). These activities have been continued at Sandia Labs and SERI. Although the ITC report provided a comprehensive compilation of end-use data, some information in the report needs to be defined and modified. To date, market characterization has concentrated on identifying industries at state and regional levels that appear to be the most energy intensive and then applying selection criteria to rank industrial groups considered most amenable to solar energy implementation. The criteria include the annual energy consumption, plant location, and temperature requirements. Current efforts include developing more detailed geographic and process requirements for solar IPH systems. The analysis was performed using the ITC data base and indicates the need for more reliable information on energy end uses.

Comparative Analysis of Solar Thermal Systems. A comparative analysis of solar thermal systems for industrial applications is being performed by SERI's Systems Development Branch. Since different solar systems and designs provide energy at different intensities for applications that require different qualities of energy, it is important to know the required energy temperatures. The Systems Development Branch has developed a decision model that attempts to evaluate the performance of the different solar systems on a site-specific basis. This branch study found that the viability of solar systems varies considerably as a function of the application temperature. SERI is developing an overall ranking of the solar systems so as to define priorities for research, development, and demonstration (RD&D) for specific solar technologies. To accomplish this, reliable data on temperature levels are needed.

Since the availability of solar energy varies considerably, information regarding the geographic distribution of U.S. industries is also desirable.

2.2 SUMMARY

This section has indicated the lack of adequate, reliable, and comprehensive information on industrial energy end uses at a disaggregated geographic and SIC level. The researchers performing these studies indicated the inadequacy of information from existing data bases. A recurrent need expressed during the discussions was for a synthesis of existing data bases, with site-specific information that provides reliable data or generic evaluations of solar applications in the industrial sector.

SERI

SECTION 3.0

REVIEW OF EXISTING INDUSTRIAL DATA BASES

3.1 PURPOSE AND BACKGROUND

This section reviews the data bases containing energy consumption information at the end-use level. These industrial data bases were reviewed to identify the sources of data, compilation methods, the level of detail and disaggregation, the primary sources of information leading to the estimates of end-use energy consumption, and the degree of verification and validation. Described here is an assessment of the potential applications of the data to support SERI research activities. First, the list of data bases is given; then, the approach for reviewing these data bases is outlined; and finally, the major findings are summarized.

3.2 LIST OF DATA BASES

In the last five years, studies on industrial energy utilization have proliferated. Most of the studies, however, address only macrolevel energy data, such as the total energy consumption or energy consumption per unit of the product. Some studies have attempted to develop process-level data, but they generally have suffered from limited information. The studies usually address only 2-digit or 3-digit level industrial groups, mainly because statistical data sources do not present information at a higher level of disaggregation.

The increasing interest in identifying and evaluating conservation, heat recovery, cogeneration, and other energy-saving measures in the industrial sector has led to the development of several data bases that represent energy consumption information at the end-use level:

- Federal Energy Administration (FEA) Energy Conservation Data Base for nine industries, developed by Gordian Associates Inc. (1975)
- Dow Chemical Company's Survey of Industrial Energy Use (1977)
- DOE's End-Use Energy Consumption Data Base (ECDB)* (1978b)
- The data base associated with the Industrial Sector Technology Use Model (ISTUM) (Energy and Environmental Analyses, Inc. 1978)
- The Industrial Process Energy Data Base of the Drexel University Industrial Applications Study (Hamel et al. 1979)
- The Industrial Plant, Energy Profiles (IPEP) Data Base* developed by General Energy Associates (1979)—a derivative of the Drexel data base
- The Facility Energy Utilization Data System (FEUDS)* developed by Ultrasystems, Inc. (Undated)
- Industrial Process Energy Data Base* developed by ITC (1977)
- Industrial Process Heat Data Base* developed by Battelle Columbus Laboratories (1977)

*For more detailed information, see Appendix A.

- The Industrial Process Heat Data Base* developed by SERI under the Industrial Energy Data Collection cooperative effort (Green 1979)
- Ongoing efforts at the Oak Ridge National Laboratory* to develop a data base on industrial steam use (Barnes 1980)
- The Environmental Protection Agency's (EPA) National Emissions Data System* (1976)
- Characterization of industrial process energy services by the Institute for Energy Analysis* of Oak Ridge Associated Universities (1979)
- Energy price distribution studies performed by Grumman Energy Data Systems (1979)
- DOE's Price Data Base (1978) as part of the Federal Energy Data System
- DOE's Major Fuel-Burning Installations (MFBI) Data Base* (1975)
- The Boiler Data Base available from the American Boiler Manufacturers Association (ABMA) (1979)
- Current DOE efforts to conduct a large-scale survey of industrial plants to obtain detailed end-use information (Wotecki 1980)
- Other special studies resulting in data bases:
  - Studies of industrial cogeneration by the Rocket Research Company (1978) for the Pacific Northwest
  - Studies of industrial energy consumption in Missouri by Synergic Resources Corporation (1980c)
  - Studies by Thermo Electron Corporation (1976) of industrial cogeneration
  - Study by Resource Planning Associates (RPA) (1977) of industrial cogeneration for DOE
  - Case studies of industrial cogeneration conducted by Synergic Resources Corporation (1980a) for the Electric Power Research Institute (EPRI)
  - The industrial energy reporting system at DOE

3.3 APPROACH FOR REVIEW AND EVALUATION OF END-USE DATA BASES

In reviewing these data bases, the following questions were addressed:

- What specific aspects of industrial energy use were covered by the data base?
- What was the major purpose of the data base?
- Did the data base reflect actual industrial plants, or hypothetical or reference plants?
- What is the level of detail in representing the SIC group?
- Was the energy use disaggregated by fuel type?
- Was the energy use disaggregated by specific end uses?

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*For more detailed information, see Appendix A.

- Were all energy uses covered?
- Was there a breakdown of the quality of energy used; in particular, did the quality definition describe the temperature of process steam or process heat used?
- How well was the data system documented?
- What type of verification or validation was performed, if any?
- For what has the data base been used?
- What were the results of the utilization?
- What current efforts are underway to improve, refine, or validate the data base?
- Are there any significant unresolved issues or problems related to the quantity or quality of data?

3.4 MAJOR FINDINGS OF THE REVIEW

Time and resource constraints made it impossible to detail all the data bases and critically examine all the documentation received. Major findings are summarized here.

- Numerous data bases on industrial energy end use exist, but, generally, the information reported was inconsistent.
- With the exception of ITC's and Battelle Laboratories' data bases, which were developed specifically to study solar industrial applications, none of the data bases provides the information required for evaluating solar energy industrial applications.
- Most data bases that report end-use information by quality and quantity of energy used represent only hypothetical or reference plants.
- Most data bases that have real plant data do not provide the detail required on the quality and quantity of energy end uses.
- No single data base can be considered uniformly better than any other.
- The Drexel University Industrial Process Energy Data Base, which details data on 108 industrial processes and uses the ITC and Battelle information, is the most detailed data source for end uses at the 4-digit SIC level.
- The data bases vary significantly, perhaps corresponding to the variant energy consumption patterns throughout the United States. Unfortunately, no attempt has been made to provide statistical measures of the actual variation in existing plants.
- Although, considerable time and resources have been expended in developing the data bases, little effort has been devoted to verifying or validating the data.
- There is a considerable gap between what these data bases claim to provide and what they actually provide.
- There is a significant need for site-specific energy consumption data that can be used to develop realistic case studies on industrial solar energy applications. DOE is conducting a large-scale survey to develop such a data base, but it probably will not be available for several years.
- Systematic validation is needed to determine the quality and reliability of the data presented in the data bases.

In summary, we believe that most existing data bases are very limited in evaluating industrial solar applications at a detailed geographic level. In particular, the information required cannot be readily obtained from the existing data bases.

In this study, data from the Drexel University Industrial Process Energy Data Base and the ITC study were used to develop a profile of industrial energy needs by temperature level for the major energy-consuming industries at the 4-digit level.

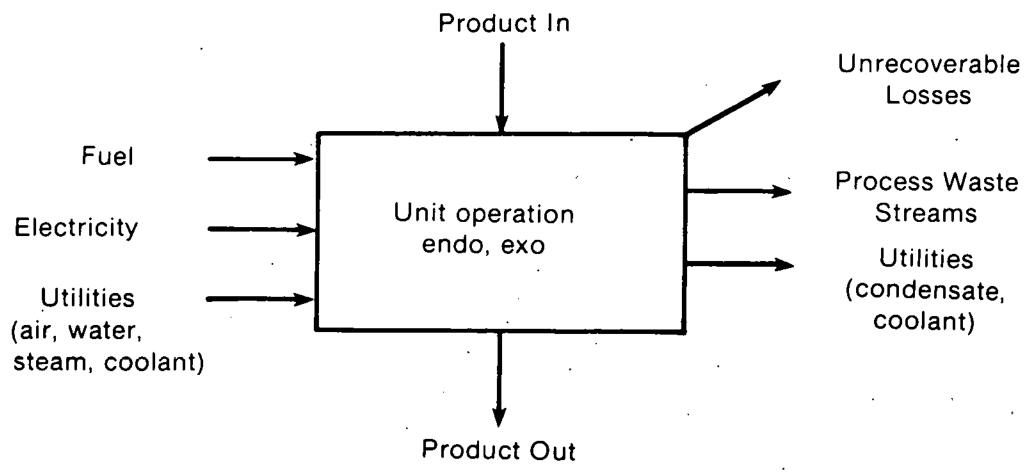
In 1976, Drexel University under contract to DOE initiated a program to develop a detailed data base of industrial energy use (Hamel et al. 1979). This data base consists of typical process configurations and energy and material balances for 108 industrial processes and represents sixty 4-digit SICs (see Table 3-1). Selected on the basis of energy intensiveness, these industries account for approximately 75% of the U.S. industrial energy consumption. Thirteen of the twenty 2-digit SIC industries in the manufacturing subsector are represented. Several 4-digit industries were further disaggregated to represent accurately the varied product lines and processes.

Typical process flow configurations were developed from available references. Sample process flows for three industrial processes are shown in Figs. 3-1 to 3-3, representing typical plants with the most prevalent operations integrated into them. Two on-site surveys were conducted for each 4-digit industry to provide a check of the general process configurations and the energy analysis performed for each process. By using engineering texts and handbooks, previous studies performed by industry and government organizations, results from on-site surveys, and industrial consultant input, heat and mass balances were developed on a per-pound-of-product basis for each of the unit operations in the industrial process. The data base generated not only includes the quantity of energy used but also information on the quality of use, such as temperature levels, pressures, flow rates, types of fuels, and contaminant data for major waste streams. A list of the unit processes covered is given in Table 3-2. Figure 3-4 shows the general type of information available for unit operation and provides an example of a lime kiln.

The Drexel data base contains a typical or national average industrial plant from which actual industrial plants may deviate significantly. For meaningful applications at the individual plant level, variations in process configuration, equipment age, and geographic location should be considered.

The level of detail in the list of unit operations makes the Drexel data base the most comprehensive source of end-use data. However, since it represents national averages only, injudicious use could be counterproductive to SERI's objective.

Another problem is the manner in which some of the averages were created. For example, in the data base, a cement plant has both wet and dry process kilns with a 60/40 production split, respectively (approximately the national production levels for 1976). If this mix between wet and dry processes is different in any state, the data base would yield erroneous results. Also, it is unlikely that actual plants would contain both processes.

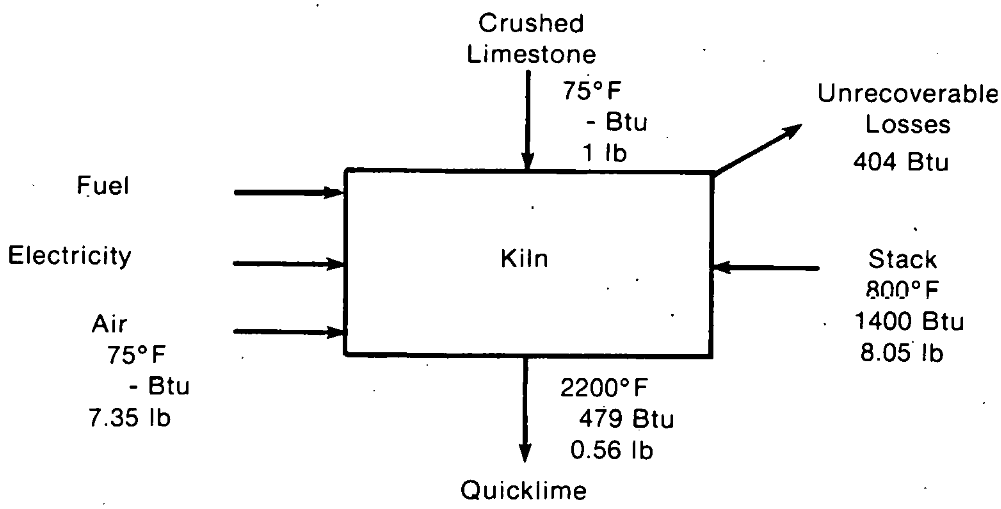


Unit Operation Data

Process temperature
Process pressure
Endothermic or exothermic
Hourly profiles
Thermal efficiency

Stream Data

Temperature
Pressure
Mass flow
Energy
Specific heat
Contaminant data (waste only)



$CaCO_3$ $CaO + CO_2$

Endothermic Reaction - 728 Btu/lb $CaCO_3$

Figure 3-4. Examples of Heat and Mass Balance for a Typical Unit Operation and a Lime Kiln

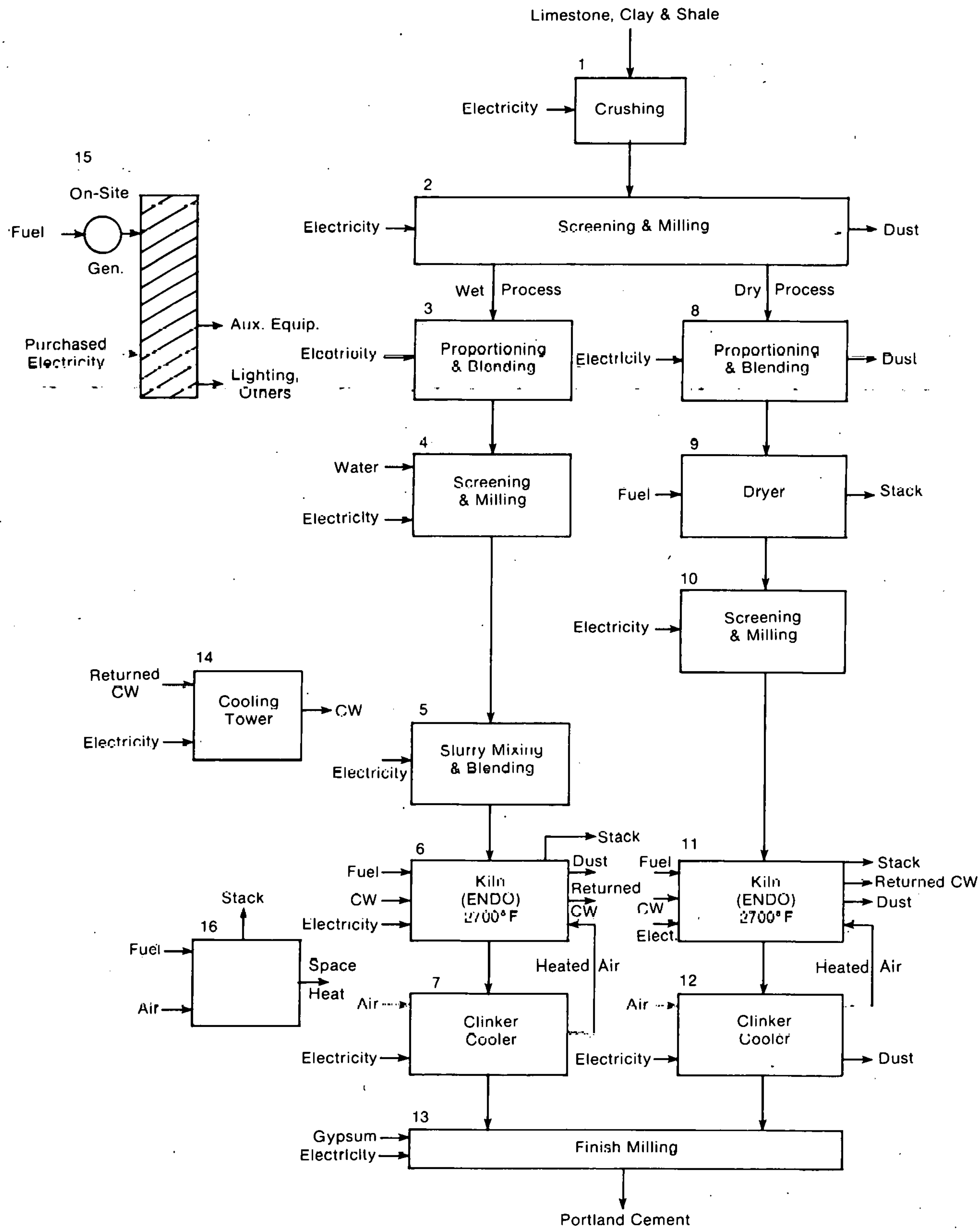


Figure 3-1. Illustrative Process Data: SIC 3241-Cement, Hydraulic

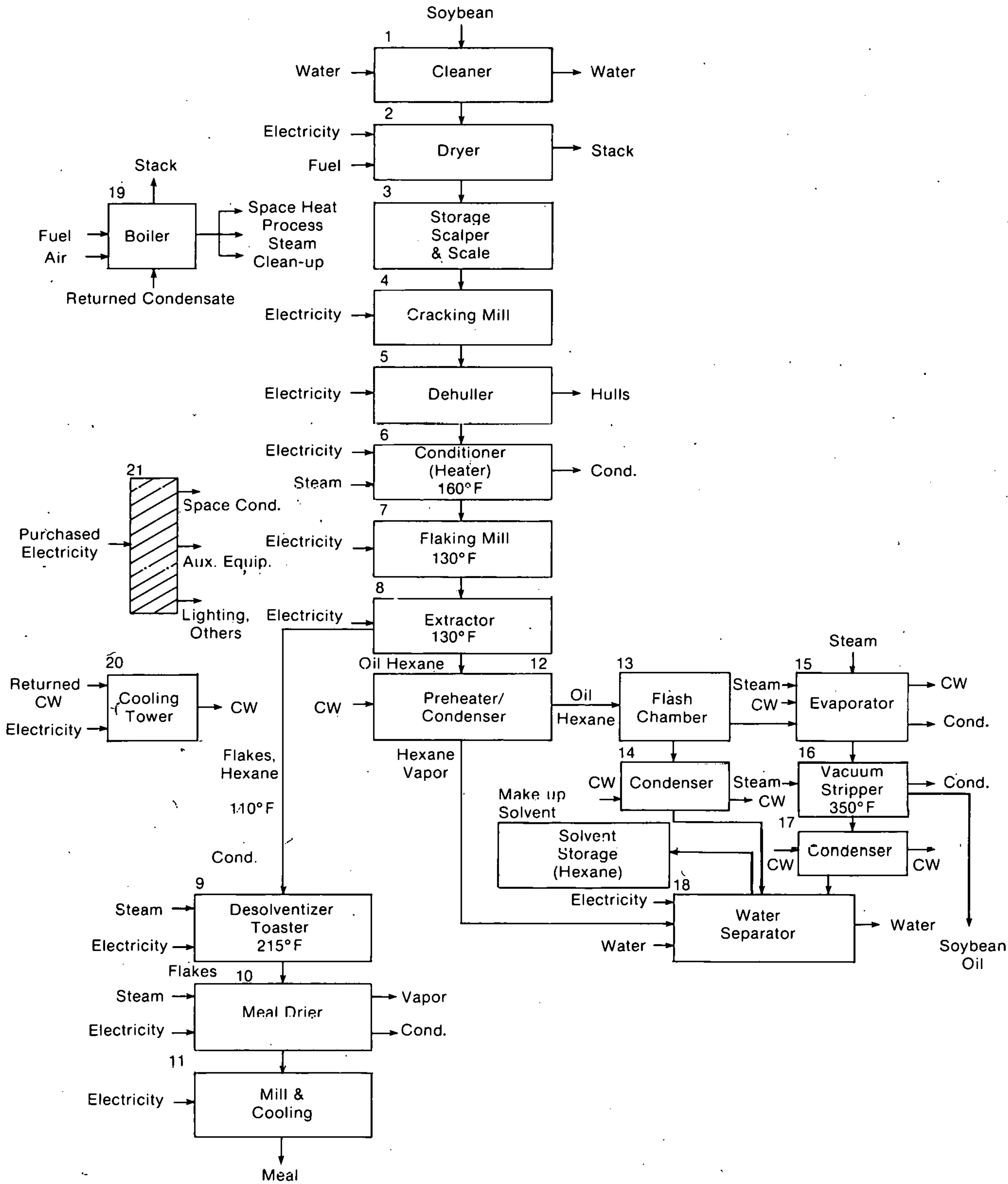


Figure 3-2. Illustrative Process Data: SIC 2075-Soybean Oil Mills

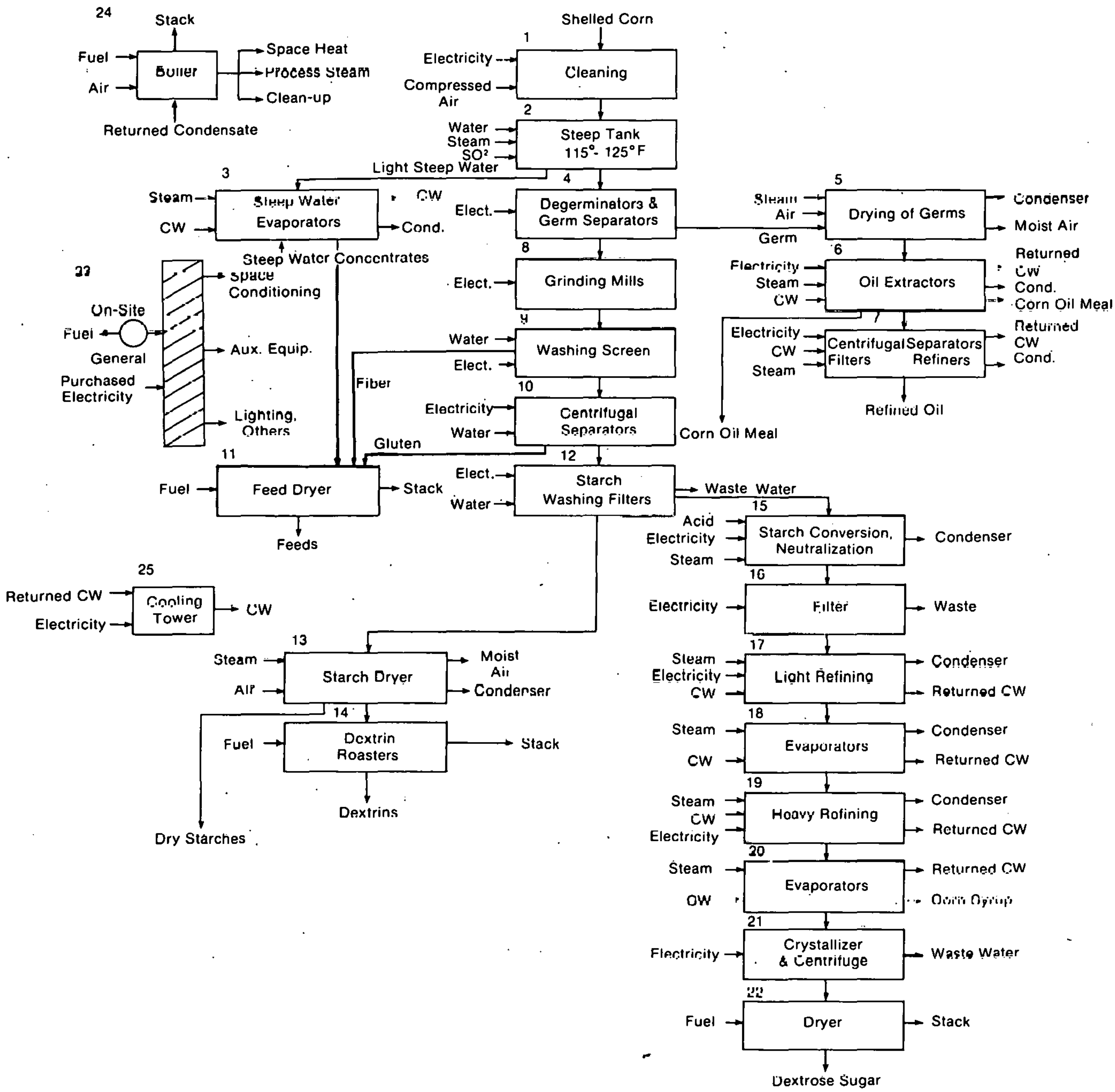
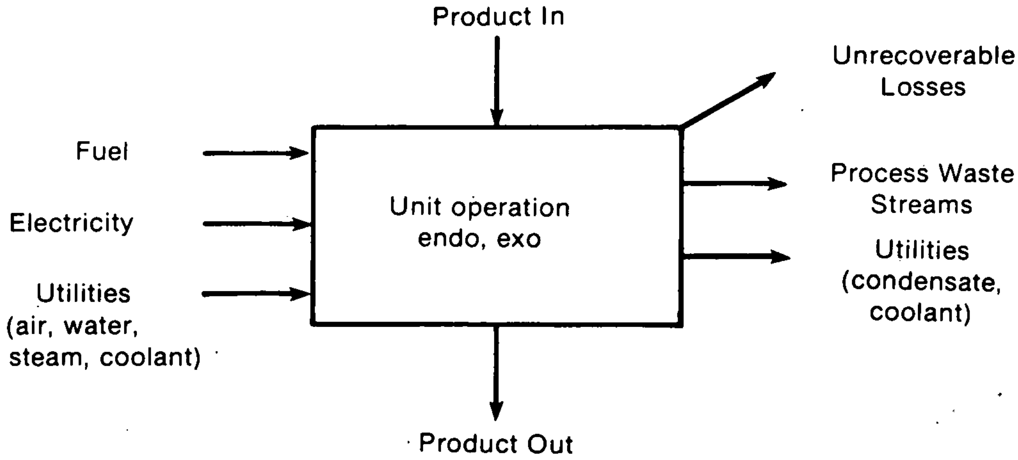


Figure 3-3. Illustratrive Process Data: SIC 2046-Wet Corn Milling

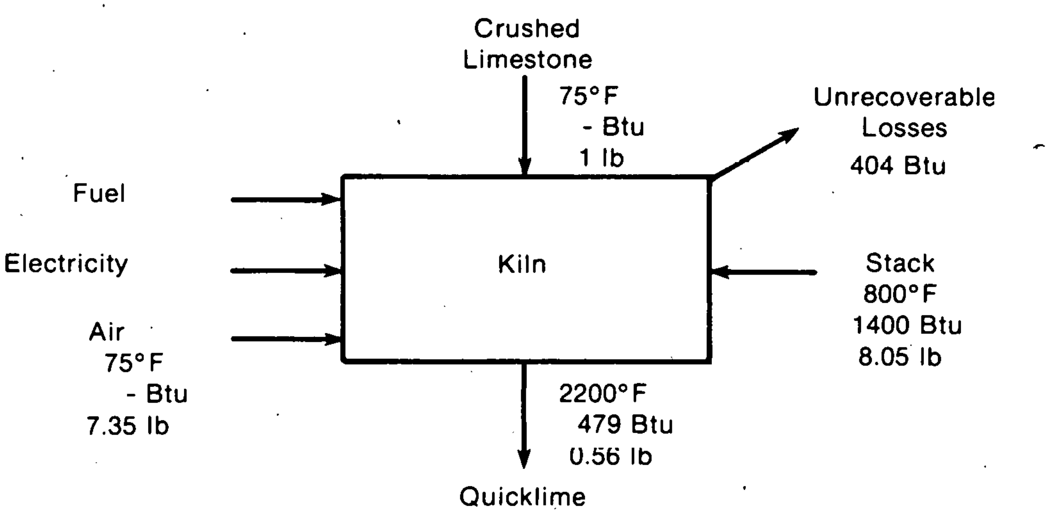


Unit Operation Data

Process temperature
Process pressure
Endothermic or exothermic
Hourly profiles
Thermal efficiency

Stream Data

Temperature
Pressure
Mass flow
Energy
Specific heat
Contaminant data (waste only)



$CaCO_3 \quad CaO + CO_2$

Endothermic Reaction - 728 Btu/lb $CaCO_3$

Figure 3-4. Examples of Heat and Mass Balance for a Typical Unit Operation and a Lime Kiln

Table 3-1. **LIST OF INDUSTRIES INCLUDED IN DREXEL INDUSTRIAL APPLICATIONS STUDY**

SIC	Industry	SIC	Industry
2011	Meat Packing Plants	2873	Nitrogenous Fertilizers
2026	Fluid Milk	2874	Phosphatic Fertilizers
2033	Canned Fruits and Vegetables	2899	Chemical Preparations, NEC
2046	Wet Corn Milling	2911	Petroleum Refining
2051	Bread, Cake, and Related Products	2951	Paving Mixtures and Blocks
2062	Cane Sugar Refining	3011	Tires and Inner Tubes
2063	Beet Sugar	3069	Fabricated Rubber Products, NEC
2075	Soybean Oil Mills	3079	Miscellaneous Plastic Products
2082	Malt Beverages	3211	Flat Glass
2221	Weaving Mills, Man-Made Fibers	3221	Glass Containers
2262	Finishing Plants, Man-Made Fibers	3229	Pressed and Blown Glass
2411	Logging Camps, Log Contractors	3241	Cement, Hydraulic
2421	Sawmills and Planning Mills, General	3251	Brick and Structural Clay Tile
2499	Wood Products, NEC[a]	3273	Ready Mix Cement
2611	Pulp Mills	3274	Lime
2621	Paper Mills	3275	Gypsum Products
2631	Paperboard Mills	3296	Mineral Wool
2653	Corrugated, Solid Fiber Boxes	3312	Blast Furnaces and Steel Mills
2661	Building Paper and Board Mills	3313	Electrometallurgical Products
2812	Alkalies and Chlorine	3321	Gray Iron Foundaries
2813	Inorganic Gases	3331	Primary Copper
2816	Inorganic Pigment	3334	Primary Aluminum
2819	Industrial Inorganic Chemicals	3341	Secondary Nonferrous Metals
2821	Plastic Materials and Resins	3353	Aluminum Sheet Plate, Foil
2822	Synthetic Rubbers	3462	Iron and Steel Forging
2823	Cellulosic Man-Made Fibers	3523	Farm Machinery and Equipment
2824	Organic Fibers, Noncellulosic	3531	Construction Machinery
2834	Pharmaceutical Preparations	3511	Motor Vehicles and Car Bodies
2865	Cyclic Crudes and Intermediates	3714	Motor Vehicles Parts and Accessories
2869	Industrial Organic Chemicals	3861	Photographic Equipment Supplies

[a]Not elsewhere classified

Other limitations

- Since only two actual plants were used in each classification, the data on national average plants may not be completely accurate.
- In some cases, a few large plants tend to bias the national averages.
- Because of the existence of heat recovery devices, pollution control requirements, etc., an actual plant may be significantly different from the national average reference plant.
- In the case of multiproduct plants, such as in the chemical industry or some integrated paper and pulp mills, the Drexel data cannot adequately represent the different product mixes.

Table 3-2. LIST OF UNIT OPERATIONS INCLUDED IN DREXEL DATA BASE

MECHANICAL (1-19)

U1. Compressor
U2. Refrigeration
U3. Mixing
U4. Crushing, Grinding
U5. Separation
U6. Filter
U7. Extruding
U8. Rolling
U9. Cutting, Trimming
U10. Centrifuge
U11. Pumps

THERMAL (20-39)

U20. Furnace
U21. Drying
U22. Cooking
U23. Ovens
U24. Washing
U25. Evaporation
U26. Annealing
U27. Pasteurizing
U28. Casting
U29. Boiler
U30. Heat Exchangers
U31. Condenser
U32. Distillation
U33. Flash Separator
U34. Turbo-Generator
U35. Turbine

THERMAL-CHEMICAL (40-49)

U40. Reactors
U41. Coking
U42. Electrolytic Cells

MISCELLANEOUS (50-59)

U50. Feedstocks
U51. Transportation
U52. Lighting
U53. Space Heating
U54. Space Cooling
U55. Other

- Some of the representative processes may have suffered technological obsolescence or may have been derived from outdated references.
- The data base does not show cascading-of-steam use.

Despite these limitations, the end-use data can be valuable, particularly if some primary data are available to compare, validate, or modify the reference plants. Other significant limitations of these data bases are

- only hypothetical or réference plants are represented without any variation in energy use patterns by geographic region or plant size indicated;
- no systematic validation has been performed;
- some relevant 4-digit groups are not covered; and
- the quality and reliability of information used to compile the data bases vary significantly.

Nevertheless, the Drexel data base represents the most detailed end-use data on industrial energy consumption and is the only data base that provides information for a large number of 4-digit SIC industries. The necessary reliance on this data base points out the need for systematically validating the data and modifying, refining, and expanding it to satisfy SERI's needs. Unfortunately, such activities were beyond the scope of this effort.

SERI's efforts, in cooperation with other DOE laboratories, in developing the cooperative effort for Industrial Energy Data Collection (IEDC) could help obtain the right information for assisting various SERI studies (Green 1979). Since a standardized data format has already been established and a list of industrial plants and trade associations has been compiled, efforts to develop plant-specific information should be continued. The information on 250-500 real plants can be compiled using data from audits and other studies already available. Such a data base could satisfy the dual objectives of validating the existing data banks and providing site-specific information useful for case studies. Furthermore, such a site-specific data base could be combined with the previously cited data sources of information on hypothetical plants or real plants to satisfy the objectives of the various SERI studies.

SECTION 4.0

U.S. INDUSTRIAL SECTOR ENERGY SERVICE CHARACTERIZATION

4.1 INTRODUCTION

To examine and determine current future energy demands, their end uses, and cost in the U.S. industrial sector, development of the disaggregated industrial energy service characteristics was undertaken. Basic data on the quantities, cost, and types of fuels and electric energy purchased by industry for heat and power were obtained from the 1972 Census of Manufacturers (U.S. Department of Commerce 1972) reporting 1971 data and the 1974 and 1976 Annual Survey of Manufacturers (U.S. DOC 1974 and 1976). These data are disaggregated by fuel type and user classification, including the 2-digit SIC industry groups, 3-digit subgroups, and 4-digit SIC industries and characterize typical energy applications and the resultant services in the U.S. manufacturing subsector.

The disaggregated data* on value added by manufacturing** provided in these data sources were used to measure economic activities and estimate the fuels and electric power required to produce one dollar of output. The quantities of fuels and electric energy purchased were converted to Btu and reported in billions of Btu. The conversion factors are presented in Table 4-1.

To facilitate the descriptive analysis, all energy cost data and value added by manufacturing were expressed in constant 1976 dollars. The industrial energy service characteristics developed and used in the descriptive analysis include the following:

- U.S. 1971, 1974, and 1976 manufacturing subsector fuels and electricity consumption by 2-, 3-, and 4-digit SIC and primary fuel (quantity and relative share);
- U.S. 1971, 1974, and 1976 manufacturing subsector fuel consumption by 2-, 3-, and 4-digit SIC and primary fuel (quantity and relative share);
- U.S. 1971, 1974, and 1976 manufacturing subsector average cost of purchased fuels and electricity per million Btu by 2-, 3-, and 4-digit SIC and primary fuel (in 1976 dollars);
- U.S. 1971, 1974, and 1976 manufacturing subsector fuels and electric energy intensity by 2-, 3-, and 4-digit SIC and primary fuel (in 1976 dollars);
- U.S. manufacturing subsector average annual growth rates of (1) fuels and electricity consumption, (2) fuels and electric energy efficiency, and (3) average cost of purchased fuels and electricity (1971-74, 1971-76, and 1974-76).

The disaggregated industrial energy service characteristics are presented in Volume II.

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*The data were obtained in machine-readable form from the Customer Service Branch, Data User Services, Census Bureau, Washington, D.C. 20233.

**Technically, value added by manufacturing is the value of goods produced less the cost of materials and energy and it represents the contribution of labor and capital to the value of a product.

Table 4-1. CONVERSION FACTORS

Type of Fuel	Standard Units of Measure	MBtu	MkWh
Propane, Butane, and Mixtures	Mbbl	4,011.0	1,175.0
Middle Distillates	Mbbl	5,825.0	1,707.0
Residual Fuel Oil	Mbbl	6,287.0	1,842.0
Chemical Feedstocks	Mbbl	4,011.0	1,175.0
Other Petroleum Products			
Gasoline	Mbbl	5,253.0	1,539.0
Kerosine	Mbbl	5,670.0	1,661.0
Lubricants	Mbbl	6,065.0	1,777.0
Wax	Mbbl	5,537.0	1,622.0
Asphalt	Mbbl	6,636.0	1,944.0
Residual Fuel Petroleum Coke, Sludge	Mbbl	6,006.0	1,760.0
Miscellaneous	Mbbl	5,796.0	1,698.0
Coal	MST	26,200.0	7,677.0
Anthracite	MST	25,400.0	7,442.0
Bituminous	MST	26,200.0	8,468.0
Lignite	MST	14,770.0	4,328.0
Natural Gas	MMCF	1,032.0	303.3
Fuels, NEC			
Coke Oven Gas	MMCF	550.0	161.2
Blast Furnace Gas	MMCF	92.0	27.0
Still Gas	MMCF	1,501.0	439.8
Coke	MST	26,000.0	7,618.0
Coke Screening and Breeze	MST	20,488.0	6,003.0
Purchased Electric Energy	MkWh	10,600.0	3,100.0

Data on the U.S. 1974 manufacturing subsector fuels and electricity consumption by 2-digit SIC and functional use (direct heat, process steam, overhead, coke generation, electricity generation, feedstock) were obtained from the data base associated with ISTUM (Energy and Environmental Analysis, Inc. 1978). Similar energy end-use data for 1975 and 1976 are being developed by Energy and Environmental Analysis, Inc.

This section demonstrates practical applications of the disaggregated energy-use data presented in Volume II.

4.2 REMARKS ON U.S. GROSS ENERGY CONSUMPTION*

Mounting demand, sharply rising costs, and changing social values have combined to place unusual stress on the study of demand, supply, and price of energy on every aggregate

*Gross energy is the total primary fuels (including imports) or their derivatives plus the generation of hydro- and nuclear power (converted to equivalent energy inputs) put into the economy.

level of the U. S. economy. The United States, with 5.76% of the world's population, consumed 34.8% of the world's energy in 1967, which is 6.05 times the per capita energy consumption of the world (Motel and Howard 1971). Total energy consumption increased from 69.1 quadrillion Btu (quads) in 1971, to 72.9 quads in 1974, and 74.7 quads in 1976. The 1971-74 and 1971-76 average annual growth rates were 1.8% and 1.6%, respectively. A breakdown by sectors is presented in Table 4-2 and Fig. 4-1.

Table 4-2. U.S. GROSS ENERGY CONSUMPTION BY SECTOR

(Quadrillion Btu)

	Consumption						Annual Average Growth Rate (Compounded)	
Item	1971 Volume	1974 %	1976 Volume	%	Volume	%	71-74	71-76
Residential	10.2	14.8	9.9	13.6	10.4	13.9	0.99	0.39
Commercial	7.5	10.8	7.7	10.6	7.9	10.6	0.88	1.04
Industrial	22.6	32.7	23.8	32.6	22.4	30.0	1.74	-0.20
Electric Utility	12.3	17.8	13.9	19.1	15.1	20.2	4.16	4.19
Transportation	16.5	23.9	17.6	24.1	18.9	25.3	2.17	2.75
Total	69.1	100.0	72.9	100.0	74.7	100.0	1.80	1.57

Source: Energy Information Administration (1979b).

The average annual growth and decline rates vary from a high of 4.2% for the electric utility sector in 1971 to 0.4% and -1.0% for the residential sector in 1974 and 1976, respectively. Industrial energy consumption increased from 22.6 quads in 1971 to 23.8 quads in 1974, then dropped to 22.4 quads in 1976. The average annual growth/decline rates for the largest industrial sector vary 1.7% over the period 1971-74 and -0.2% from 1971-76. Although its relative share of the total gross energy inputs into the economy declined between 1971 and 1976, industry still uses the most energy, 39.3% of the nation's total energy consumed in 1976.

Transportation has grown at a slightly lower rate than the total and continues to account for about one-quarter of the total energy consumed. Commercial consumption increased 0.9% from 1971 to 1974 and 1.0% from 1971 to 1976 and accounts for almost 11.0% of the total.

Energy requirements are met from a variety of primary and secondary sources including natural gas, crude petroleum products, coal, and hydro- and nuclear power. Table 4-3 and Fig. 4-2 present the annual consumption of mineral energy resources and electricity from hydro- and nuclear power (1971-74, 1971-76).

Crude petroleum products contributed 45.3% of all energy used in 1971, 46.5% in 1974, and 47.6% in 1976. Their consumption increased from 31.3 quads in 1971 to 35.6 quads in 1976. The 1971-76 average annual rate of growth was 2.6%. The natural gas contribution decreased from 32.6% in 1971 to 30.0% in 1974 and 27.6% in 1976. It declined 0.9%/yr from 1971 to 1974 and 1.8% between 1971 and 1976. Coal consumption grew only 1.9%/yr between 1971 and 1974 and 2.4%/yr from 1971-76. It accounted for about 17.5% of the total energy consumed in 1971 and 1974, and 18.2% in 1976. Energy

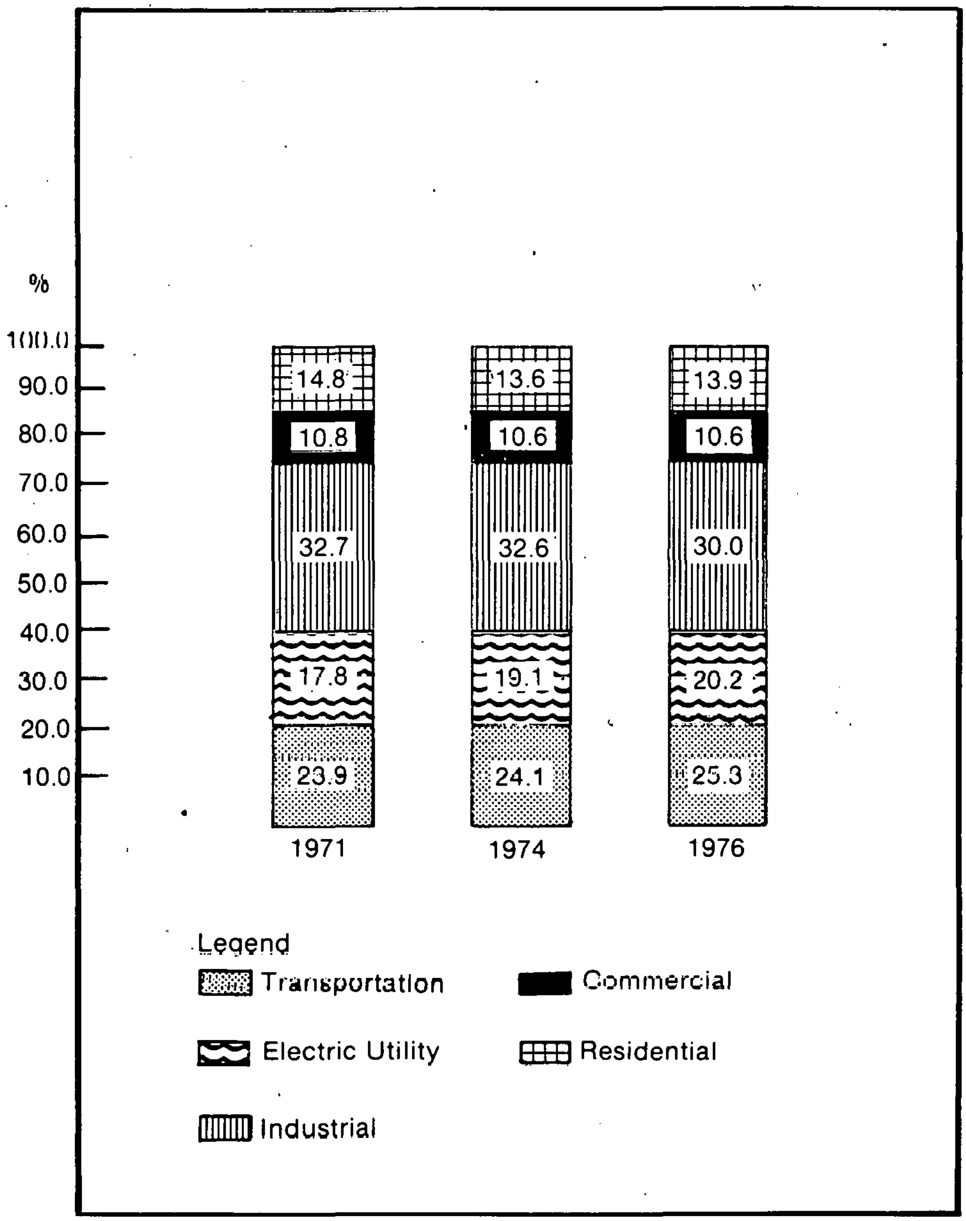


Figure 4-1. Total Energy Consumption in U.S. by Consuming Sector

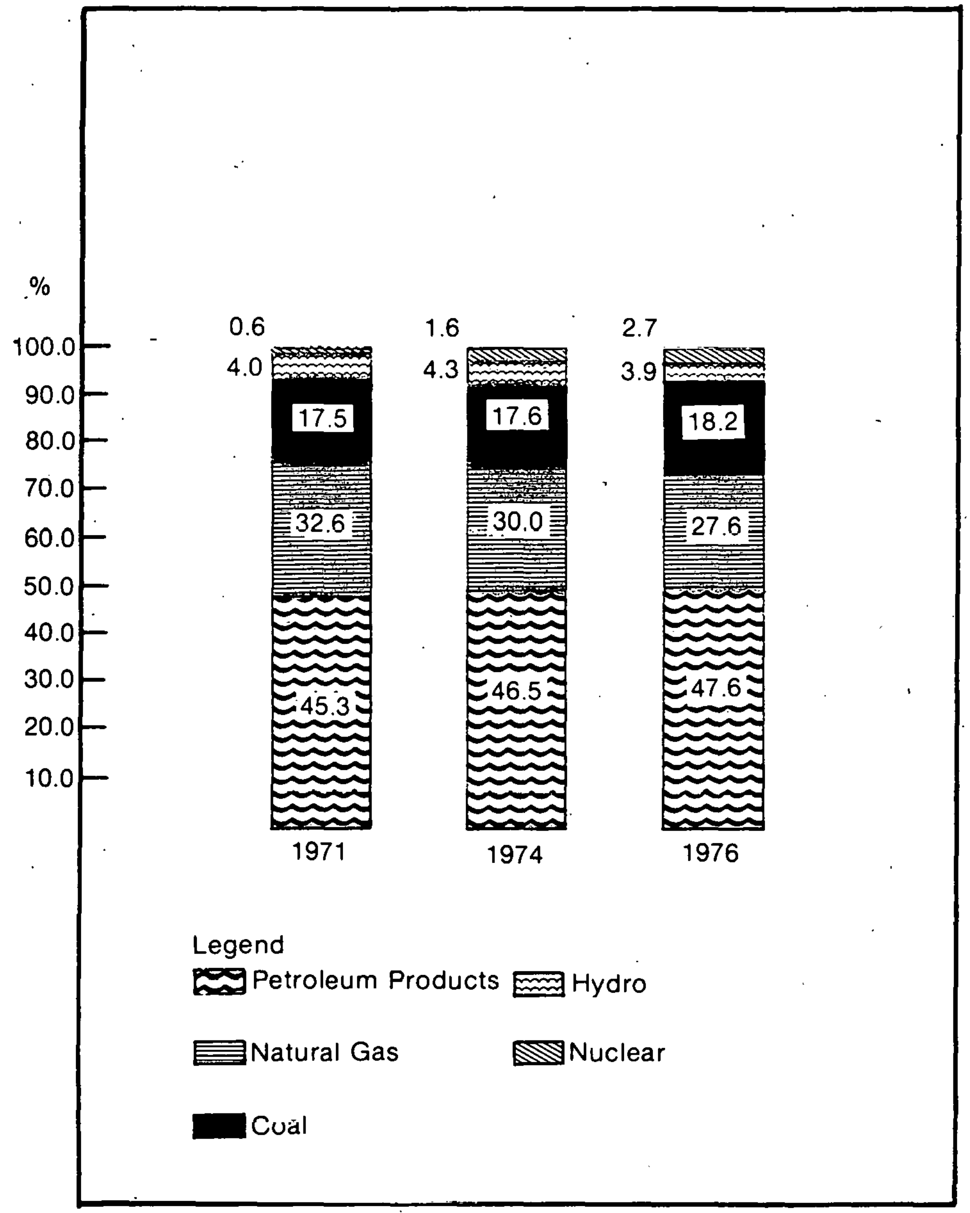


Figure 4-2. Annual Consumption of Mineral Energy Resources and Electricity From Hydropower and Nuclear Power in U.S.

produced by waterpower was consumed at a relatively high rate of 3.5%/yr from 1971 to 1974 and grew only 0.7%/yr between 1971 and 1976. However, its contribution to total energy consumed was only 4.0% in 1971, 4.3% in 1974, and 3.9% in 1976. Nuclear power contributed 0.6% to the total in 1971, 1.6% in 1974, and 2.7% in 1976.

Table 4-3. ANNUAL CONSUMPTION OF MINERAL ENERGY RESOURCES AND ELECTRICITY IN 1971, 1974, AND 1976

(Quadrillion Btu)

	Consumption						Annual Average Growth Rate (Compounded) %	
Item	1971 Volume	1974 %	1976 Volume	%	Volume	%	71-74	71-76
Petroleum Products	31.3	45.3	33.9	46.5	35.6	47.6	2.70	2.61
Natural Gas	22.5	32.6	21.9	30.0	20.6	27.6	-0.90	-1.75
Coal	12.1	17.5	12.8	17.6	13.6	18.2	1.89	2.36
Hydro	2.8	4.0	3.1	4.3	2.9	3.9	3.45	0.70
Nuclear	0.4	0.6	1.2	1.6	2.0	2.7	44.22	10.76
Total	69.1	100.0	72.9	100.0	74.7	100.0	1.80	1.57

Source: Energy Information Administration (1979).

The United States is a large nation with widely varying geographic conditions, population concentrations, and economic activities. Thus, the nature of energy end use, the sources of energy used, and per capita use vary substantially from region to region. Regional use of the five primary energy sources is indicated in Table 4-12.

The East Coast depends heavily on petroleum products. Its three census divisions—New England, Middle Atlantic, and South Atlantic—create the single largest regional market for oil. In 1971, they accounted for 84.1%, 56.4%, and 53.3%, and in 1976, 79.9%, 56.1%, and 54.1% of the national consumption. The North Central region (East North Central and West North Central) ranks second. For natural gas, the Gulf Coast (East South Central and West South Central) is the largest market and the North Central region is almost as large. More than half of all coal is consumed in the North Central region and about one-third on the East Coast. Relatively little is used elsewhere. The mountainous areas on the West Coast (Mountain and Pacific) used as much as 64.3% of the nation's waterpower in 1971 and 67.6% in 1976, with much smaller proportions located in the other regions. Thus far, very little nuclear power is used, and most of that is in the East Coast and North Central regions.

Petroleum products and natural gas (see Fig. 4-2) are the nation's foremost source of primary energy. They satisfy three-fourths of the energy requirements for all purposes. However, resulting from the decrease in domestic oil and gas production and the sevenfold increase in foreign oil prices, the relative shares for natural gas and for petroleum products in some census divisions declined from 1971 to 1976. Over the same period, the use of coal as the nation's source of primary energy increased.

The descriptive analysis of past energy consumption by the five major consuming sectors and the relative changes in its major structural components indicated that the basic use pattern was not altered significantly from 1971 to 1976. Industrial use remained the dominant use of energy at 30.0% of the nation's total consumption. Its pattern for energy consumption is examined in the following analysis.

4.3 INDUSTRIAL SECTOR ENERGY CONSUMPTION BY PRIMARY FUEL AND SIC GROUP

The total energy consumed by industry is broken down by energy sources and shown in Table 4-4.

Table 4-4. INDUSTRIAL ENERGY CONSUMED BY ENERGY SOURCES

Energy Sources	1971[a] %	1974 %	1976[a] %
Natural Gas	43.7	42.3	39.6
Residual Fuel Oil	4.9	5.3	6.0
Distillate Fuel Oil	1.9	2.2	2.7
LPG	1.1	1.4	1.9
Gasoline	1.2	1.0	0.9
Diesel	1.3	1.2	1.4
Petrocoke	1.4	1.6	1.8
Coal	9.4	7.4	5.9
Coking Coal	9.6	9.8	10.2
Special Fuels[b]	16.7	17.9	18.5
Electricity	8.9	9.9	11.0

[a]May not total 100% because of rounding.
[b]Includes feedstocks, lubes and waxes, and still gas.

Other than natural gas, gasoline, and coal, the use of all other energy sources increased in 1976 compared with 1971. In 1974, diesel had declined slightly compared with 1971.

Natural gas, special fuels, coal, coking coal, electricity, and residual fuel oil are the most important energy sources used by U.S. industry, meeting about 90% of their energy demand. Natural gas, industry's primary energy, increased from 9.9 quads in 1971 to 10.1 quads in 1974 and decreased to 8.9 quads in 1976 (see Fig. 4-2).

4.3.1 Manufacturing Subsector (SIC 20-39) Energy Consumption by Primary Fuel

Of the industrial subsectors, which include manufacturing, agricultural, mining, and construction, manufacturing used the most significant portion of industry's total energy. In 1976, they used 12.6 quads of electricity and fuels (distillate, residual, coal, coke and breeze, and natural gas) compared with 13.4 quads in 1974 and 13.1 quads in 1971. They accounted for 56.3% of the electricity and fuels used by the entire industrial sector in 1976 and 1974 and 58.0% in 1971. Its relative share of electricity and fuels consumed declined slightly from 1971 to 1976. Tables for the manufacturing subsector listing electricity and fuels consumed by type of fuel and industry for 1971, 1974, and 1976 are presented in Volume II.

In 1976, manufacturing accounted for 82.8% of the total purchased fuels compared with 84.3% in 1974 and 86.6% in 1971. The manufacturing sector's fuels consumption declined 0.25%/yr from 1971 to 1974 and 1.66%/yr between 1971 and 1976. Over the same period, the relative shares for purchased electricity increased from 13.4% in 1971 to 15.7% in 1974 and 17.2% in 1976. Consumption of electricity grew at a relatively high rate of 5.53%/yr between 1971 and 1974 and 4.29% from 1971 to 1976.

Fuels consumed are broken down by fuel type and shown in the following table.

Purchased Fuels	1971 %	1974 %	1976 %
Natural Gas	50.9	49.0	48.4
Coal	12.2	9.3	9.9
Residual Fuel Oil	6.7	7.5	11.4
Distillate Fuel Oil	4.7	5.4	4.3
Coke and Breeze	2.7	2.9	3.2
Other Fuels	22.8	25.9	22.8

In 1976, natural gas consumption decreased 2.5% from 1971. Natural gas consumption declined at the rate of 0.59%/yr from 1971 to 1974 and 1.77%/yr from 1971 to 1976. Figure 4-3 presents annual consumption of primary fuels for SICs 20-39 in 1971, 1974, and 1976.

Residual fuel oil, distillate fuel oil, and coke and breeze increased their share, and coal decreased its share in 1974 compared with 1971. In 1976, coal, residual fuel oil, and coke and breeze increased their share and distillate fuel oil decreased its share compared with 1974. The growth/decline rates of fuels consumed by all manufacturing establishments and their relative shares are presented in Volume II.

Over the same six-year period, the average price of residual fuel oil grew 13.24%/yr from 1971 to 1974 and only 3.67%/yr between 1971 and 1976. The manufacturing consumers paid $1.88/MBtu for residual fuel oil in 1976 compared with $1.57/MBtu in 1971. The price in 1974 was $2.28/MBtu.

Finally, the average price for distillate fuel oil increased about 29.7% in 1974 and 22.9% in 1976. Its annual average growth rate decreased from 9.05% during the period 1971 to 1974 to 4.21% between 1971 and 1976.

Table 4-13 and Fig. 4-4 summarize data on manufacturing fuels and electricity consumption by primary fuel and function. IPH is the most important energy end use in the subsector. About 26.3% of the total energy consumed is used for direct heat. Of the balance, about 21.0% is used for process steam, 19.2% for feedstock, 4.9% for machine drive, 2.4% for electricity generation, 1.9% for electrolite process, and 1.7% for coke production.

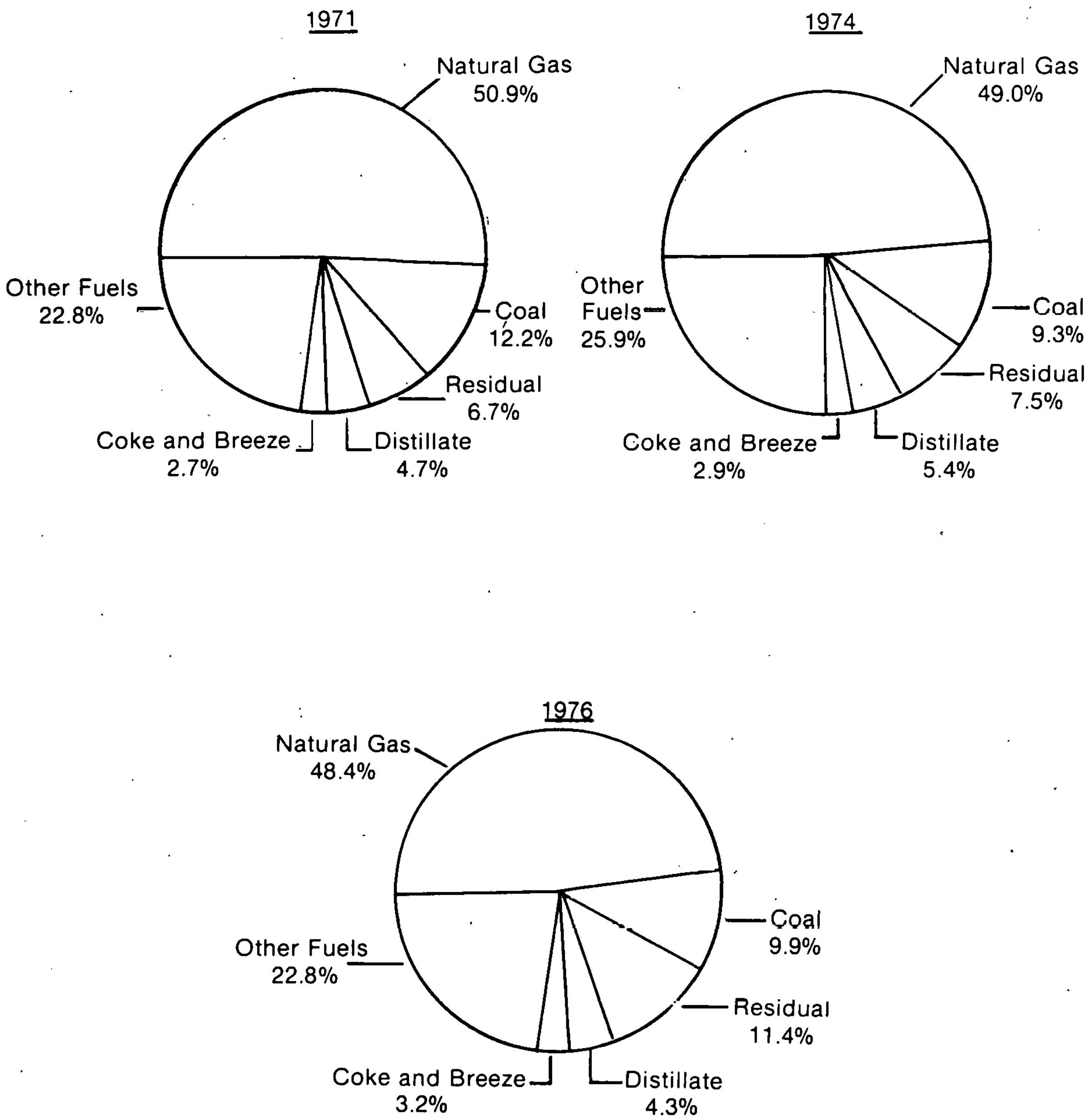


Figure 4-3. United States Manufacturing Subsector (SIC 20-39) Energy Consumption by Primary Fuel

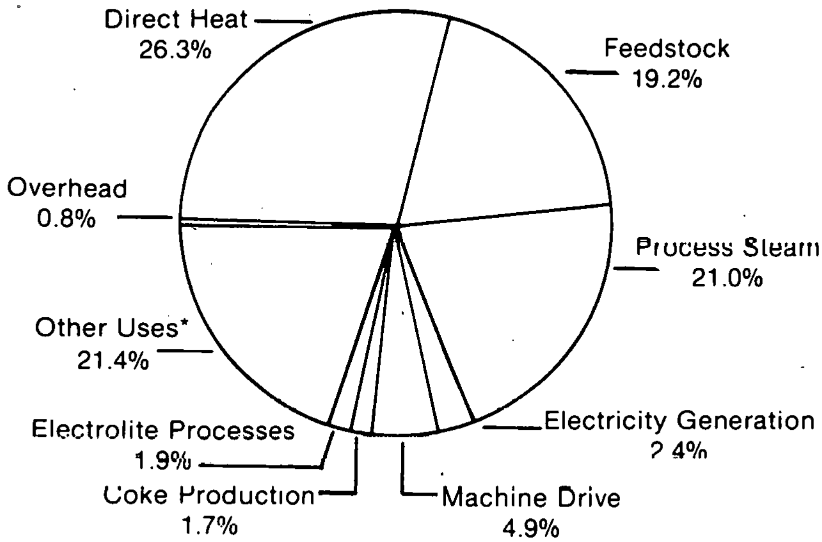


Figure 4-4. U.S. Manufacturing Subsector 1974 Energy Consumption by Primary Fuel and Functional Use

4.3.2 Manufacturing Subsector Energy Consumption by SIC Group

The tables in Volume II show the U.S. consumption of fuels and electricity by 2-, 3-, and 4-digit SIC and primary fuel in 1971, 1974, and 1976. Six energy-intensive industry groups—primary metal industries (SIC 33), chemicals and allied products (SIC 28), petroleum refining and related industries (SIC 24), food and kindred products (SIC 20), paper and allied products (SIC 26), and stone, clay, glass, and concrete products (SIC 32)—accounted for about 80.3% of the purchased fuels and electricity in 1974 and 1976 compared with 79.7% in 1971.

The fuels and electricity consumed by these six industry groups and by primary fuel in 1971, 1974, and 1976 follow:

- Electricity consumption as a percentage of the purchased fuels and electricity by the most energy-intensive manufacturing SIC groups:

SIC	Manufacturing Industries	1971 %	1974 %	1976 %
33	Primary Metal Industries	18.6	19.7	18.9
28	Chemical and Allied Products	21.2	21.9	23.9
24	Petroleum Refining and Related Industries	12.1	11.7	10.2
20	Food and Kindred Products	7.8	7.1	7.4
26	Paper and Allied Products	10.0	9.9	10.3
32	Stone, Clay, Glass, and Concrete Products	9.9	10.0	9.7

- Natural gas consumption as a percentage of the purchased fuels and electricity by the most energy-intensive manufacturing SIC groups:

SIC	Manufacturing Industries	1971 %	1974 %	1976 %
33	Primary Metal Industries	17.1	16.8	15.9
28	Chemical and Allied Products	22.1	25.1	28.3
24	Petroleum Refining and Related Industries	20.5	18.5	17.7
20	Food and Kindred Products	7.4	7.3	7.4
26	Paper and Allied Products	7.4	6.7	6.1
32	Stone, Clay, Glass, and Concrete Products	10.9	10.7	9.9

- Coal consumption as a percentage of the purchased fuels and electricity by the most energy-intensive manufacturing SIC groups:

SIC	Manufacturing Industries	1971 %	1974 %	1976 %
33	Primary Metal Industries	15.4	12.5	10.8
28	Chemical and Allied Products	29.8	28.6	26.9
24	Petroleum Refining and Related Industries	0.6	*	0.5
20	Food and Kindred Products	7.3	6.3	6.9
26	Paper and Allied Products	15.4	17.6	17.7
32	Stone, Clay, Glass, and Concrete Products	15.8	19.6	23.0

*Data are unavailable.

- Coke and breeze consumption as a percentage of the purchased fuels and electricity by the most energy-intensive manufacturing SIC groups:

SIC	Manufacturing Industries	1971 %	1974 %	1976 %
33	Primary Metal Industries	89.0	93.0	94.3
28	Chemical and Allied Products	1.1	0.7	0.1
24	Petroleum Refining and Related Industries	0.0	*	0.0
20	Feed and Kindred Products	1.1	0.4	0.4
26	Paper and Allied Products	*	*	*
32	Stone, Clay, Glass, and Concrete Products	2.2	3.6	3.0

*Data are unavailable.

- Residual fuel oil consumption as a percentage of the purchased fuels and electricity by the most energy-intensive manufacturing SIC groups:

SIC	Manufacturing Industries	1971 %	1974 %	1976 %
33	Primary Metal Industries	14.9	22.6	17.2
28	Chemical and Allied Products	13.5	16.0	17.0
24	Petroleum Refining and Related Industries	7.6	4.1	5.5
20	Food and Kindred Products	7.0	6.5	7.3
26	Paper and Allied Products	33.0	29.7	30.8
32	Stone, Clay, Glass, and Concrete Products	6.0	4.9	4.7

- Distillate fuel oil consumption as a percentage of the purchased fuels and electricity by the most energy-intensive manufacturing SIC groups:

SIC	Manufacturing Industries	1971 %	1974 %	1976 %
33	Primary Metal Industries	15.2	12.6	12.1
28	Chemical and Allied Products	14.1	16.7	17.4
24	Petroleum Refining and Related Industries	3.1	6.7	3.0
20	Food and Kindred Products	10.4	9.2	13.1
26	Paper and Allied Products	17.2	21.4	11.4
32	Stone, Clay, Glass, and Concrete Products	10.6	10.5	13.7

The primary metal industries, chemical and allied products, and paper and allied products, increased their share of electricity consumed; and food and kindred products, petroleum refining and related industries, and stone, clay, glass, and concrete products decreased their share of the total in 1976 compared with 1971. These six 2-digit SIC industries accounted for about 80.4% of the total fuels and electricity consumed by all manufacturing industries in 1976 compared with 79.6% in 1971.

Natural gas consumed by these six groups did not change significantly from 1971 to 1976; their relative share of the total consumption slightly declined from 85.4% in 1971 to 85.1% in 1974 and 85.3% in 1976. However, the primary metal industries and petroleum refining and related industries significantly decreased their relative shares; and stone, clay, glass, and concrete products, and paper and allied products substantially increased their share of the total over the 1971-76 period.

Coal consumption increased from 84.3% in 1971 to 84.6% in 1974 and 85.8% in 1976. The relative shares varied substantially among these six industry groups. In 1976, the primary metal industries had decreased their share 2.9% from 1974 and 4.6% in 1971. Also, chemical and allied products decreased their relative share of the total 2.9% from 1971 to 1976. Over the same period, stone, clay, glass, and concrete products and paper and allied products increased their use of coal 7.2% and 2.3%, respectively, from 1971 to 1976.

These six groups accounted for 97.8% of the total consumption of coke and breeze in 1976, compared with 97.7% in 1974, and 93.9% in 1971. Note that the primary metal industries' consumption increased at about 1.0%/yr from 1971 to 1976.

Consumption of residual fuel oil increased from 82.0% in 1971 to 83.8% in 1974, then decreased to 82.5% in 1976. While the primary metal industries, chemical and allied products, and food and kindred products increased their share, the petroleum refining and related industries, paper and allied products, and stone, clay, glass, and concrete products decreased their share of the total in 1976 compared with 1971. Paper and allied products consumed the most residual fuel oil and increased its consumption at the rate of 0.89%/yr from 1971 to 1974, and at 8.76%/yr between 1971 and 1976.

Finally, the consumption of distillate fuel oil rose from 70.6% in 1971, to 77.1% in 1974, and then to only 70.7% in 1976. The chemical and allied products, food and kindred products, and stone, clay, glass, and concrete products significantly increased their consumption in 1976 compared with 1971. Over the same period, the primary metal industries and paper and allied products substantially decreased their relative share.

The principal factors influencing the changes in manufacturing energy usage patterns can largely be explained by the activities measured by value added by manufacturing and the average unit costs for the purchased fuels and electricity. These are summarized in Table 4-5 and their development is shown in Fig. 4-5.

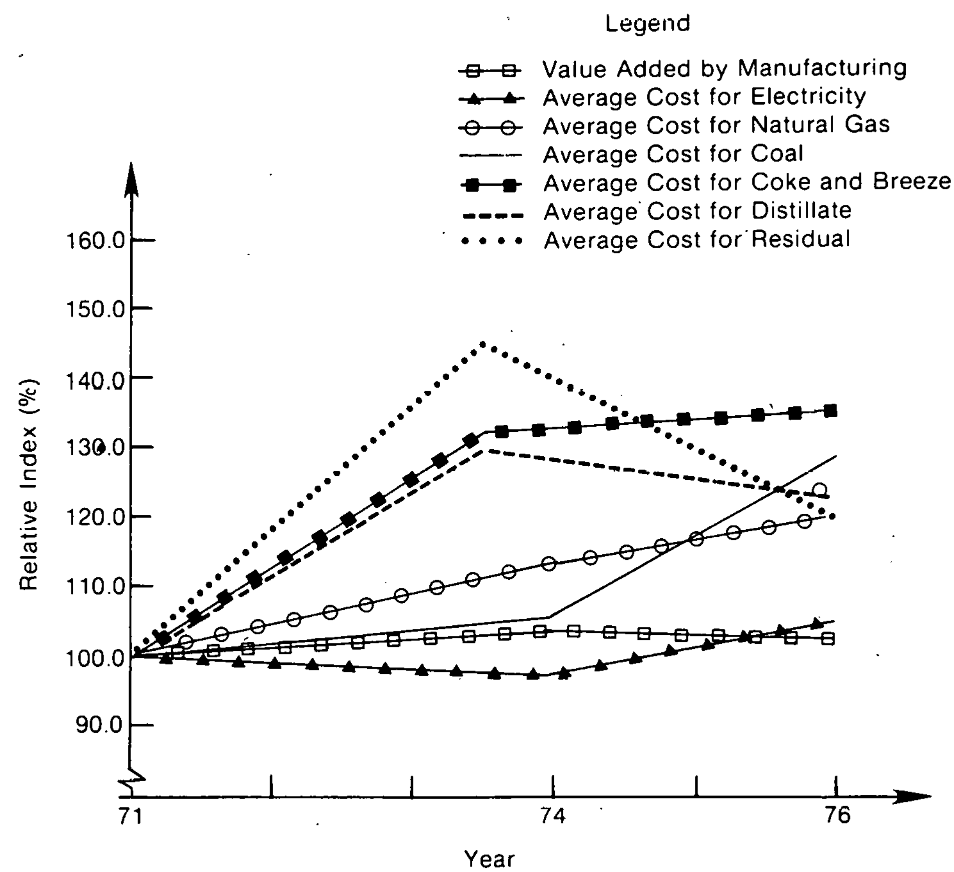


Figure 4-5. Value Added by Manufacturing and Average Cost for Purchased Fuels and Electricity by Manufacturing Subsector

Table 4-5. **VALUE ADDED BY MANUFACTURING AND AVERAGE COST OF PURCHASED FUELS AND ELECTRICITY BY MANUFACTURING SUBSECTOR**

Item	Year 1971	Year 1974	Year 1976	Annual Average Growth Rate (Compounded) % 1971-74	Annual Average Growth Rate (Compounded) % 1971-76
Value Added by Manufacturing	497.65	517.12	511.47		
(in Billions of 1976 Dollars)	100.0	103.9	102.8	1.29	0.55
Average Cost for Electricity ($/MBtu)	5.28	5.15	5.58	-0.83	1.11
Relative Index	100.0	97.5	105.7		
Average Cost for Natural Gas ($/MBtu)	1.02	1.16	1.23	4.38	3.82
Relative Index	100.0	113.7	120.6		
Average Cost for Coal ($MBtu)	0.83	0.96	1.07	4.96	5.21
Relative Index	100.0	115.7	128.9		
Average Cost for Coke & Breeze ($/MBtu)	2.07	2.74	2.80	9.80	6.23
Relative Index	100.0	132.4	135.3		
Average Cost for Residual Fuel Oil ($/MBtu)	1.57	2.28	1.88	13.24	3.67
Relative Index	100.0	145.2	119.7		
Average Cost for Distillate Fuel Oil ($/MBtu)	1.92	2.49	2.36	9.05	4.21
Relative Index	100.0	129.7	122.9		

Expressed in constant dollars in relation to the average prices of a given fuel and other fuels considered competitive energy sources, value added by manufacturing should closely approximate "real" growth of manufacturing activities and possibly explain the growth of a given fuel consumed by manufacturing establishments.

Value added by manufacturing from 1971 to 1976, increased by only 2.8%. Its annual average growth rate dropped from 1.29%/yr between 1971 to 1974 to 0.55%/yr between 1974 and 1976. During the same period, the purchased fuels and electricity consumed increased at an annual average rate of 2.8%.

The average price of electricity decreased from $5.25/MBtu in 1971 to $5.15/MBtu in 1974, but in 1976; it was 105.7% that of 1971. The average price of electricity declined 0.83%/yr between 1971 and 1974 and grew 1.11%/yr from 1971 to 1976.

Over the same six-year period, the average price of natural gas grew at an annual rate of 4.38% from 1971 to 1974 and at 3.82% between 1971 and 1976. The relative indexes in 1974 and 1976 were 113.7% and 120.6%, respectively.

The average price of coal grew 5.21%/yr from 1971. Manufacturing establishments had to pay 15.7% more in 1974 and 20.6% more in 1976 than they paid per MBtu in 1971.

The average price for coke and breeze increased from $2.07/MBtu in 1971 to $2.74 /MBtu in 1974 and $2.80/MBtu in 1976. In 1974, it was 132.4%, and in 1976, it was 135.3% that of 1971. Its annual growth rate dropped from 9.80%/yr between 1971 and 1974 to 6.23%/yr from 1971 to 1976.

The next six subsections provide additional data breakdowns by individual manufacturing industry.

4.3.2.1 Primary Metal Industries (SIC 33)

Fuels and electric power consumed by the primary metal industries by 3- and 4-digit SIC group are summarized in the tables in Volume II. Primary metal industries' energy use increased from 2.5 quads in 1971 to 2.6 quads in 1974, but in 1976, it was only 97.1% that of 1971. It declined at the rate of 0.55%/yr from 1971 to 1976.

The primary metal industries fuels and electricity consumption by primary fuel is presented in Fig. 4-6 and in the following table:

Fuels and Electricity	1971 %	1974 %	1976 %
Electricity	16.9	21.1	21.2
Natural Gas	46.6	41.6	40.7
Coal	10.1	5.9	5.7
Coke and Breeze	13.0	13.4	6.1
Distillate Fuel Oil	3.8	3.4	2.8
Residential Fuel Oil	5.4	8.7	10.4
Other Fuels	4.2	5.9	13.1

Between 1971 and 1976, electricity, residual fuel oil, and other fuels increased their share, and natural gas, coal, coke and breeze, and distillate fuel oil substantially decreased their relative share of the total. Also, during this period, the fuels and electric power required to produce one dollar of value added (in 1976 dollars) declined by 3.3%, from 72,050 to 69,642 Btu. The primary metal industries intensity in fuels and electricity consumption by 3- and 4-digit SIC and primary fuel is presented in the tables in Volume II.

The primary metal industries' activities measured in value added by manufacturing and average costs of purchased fuels and electricity in 1971, 1974, and 1976, are summarized in Table 4-6 and Fig. 4-7. Value added by manufacturing and the average cost of fossil fuels grew at a significantly high annual average rate between 1971 and 1974. The same

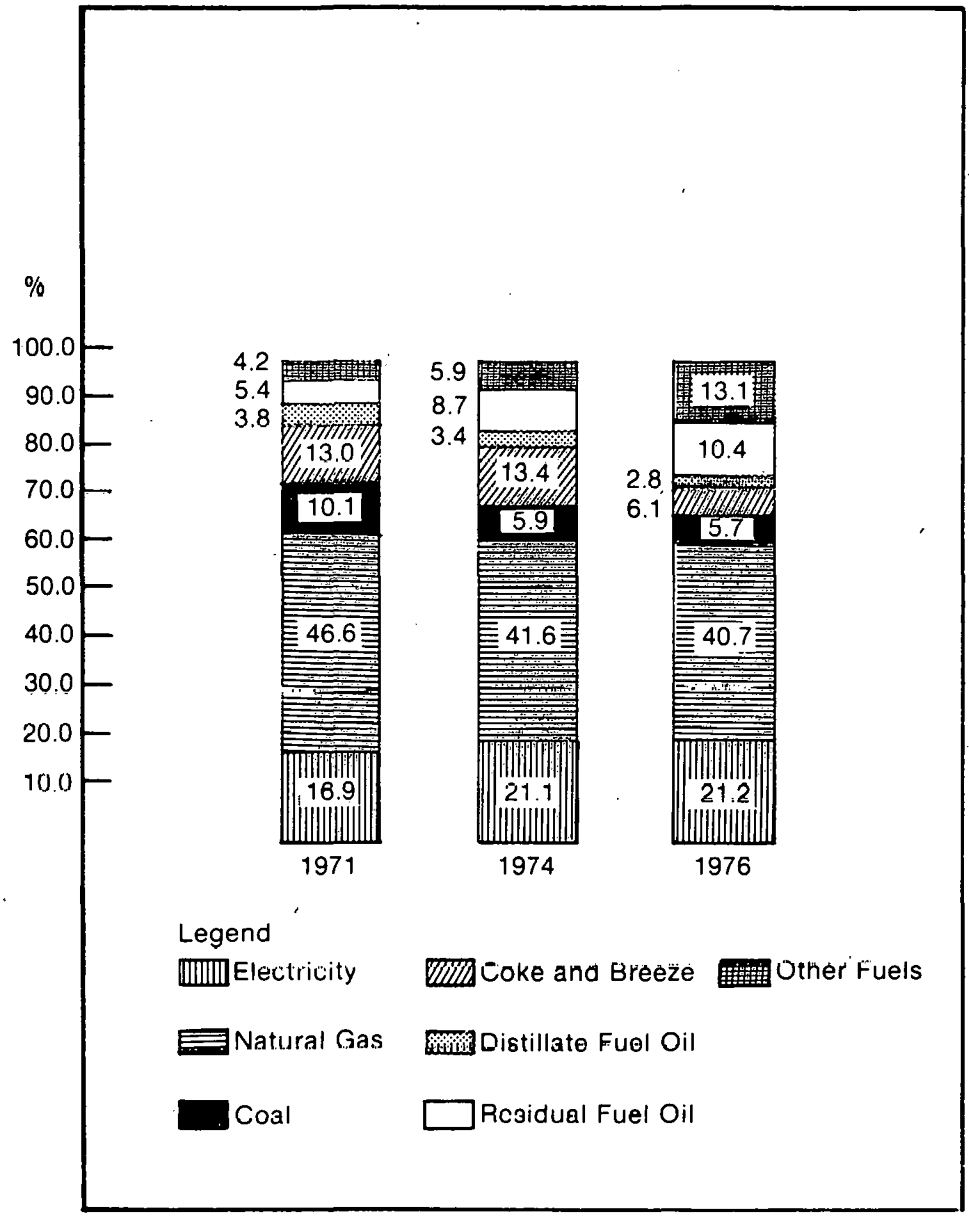


Figure 4-6. Primary Metals Industries Fuels and Electricity Consumption by Primary Fuel

Table 4-6. **VALUE ADDED BY MANUFACTURING AND AVERAGE COST OF PURCHASED FUELS AND ELECTRICITY IN THE PRIMARY METAL INDUSTRIES**

Item	Year			Annual Average Growth Rate (%)	
	71	74	76	71-74	71-76
Value Added by Manufacturing (in Billions of 1976 Dollars)	34.0	42.6	34.2	7.8	-0.1
Relative Index	100.0	125.3	100.6		
Average Cost for Electricity ($/MBtu)	4.24	3.94	4.40	-2.4	0.7
Relative Index	100.0	92.9	103.8		
Average Cost for Natural Gas ($/MBtu)	1.22	1.23	1.21	0.3	-0.2
Relative Index	100.0	100.8	99.2		
Average Cost for Coal ($/MBtu)	0.74	1.01	1.15	10.9	9.2
Relative Index	100.0	136.5	155.4		
Average Cost for Coke and Breeze ($/MBtu)	2.10	2.75	2.78	9.4	5.8
Relative Index	100.0	131.0	132.4		
Average Cost for Distillate Fuel Oil ($/MBtu)	1.96	2.69	2.39	11.1	4.0
Relative Index	100.0	137.2	121.9		
Average Cost for Residual Fuel Oil ($/MBtu)	1.71	2.50	1.87	13.5	1.8
Relative Index	100.0	146.2	109.4		

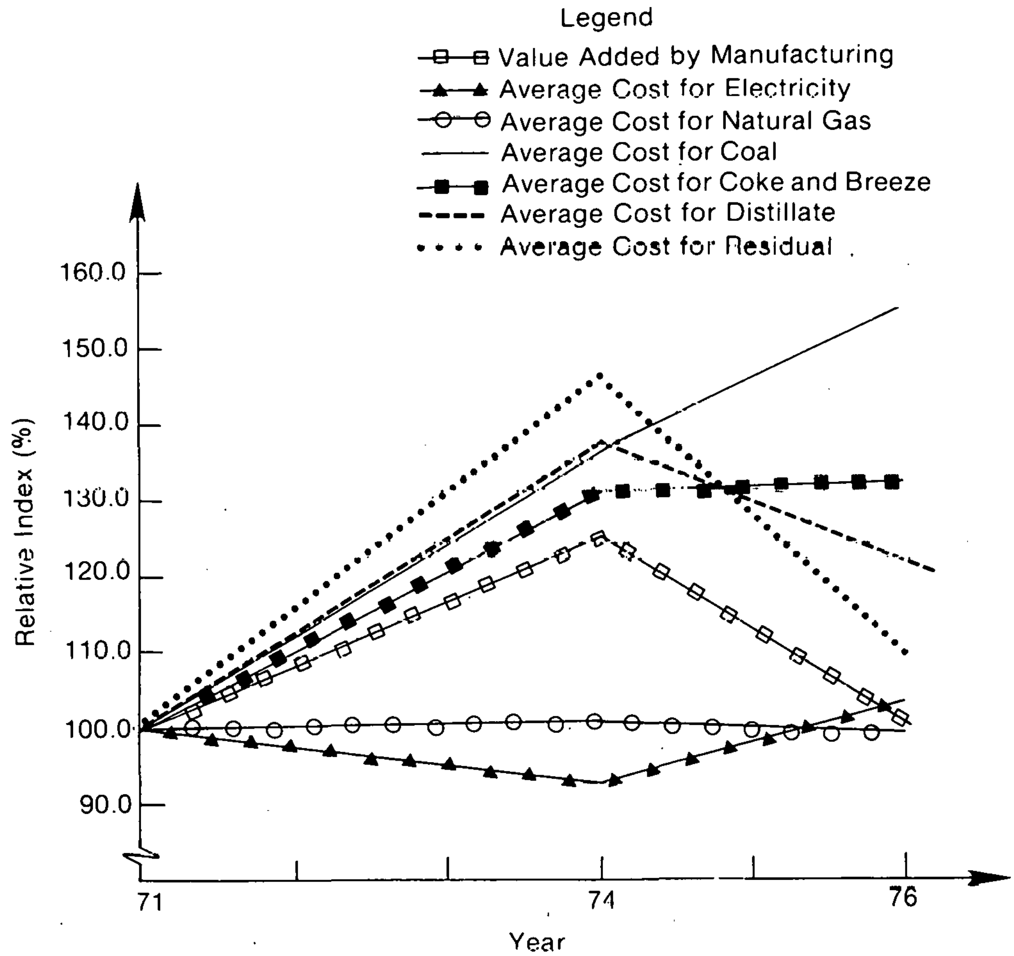


Figure 4-7. Value Added by Manufacturing and Average Cost of Purchased Fuels and Electricity in the Primary Metal Industries

phenomenon can be observed between 1971 and 1976 but at a relatively smaller rate of growth. The average cost of electricity declined from 1971 to 1974 but grew between 1971 and 1976.

Table 4-14 and Fig. 4-8 present the primary metal industries' 1974 energy consumption by primary fuel and functional use. The major end uses of the energy consumed in 1974 were for direct heat, feedstock, coke production, electrolyte processes, and electricity generation.

4.3.2.2 Chemicals and Allied Products (SIC 28)

The chemicals and allied products fuels and electricity consumption by 3- and 4-digit SIC group and primary fuel is presented in the tables in Volume II. Between 1971 and 1976, these industries' fuels and electricity consumption increased from 2.8 quads in 1971, to 2.9 quads in 1974, and 3.0 quads in 1976. It grew about 1.7%/yr from 1971 to 1976.

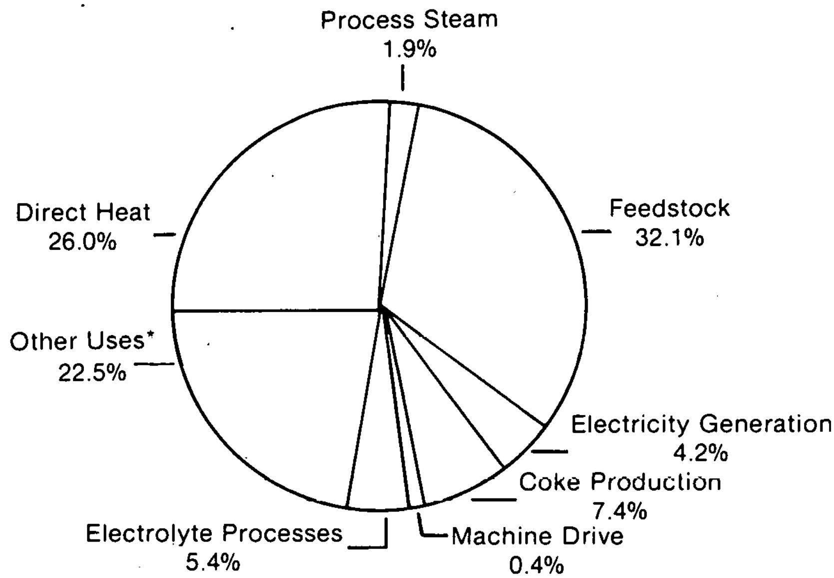


Figure 4-8. U.S. Primary Metal Industries 1974 Energy Consumption by Primary Fuel and Functional Use

The chemicals and allied products consumption is presented in Fig. 4-9 and summarized in the following table:

Fuels and Electricity	1971 %	1974 %	1976 %
Electricity	12.2	10.5	11.5
Natural Gas	53.2	32.9	28.6
Coal	17.3	16.6	17.1
Distillate Fuel Oil	3.1	11.7	4.8
Residual Fuel Oil	4.3	22.5	34.4
Other Fuels	9.8	5.8	3.6

Between 1971 and 1976, the manufacturing industries consumption of electricity, natural gas, coal, distillate fuel oil, and other fuels substantially declined, while consumption of residual fuel oil in 1976 was 8.5 times higher than that of 1971.

Over the 1971-76 period, the fuels and electric power required to produce one dollar of value added (in 1976 dollars) was practically unchanged. In 1976, it was 58,690 Btu or 99.93% that of 1971. Detailed data on the chemicals and allied products intensity in fuels and electricity consumption is presented in the tables in Volume II.

Their activities measured in value added for manufacturing in 1971, 1974, and 1976, are presented in Table 4-7 and Fig. 4-10. They indicate that the growth in overall

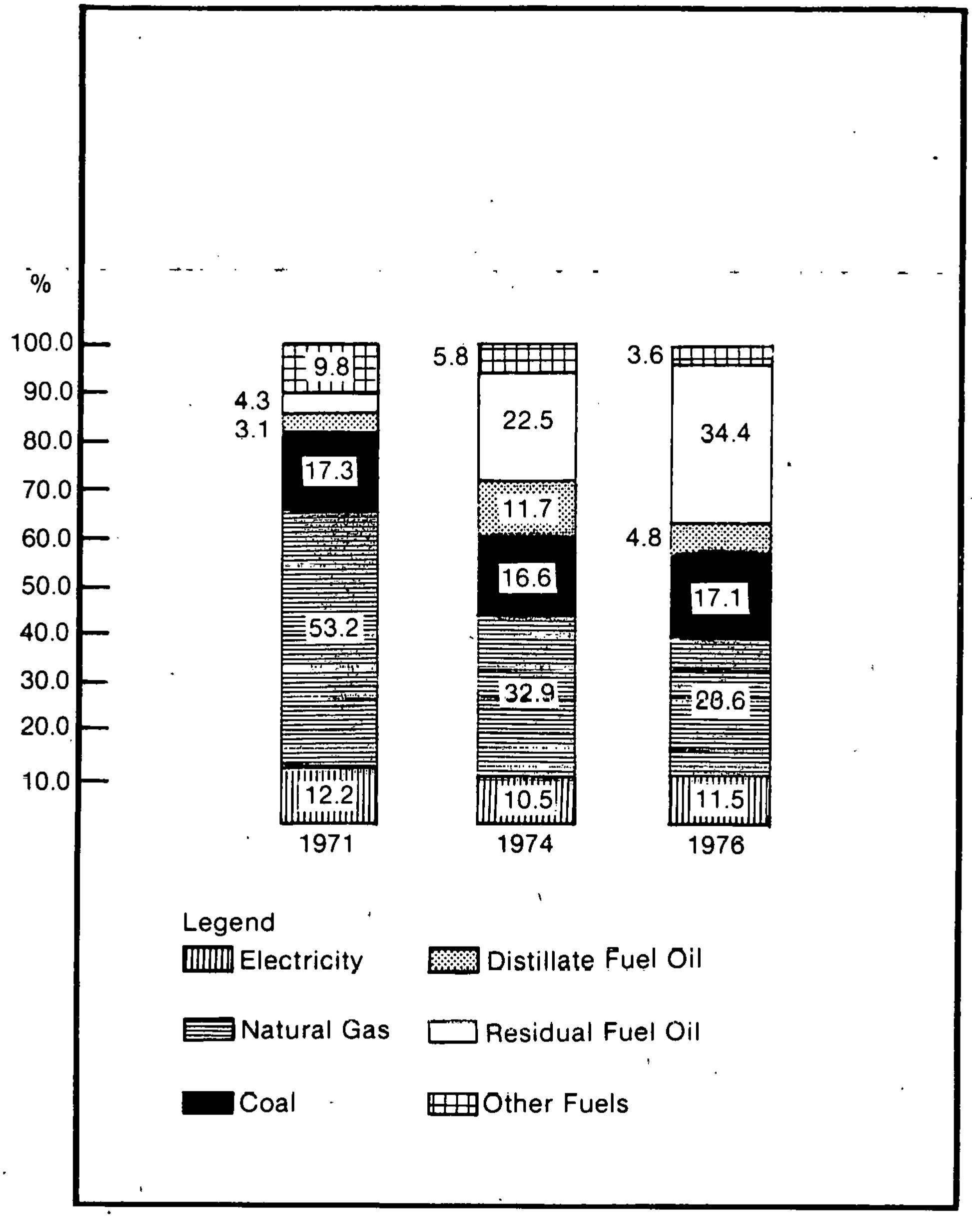


Figure 4-9. Chemicals and Allied Products Industries Energy Consumption by Primary Fuel

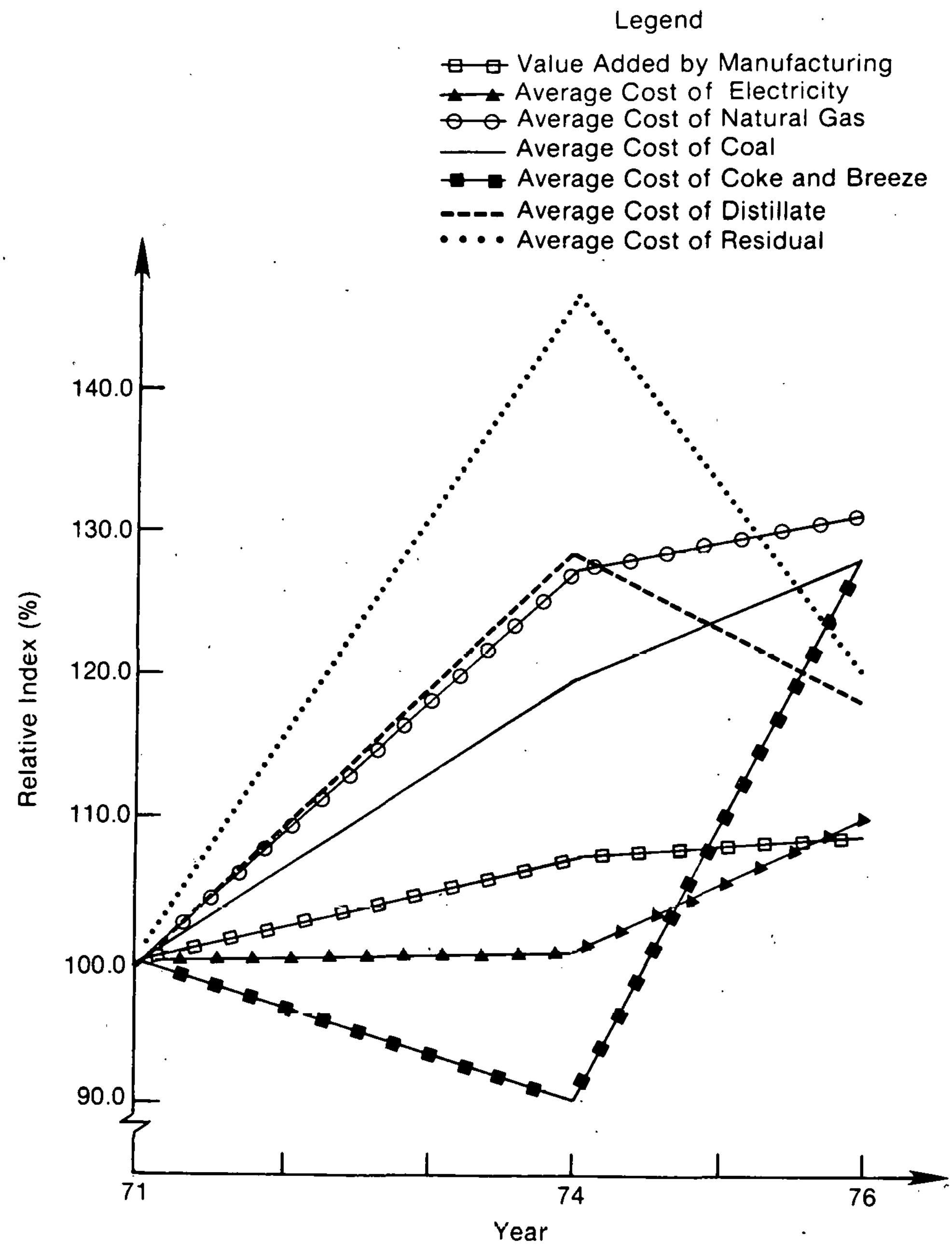


Figure 4-10. Value Added by Manufacturing and Average Cost of Fuels and Electricity in the Chemicals and Allied Products Industries

manufacturing activities was followed by a growth in average cost of fuels and electricity paid by the chemicals and allied products industries. Their 1974 fuels and electricity consumption by primary fuel and functional use are presented in Table 4-15 and Fig. 4-11.

In 1974, IPH accounted for 36.4% of the total fuels and electricity consumed; however, the major functional use of fuels and electricity was feedstock, which relative share was 44.7%. The other end uses were machine drive, electricity generation, and electrolyte processes.

Table 4-7. VALUE ADDED BY MANUFACTURING AND AVERAGE COST OF FUELS AND ELECTRICITY IN THE CHEMICALS AND ALLIED PRODUCTS INDUSTRIES

Item	Year			Annual Average Growth Rate (%)	
	1971	1974	1976	1971-74	1971-76
Value Added by Manufacturing (in Billions of 1976 Dollars)	47.3	50.8	51.4	2.4	1.7
Relative Index	100.0	107.4	108.9		
Average Cost for Electricity ($/MBtu)	4.17	4.20	4.59	0.2	1.9
Relative Index	100.0	100.7	110.1		
Average Cost for Natural Gas ($/MBtu)	0.80	1.02	1.05	8.4	5.6
Relative Index	100.0	127.5	131.3		
Average Cost for Coal ($/MBtu)	0.81	0.97	1.04	6.2	5.1
Relative Index	100.0	119.8	128.4		
Average Cost for Coke and Breeze ($/MBtu)	2.47	2.23	3.18	-3.3	5.2
Relative Index	100.0	90.3	128.7		
Average Cost for Distillate Fuel Oil ($/MBtu)	1.93	2.48	2.28	8.7	3.4
Relative Index	100.0	128.5	118.1		
Average Cost for Residual Fuel Oil ($/MBtu)	1.58	2.32	1.90	-13.7	3.8
Relative Index	100.0	146.8	120.3		

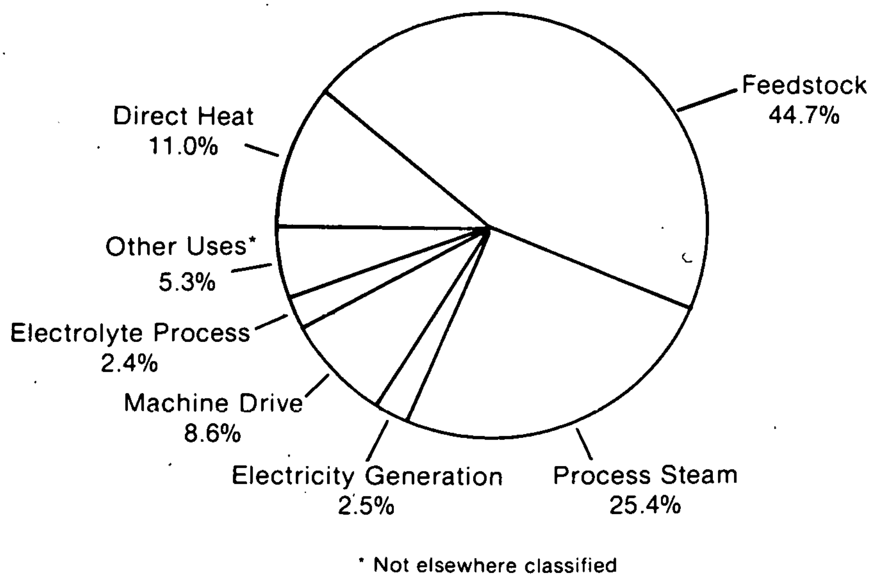


Figure 4-11. U.S. Chemicals and Allied Products Industries 1974 Energy Consumption by Primary Fuel and Functional Use

4.3.2.3 Petroleum Refining and Related Industries (SIC 29)

In petroleum refining and related manufacturing industries, energy is consumed by converting crude oil to usable energy forms. These industries used 1.29 quads in 1976, and 1.57 quads in 1974, compared with 1.59 quads in 1971. Their energy consumption declined 0.53%/yr from 1971 to 1974, and 4.11%/yr between 1971 and 1976.

The tables in Volume II provide data on fuels and electricity consumption, intensity, and cost in the petroleum refining and related industries. The major sources of fuels and electricity are summarized in Fig. 4-12 and in the following table:

Fuels and Electricity	1971 %	1974 %	1976 %
Electricity	5.1	5.9	7.3
Natural Gas	85.8	77.6	83.5
Distillate Fuel Oil	1.2	3.1	1.2
Residual Fuel Oil	4.2	2.6	6.2
Other Fuels	3.7	10.8	1.8

The largest energy source is natural gas, which dropped its relative share of total consumption. The remaining energy sources are electricity, distillate and residual fuel oils, and other fuels.

Volume II presents data on fuels and electricity intensity by 2-, 3-, and 4-digit SIC group and primary fuels in 1971, 1974, and 1976. From 1971 to 1976, the fuels and electric power required to produce one dollar of value added (in 1976 dollars) decreased from 176,463 to 137,880 Btu (78.1%) in 1974 and 98,087 Btu (55.6%) in 1976.

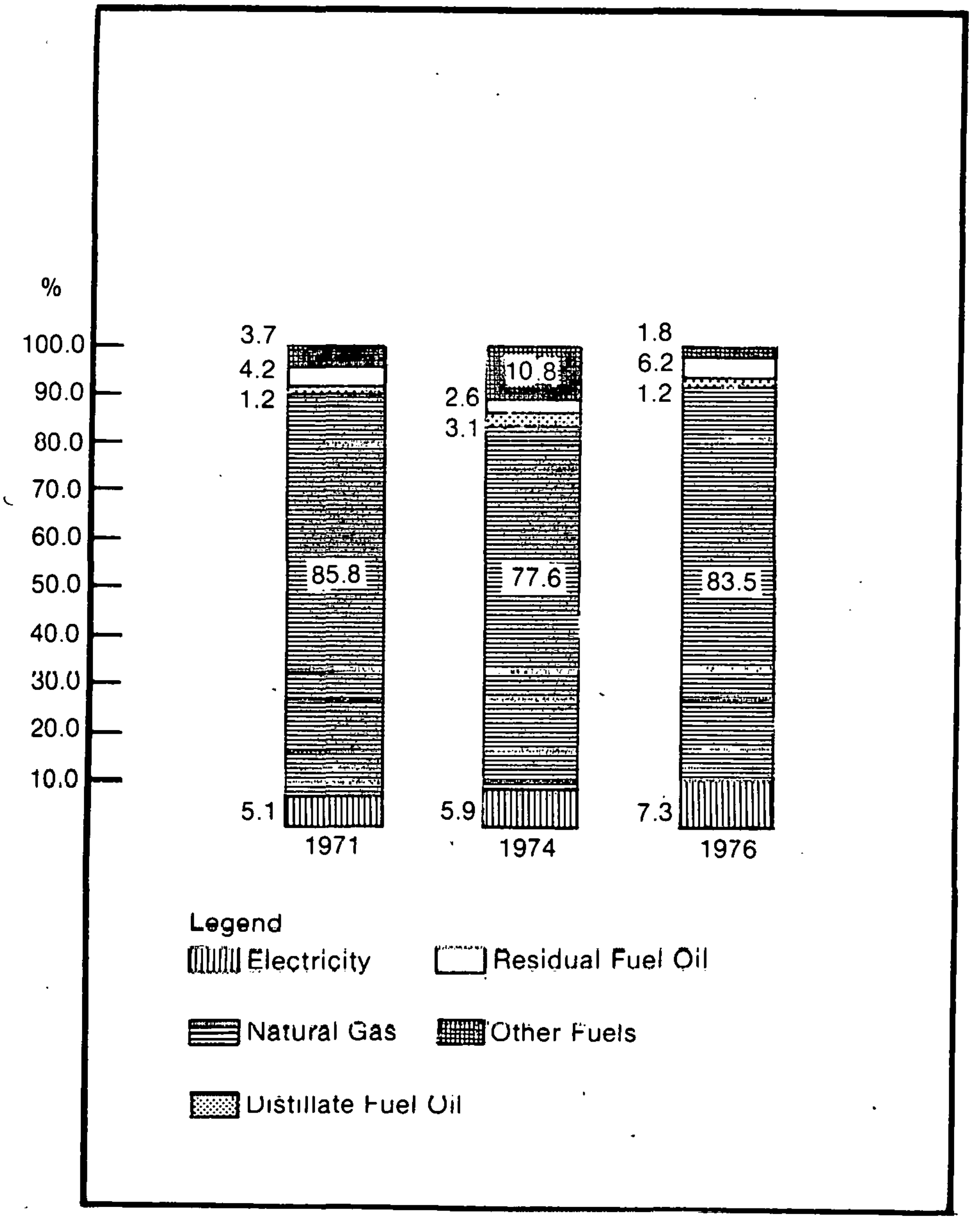


Figure 4-12. Petroleum Refining and Related Industries Energy Consumption by Primary Fuel

Over those six years, manufacturing activities grew substantially. In 1976, the value added was 146.7% that of 1971; it grew 8.0%/yr over that period. Also, a relatively high upward trend was observed for the average cost of fuels and electricity from 1971 to 1976. For example, the average cost of natural gas increased at the rate of 13.2%/yr between 1971 and 1976. These data are summarized in Table 4-8 and Fig. 4-13.

The U.S. petroleum refining and related industries 1974 energy consumption by primary fuel and functional use is summarized in Table 4-16 and Fig. 4-14. About 72.2% of the total energy consumed is for direct heat; of the rest, about 20.8% is used for process steam, 4.8% for machine drive, and 1.1% for electricity generation.

Table 4-8. VALUE ADDED BY MANUFACTURING AND AVERAGE COST OF FUELS AND ELECTRICITY IN THE PETROLEUM REFINING AND RELATED INDUSTRIES

Item	Year			Annual Average Growth Rate (%)	
	1971	1974	1976	1971-74	1971-76
Value Added by Manufacturing (in Billions of 1976 Dollars)	9.0	11.4	13.2	8.2	8.0
Relative Index	100.0	126.7	146.7		
Average Cost for Electricity ($/MBtu)	4.30	4.53	5.06	1.8	3.3
Relative Index	100.0	105.3	117.7		
Average Cost for Natural Gas ($/MBtu)	0.69	0.94	1.28	10.9	13.2
Relative Index	100.0	136.2	185.5		
Average Cost for Coal ($/MBtu)	0.69	NA	1.04	—	8.6
Relative Index	100.0	—	150.7		
Average Cost for Coke and Breeze ($/MBtu)	NA	NA	NA	—	—
Relative Index					
Average Cost for Distillate Fuel Oil ($/MBtu)	1.76	1.97	2.37	3.8	6.1
Relative Index	100.0	111.9	134.7		
Average Cost for Residual Fuel Oil ($/MBtu)	1.41	2.29	1.89	17.5	6.0
Relative Index	100.0	162.4	134.0		

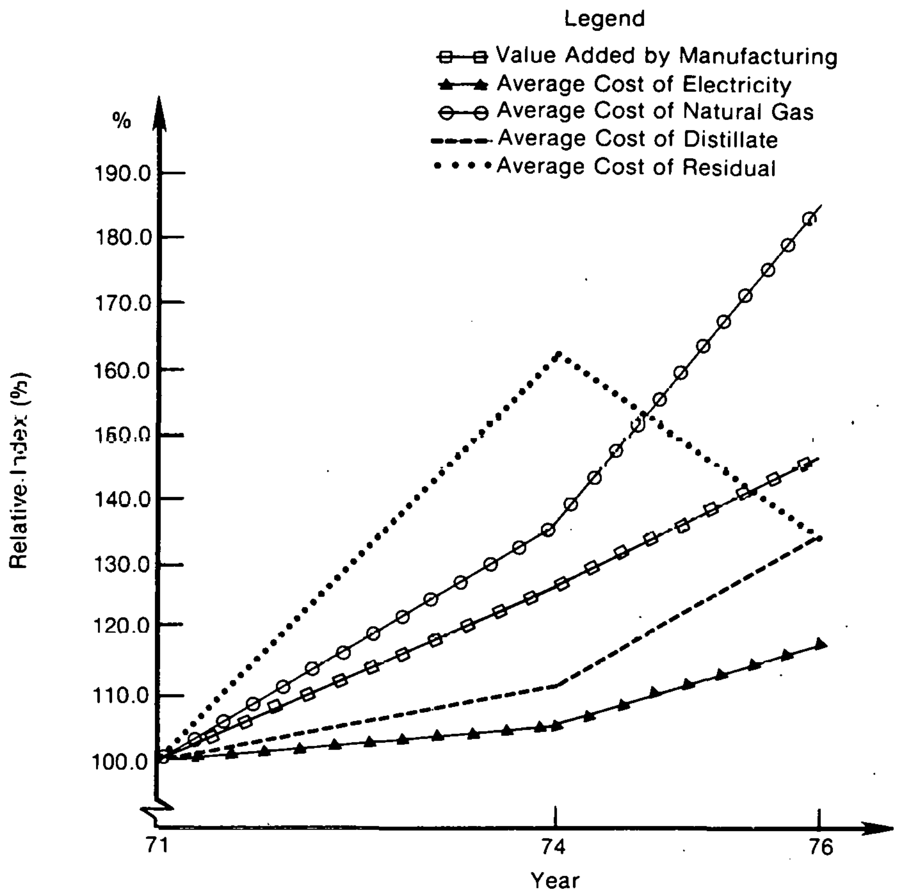


Figure 4-13. Value Added by Manufacturing and Average Cost of Fuels and Electricity in the Petroleum Refining and Related Industries

4.3.2.4 Paper and Allied Products (SIC 26)

Paper and allied products accounted for about 10.3% of the 1976 manufacturing subsector consumption of energy compared with 10.0% in 1971. Their consumption of fuels and electricity slightly declined from 1.32 quads in 1971 to 1.29 quads (98.0%) in 1976. The average annual rate of decline was 0.32%. The tables in Volume II present data on fuels and electricity consumption, intensity, and cost by 3- and 4-digit SIC group and primary fuel. The individual fuels and purchased electricity accounted for the shares of the total presented in Fig. 4-15 and in the following table.

Fuels and Electricity	1971 %	1974 %	1976 %
Electricity	9.1	10.5	11.5
Natural Gas	37.5	32.9	28.6
Coal	18.8	16.6	17.1
Distillate Fuel Oil	8.0	11.7	4.8
Residual Fuel Oil	22.2	22.5	34.4
Other Fuels	4.4	5.8	3.6

Over the 1971-76 period, electricity increased its share 2.4% and residual fuel oil, 12.2%. Coal declined in importance 1.7%, as did natural gas, 8.9%; distillate fuel oil, 3.2%; and other fuels, 0.8%.

Between 1971 and 1976, the fuels and electric power required to produce one dollar of value added (in 1976 dollars) declined from 70,037 Btu in 1971 to 60,985 Btu (87.1%) in 1974, and 62,833 Btu (89.7%) in 1976. The tables in Volume II present data on their intensity by 3- and 4-digit SIC group and primary fuel.

Value added by manufacturing and average cost of fuels and electricity are summarized in Table 4-9 and Fig. 4-16. Production measured by value added (in 1976 dollars) increased from $18.8 billion in 1971 to $21.8 billion in 1974 and $20.6 billion in 1976. Production grew at the rate of 5.1%/yr from 1971 to 1974 and at 1.8% between 1971 and 1976. Between 1971 and 1976, the average cost of purchased fuels and electricity grew at relatively high rates.

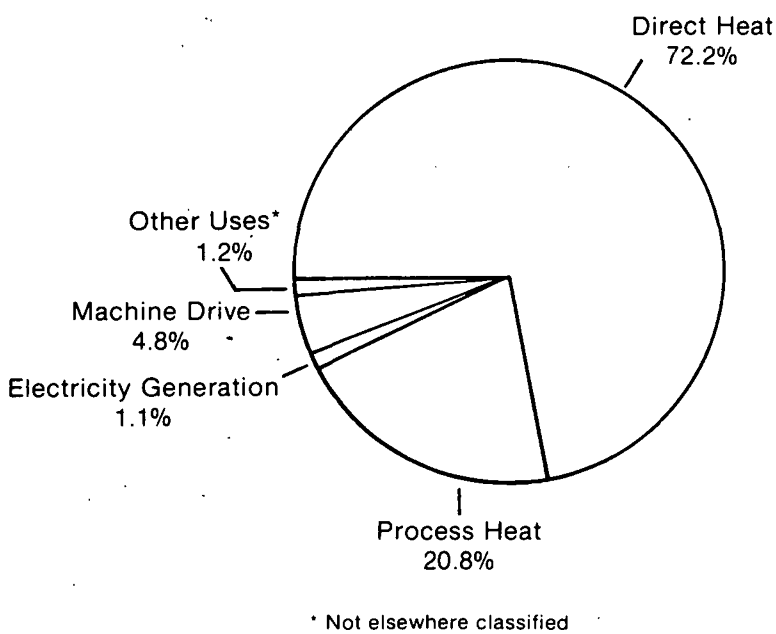


Figure 4-14. U.S. Petroleum Refining and Related Industries 1974 Energy Consumption by Primary Fuel and Functional Use

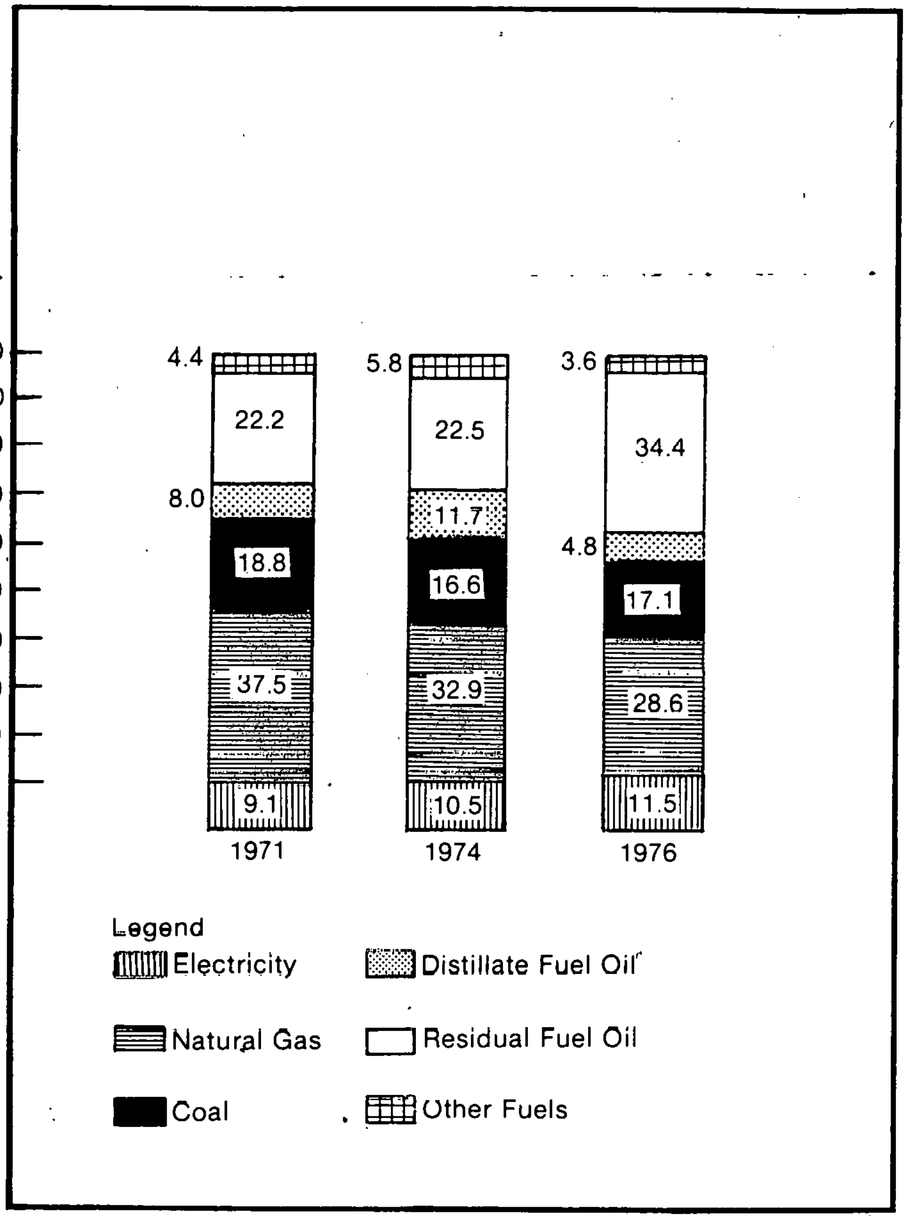


Figure 4-15. Paper and Allied Products Industries Energy Consumption by Primary Fuel

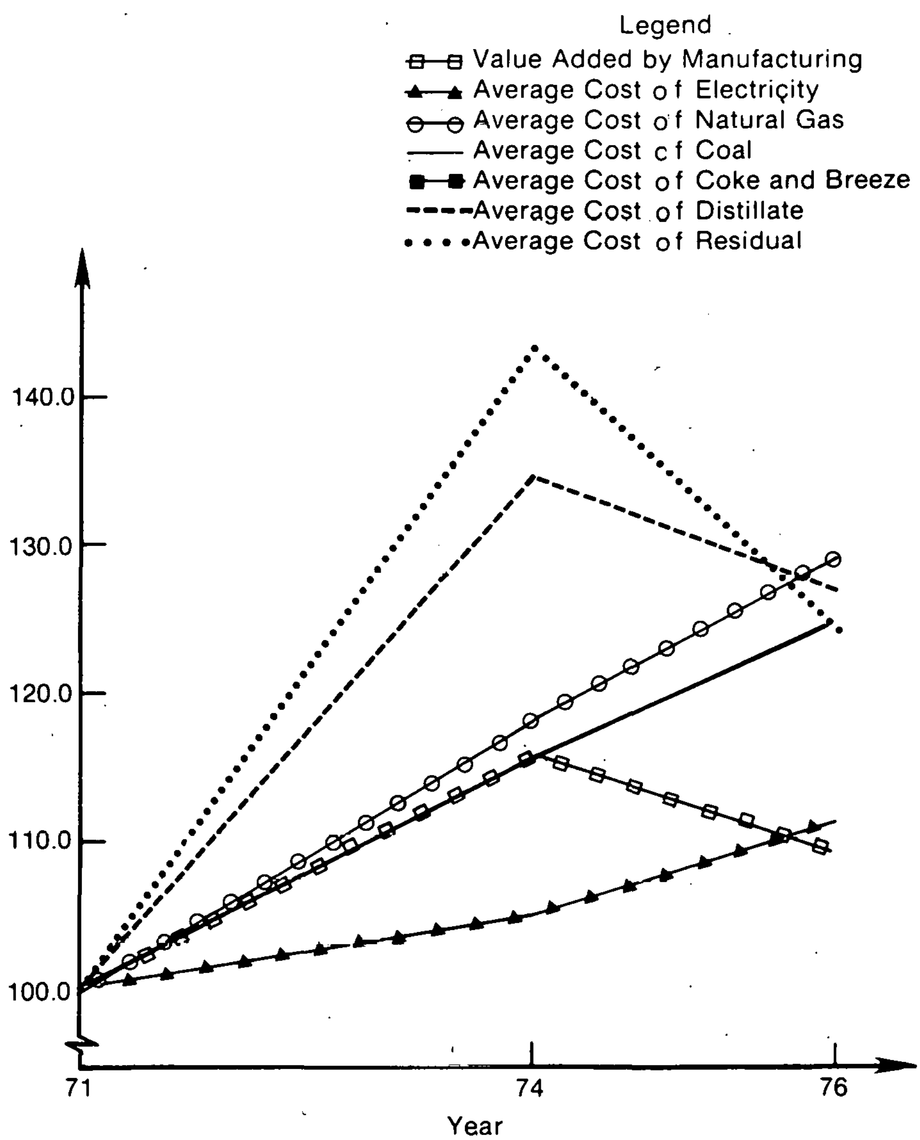


Figure 4-16. Value Added by Manufacturing and Average Cost of Fuels and Electricity in the Paper and Allied Products Industries

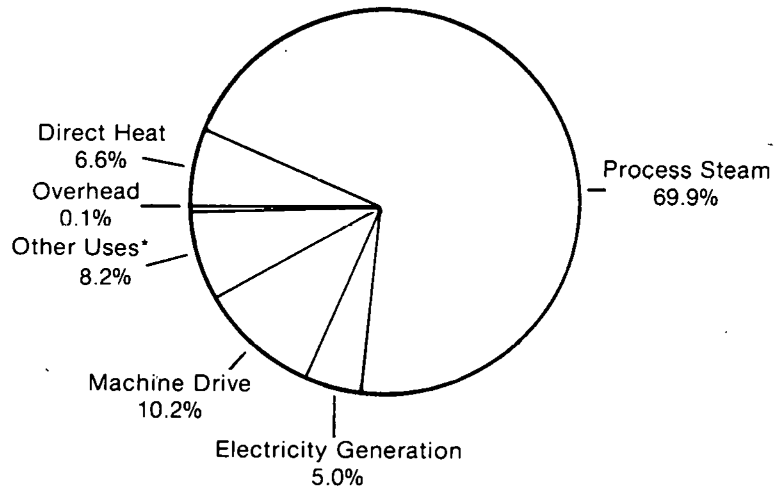
Table 4-9. VALUE ADDED BY MANUFACTURING AND AVERAGE COST OF FUELS AND ELECTRICITY IN THE CHEMICALS AND ALLIED PRODUCTS INDUSTRIES

Item	Year			Annual Average Growth Rate (%)	
	1971	1974	1976	1971-74	1971-76
Value Added by Manufacturing (in Billions of 1976 Dollars)	18.8	21.8	20.6	5.1	1.8
Relative Index	100.0	116.0	109.6		
Average Cost for Electricity ($/MBtu)	4.70	4.94	5.24	1.7	2.2
Relative Index	100.0	105.1	111.5		
Average Cost for Natural Gas ($/MBtu)	0.99	1.17	1.28	5.7	5.3
Relative Index	100.0	118.2	129.3		
Average Cost for Coal ($/MBtu)	0.88	1.02	1.10	5.0	4.6
Relative Index	100.0	115.9	125.0		
Average Cost for Coke and Breeze ($/MBtu)	NA	NA	NA	—	—
Relative Index					
Average Cost for Distillate Fuel Oil ($/MBtu)	1.65	2.22	2.10	10.4	4.9
Relative Index	100.0	134.5	127.3		
Average Cost for Residual Fuel Oil ($/MBtu)	1.43	2.05	1.78	12.8	4.5
Relative Index	100.0	143.4	124.5		

The U.S. paper and allied products manufacturing industries 1974 fuel and electric power consumption by primary fuel and functional use is presented in Table 4-17 and Fig. 4-17. This energy is typically consumed in two forms—steam and electric power. The purchased fuels and electricity is for IPH—76.5% (process steam 69.9% and direct heat 6.6%) of the total energy consumption. Electricity generation accounts for 5.0% of the total energy consumption, and machine drive for about 10.2%.

4.3.2.5 Stone, Clay, Glass, and Concrete Products (SIC 32)

Total fuels and electricity consumption in stone, clay, glass, and concrete products amounted to about 9.9% of the total used by the manufacturing subsector in 1971 and were about 9.7% in 1976. In 1976, they consumed 1.22 quads or 93.8% of fuels and electricity compared with 1.30 quads in 1971. Over that period, their energy consumption declined at the rate of 1.34%/yr. However, it grew at an annual average rate of 0.79% from 1971 to 1974. The tables in Volume II present data on fuels and electricity consumption, intensity, and cost by 2-, 3- and 4-digit SIC group and by primary fuel.



* Not elsewhere classified

Figure 4-17. U.S. Paper and Allied Products Industries 1974 Energy Consumption by Primary Fuel and Functional Use

Between 1971 and 1976, fuels and electricity per one dollar of value added (in 1976 dollars) declined by 3.6%, from 75,436 Btu to 72,712 Btu. Their intensity in fuels and electricity consumption by 3- and 4-digit SIC group and primary fuel is presented in Volume II.

Natural gas and coal are the major fossil fuels used by this industry. Together, they accounted for about 73.5% of the total amount of fuels and electric power used in 1976 compared with 75.3% in 1971. The other sources of energy used are distillate and residual fuel oils and coke and breeze. These are summarized in the following table and in Fig. 4-18.

Fuels and Electricity	1971 %	1974 %	1976 %
Electricity	6.5	7.4	8.2
Natural Gas	55.8	52.4	49.8
Coal	19.5	18.4	23.7
Coke and Breeze	0.6	1.0	1.0
Distillate Fuel Oil	5.0	5.7	6.1
Residual Fuel Oil	4.1	3.7	5.6
Other Fuels	8.5	11.4	5.6

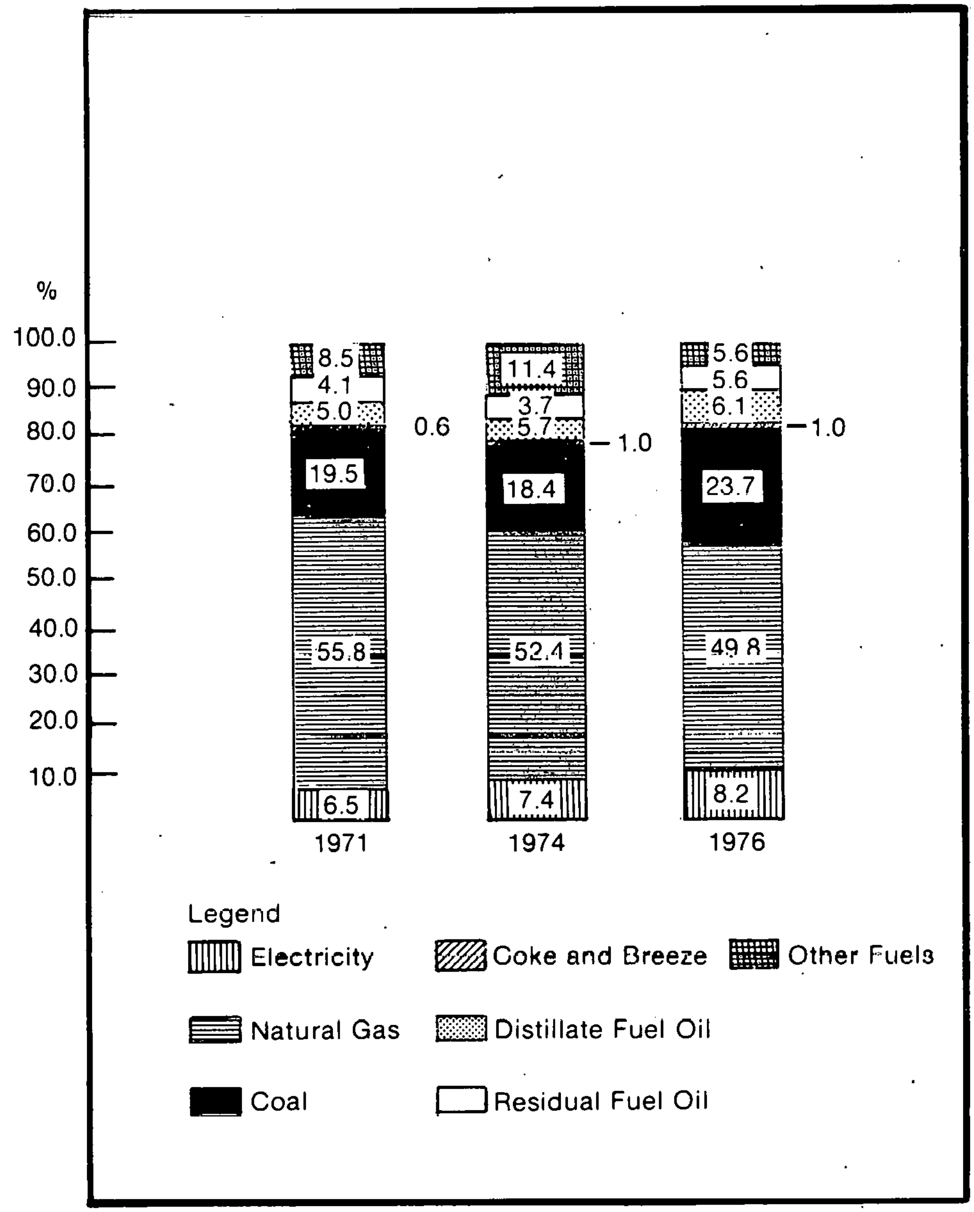


Figure 4-18. U.S. Stone, Clay, Glass, and Concrete Products Industries Energy Consumption by Primary Fuel

Table 4-10 and Fig. 4-19 present the value added in manufacturing and average cost of fuels and electricity in 1971, 1974, and 1976. Production declined at the rate of 0.6%/yr from 1971 to 1976; it dropped from $17.3 billion (in 1976 dollars) in 1971 to $16.8 billion in 1976. Average cost of fuels and electricity, besides coke and breeze, increased at a relatively high average annual growth rate.

Direct heat is the major end use of the purchased fuels and electricity in this industry. In 1974, its relative share was 77.2% of the total amount of energy consumed. The other end uses are machine drive, electricity generation, and overhead. These data are presented in Table 4-18 and Fig. 4-20.

Table 4-10. VALUE ADDED BY MANUFACTURING AND AVERAGE COST OF FUELS AND ELECTRICITY IN THE STONE, CLAY, GLASS, AND CONCRETE PRODUCTS INDUSTRIES

	Year			Annual Growth Rate (%)	
Item	1971	1974	1976	1971-74	1971-76
Value Added by Manufacturing (in Billions of 1976 Dollars)	17.3	16.9	16.8	-0.8	-0.6
Relative Index	100.0	97.7	97.1		
Average Cost for Electricity ($/MBtu)	5.66	5.90	6.41	1.4	2.5
Relative Index	100.0	104.2	113.3		
Average Cost for Natural Gas ($/MBtu)	1.14	1.23	1.28	2.6	2.3
Relative Index	100.0	107.9	112.3		
Average Cost for Coal ($/MBtu)	0.83	0.89	0.99	2.4	3.6
Relative Index	100.0	107.2	119.3		
Average Cost for Coke and Breeze ($/MBtu)	1.87	1.42	1.83	-8.8	-0.4
Relative Index	100.0	75.9	97.9		
Average Cost for Distillate Fuel Oil ($/MBtu)	1.97	2.63	2.43	10.1	4.3
Relative Index	100.0	133.5	123.4		
Average Cost for Residual Fuel Oil ($/MBtu)	1.44	2.16	1.83	14.5	4.9
Relative Index	100.0	150.0	127.1		

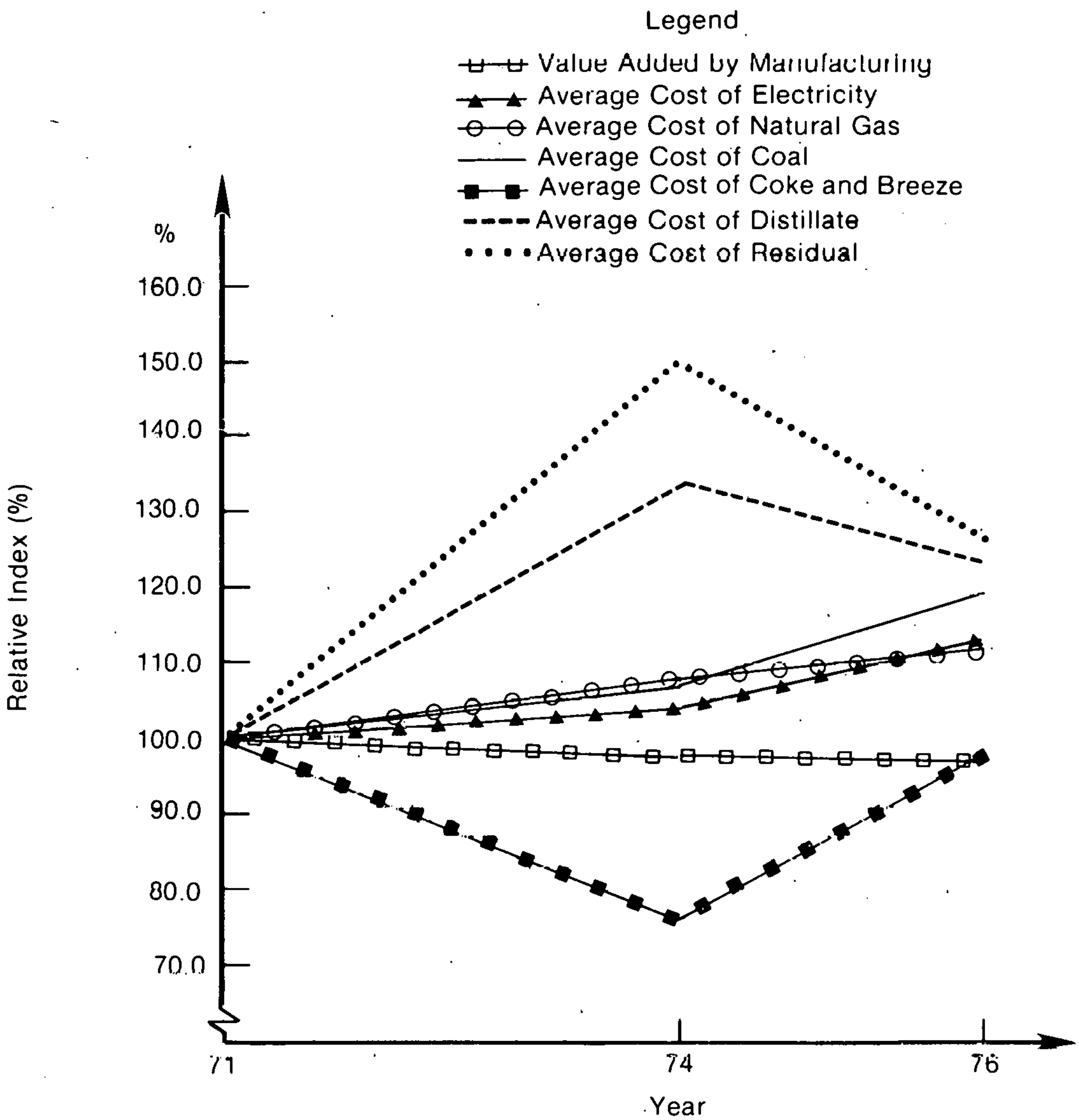
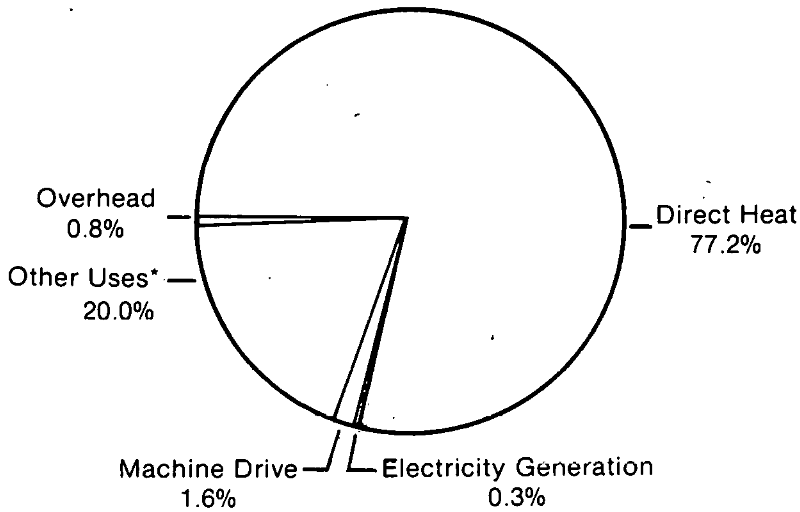


Figure 4-19. Value Added by Manufacturing and Average Cost of Fuels and Electricity in the Stone, Clay, Glass, and Concrete Product Industries



* Not elsewhere classified

Figure 4-20. U.S. Stone, Clay, Glass, and Concrete Products Industries Energy Consumption by Primary Fuel and Functional Use

4.3.2.6 Food and Kindred Products (SIC 20)

During the 1971-76 period, fuels and electricity use in the food and kindred product manufacturing industries decreased by 9.7%, from 1.03 quads to 0.94 quads—an annual average rate of decline of 1.79%. Volume II presents data on fuels and electricity consumption, intensity, and cost by 3- and 4-digit SIC group and primary fuel.

During this period, natural gas and coal decreased their share, and electricity and residual fuel oil increased their share of the total amount of energy used. These data are shown in the following table and are portrayed in Fig. 4-21.

Fuels and Electricity	1971 %	1974 %	1976 %
Electricity	13.4	13.2	14.2
Natural Gas	50.9	49.0	48.4
Coal	12.2	9.3	9.9
Coke and Breeze	2.7	1.1	3.2
Distillate Fuel Oil	4.7	7.0	7.6
Residual Fuel Oil	6.7	6.8	11.2
Other Fuels	9.4	13.6	5.5

From 1971 to 1976, production measured in value added (in 1976 dollars) decreased from $54.8 billion to $52.8 billion. In 1976, the relative index was 96.4%. It declined at the rate of 2.2%/yr from 1971 to 1974, and 0.74%/yr between 1971 and 1976. Over the same

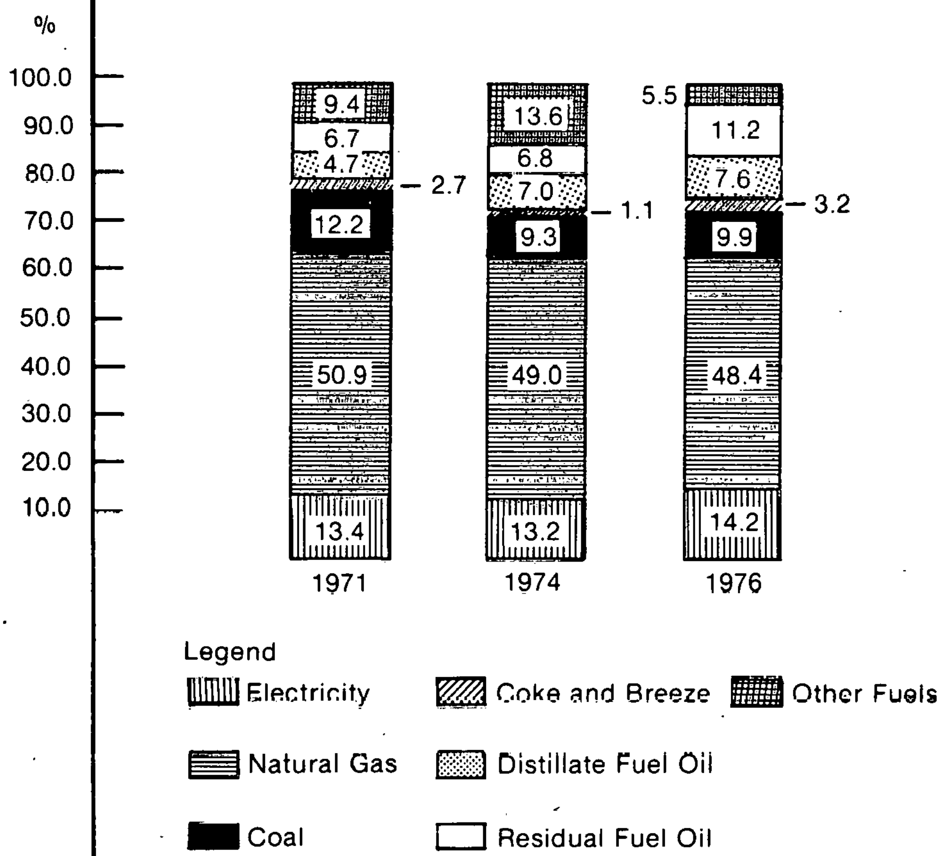


Figure 4-21. U.S. Food and Kindred Product Industries Energy Consumption by Primary Fuel

period, average cost of fuels and electricity grew at a relatively high rate. However, between 1971 and 1974, the average cost of electricity declined at the rate of 1.6%/yr and average cost of coal at 4.0%/yr. The above growth tendencies are presented in Table 4-11 and Fig. 4-22.

Between 1971 and 1976, the fuel and electric power required to produce one dollar of value added (in 1976 dollars) declined by 5.1%, from 18,708 to 17,769 Btu. The tables in Volume II present data on the U.S. food and kindred product manufacturing industries intensity in fuels and electricity consumption by 3- and 4-digit SIC group and primary fuel.

The bulk of the energy used in 1974 was for producing process steam—about 51.3%—with about 10% for direct heat. Of the balance, about 10.5% was used for machine drive, 7% for overhead, and 2.0% for electricity generation. These are summarized in Table 4-19 and Fig. 4-23.

Table 4-11. VALUE ADDED BY MANUFACTURING AND AVERAGE COST OF FUELS AND ELECTRICITY IN THE FOOD AND KINDRED PRODUCT INDUSTRIES

	Year			Annual Growth	Average Rate (%)
Item	1971	1974	1976	1971-74	1971-76
Value Added by Manufacturing (in Billions of 1976 Dollars)	54.8	51.2	52.8	-2.2	-0.74
Relative Index	100.0	93.4	96.4		
Average Cost for Electricity ($/MBtu)	6.66	6.35	6.78	-1.6	0.4
Relative Index	100.0	95.3	101.8		
Average Cost for Natural Gas ($/MBtu)	1.18	1.31	1.36	3.5	2.9
Relative Index	100.0	111.0	115.3		
Average Cost for Coal ($/MBtu)	0.78	0.69	0.96	-4.0	4.2
Relative Index	100.0	88.5	123.1		
Average Cost for Coke and Breeze ($/MBtu)	2.16	2.76	4.10	8.5	13.7
Relative Index	100.0	127.8	189.8		
Average Cost for Distillate Fuel Oil ($/MBtu)	2.04	2.63	2.41	8.8	3.4
Relative Index	100.0	128.9	118.1		
Average Cost for Residual Fuel Oil ($/MBtu)	1.80	2.36	2.01	9.4	2.2
Relative Index	100.0	131.1	111.7		

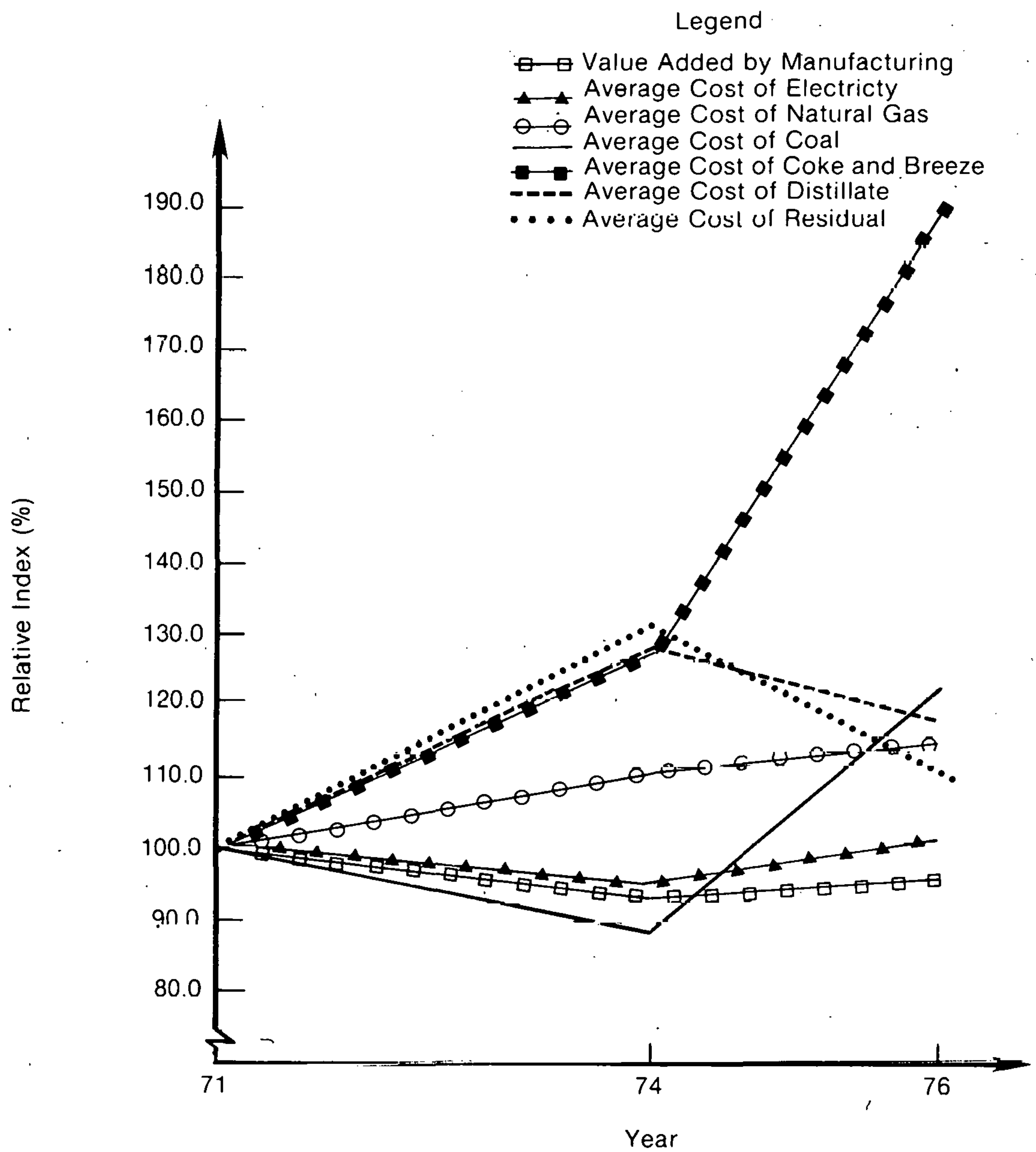
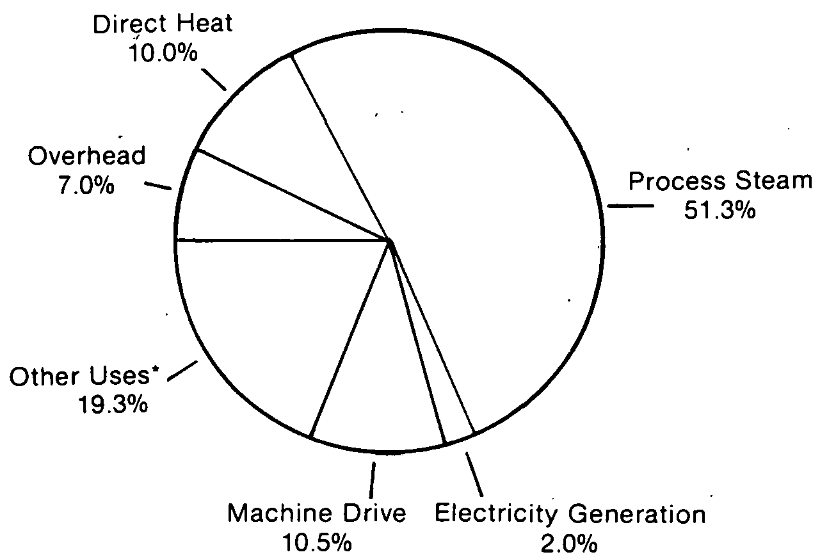


Figure 4-22. Value Added by Manufacturing and Average Cost of Fuels and Electricity in the Food and Kindred Product Industries



* Not elsewhere classified

Figure 4-23. U.S. Food and Kindred Product Industries Energy Consumption by Functional Use

Table 4-12. REGIONAL USE OF THE F

(Percentage of Total Energy Used)

Energy Source \ Census Division	New England 1971	New England 1976	Middle Atlantic 1971	Middle Atlantic 1976	South Atlantic 1971	South Atlantic 1976	East North Central 1971	East North Central 1976	West North Central 1971	West North Central 1976
Petroleum Products	84.1	79.9	56.4	56.1	53.3	54.1	35.8	38.4	40.6	43.5
Natural Gas	8.9	8.7	18.7	16.3	18.2	13.4	30.3	26.7	39.4	31.4
Coal	2.2	0.9	21.2	20.9	26.2	25.6	33.0	31.3	14.0	10.5
Hydro	1.5	1.8	2.6	3.0	2.0	1.8	0.3	0.2	2.9	2.4
Nuclear	3.3	8.7	1.1	3.7	0.3	5.1	0.6	3.4	0.2	3.2

Source: Energy Information Administration (1979)

Table 4-13. U.S. MANUFACTURING SUBSECTOR 1974 ENERGY

Functional End Use \ Fuel Type	Coal Volume	Coal %	Coke Volume	Coke %	Distillate Fuel Oil Volume	Distillate Fuel Oil %	Residual Fuel Oil Volume	Residual Fuel Oil %	Misc. Petro Products Volume	Misc. Petro Products %
Space Heating	4,584.4	0.1			6,164.2	1.1	7,445.5	0.5		
Space Cooling										
Space Conditioning, NSK/NEC										
Lighting										
Total Direct Heat	237,631.6	6.5	29,418.3	1.8	144,604.5	26.2	578,622.5	38.7	382,218.7	32.0
Direct Heat - below 600° F					18,934.9	3.4	56,807.1	3.8		
Direct Heat - 600°-1000° F					28,856.7	5.2	158,217.4	10.6		
Direct Heat - 1000°-1500° F					7,567.2	1.4	10,603.5	0.7	372,100.1	31.2
Direct Heat - above 1500° F					12,537.8	2.3	16,689.5	1.1		
Direct Heat, NSK	237,631.6		29,418.3	1.8	76,707.9	13.9	269,405.8	18.0	10,118.7	0.9
Raw Material			1,402,409.0	88.7					808,114.8	67.8
Process Steam	544,832.4	15.0	1,689.4	0.1	141,333.9	25.6	555,481.3	37.1		
Electricity Generation	227,997.2	6.3	2,388.4	0.2	12,729.7	2.3	99,780.6	6.7	801.5	0.1
Coke Production	2,363,105.0	64.9	-1,629,154.0	-98.8	3,397.1	0.6				
Machine Drive					28,868.3	5.2	15,665.8	1.0	1,067.9	0.1
Electrolyte Processes										
Other Uses, NSK/NEC	263,911.2	7.2	113,097.4	6.9	214,509.1	38.9	238,602.3	16.0		
Total	3,642,061.8	100.0	-20,091.5	-1.2	551,606.7	100.0	1,495,598.0	100.0	1,192,202.9	100.0

Source: Energy and Environmental Analysis, Inc. (1978).

PRIMARY SOURCES OF ENERGY IN THE UNITED STATES

East South Central		West South Central		Mountain		Pacific	
1971	1976	1971	1976	1971	1976	1971	1976
32.8	40.5	37.2	42.9	39.5	39.0	48.0	53.3
25.9	18.2	61.9	54.5	37.8	37.8	31.3	25.2
36.2	35.8	0.5	1.9	13.4	13.4	1.2	1.8
5.1	4.6	0.4	0.4	9.3	9.3	18.7	18.6
—	0.9	—	0.3	—	—	0.8	1.1

CONSUMPTION BY PRIMARY FUEL AND FUNCTIONAL USE

LPG		Natural Gas		Other Gas		Hydro		Electricity		Other Energy		Total	
Volume	%	Volume	%	Volume	%	Volume	%	Volume	%	Volume	%	Volume	%
		39,763.5	0.6					2,108.1	0.1			00,065.7	0.3
								30,350.5	1.3			30,350.5	0.2
								3,389.5	0.1			3,389.5	NS
								42,261.9	1.8			42,261.9	0.2
30,897.0	2.6	2,705,921.0	38.1	1,030,740.8	80.7	415.9	1.7	102,691.8	4.3	61,279.4	3.1	5,304,441.4	26.3
5,900.8	0.5	256,484.6	3.6	158,898.9	12.4							497,026.3	2.5
21,217.6	1.8	636,846.6	9.0	558,474.6	43.7							1,403,612.9	7.0
1,381.1	0.1	234,383.7	3.3	37,383.1	2.9			36,049.7	1.5	25,349.5	1.3	724,817.9	3.6
		126,208.4	1.8					2,982.2	0.1			158,417.9	0.8
2,397.5	0.2	1,372,452.0	19.3	275,984.1	21.7	415.9	1.7	63,659.8	2.7	35,929.9	1.8	2,374,121.5	11.8
1,074,364.0	91.0	475,424.9	6.7							55,600.0	2.8	3,875,972.7	19.3
9,772.7	0.8	1,699,607.0	23.0	374,667.4	31.6					1,003,972.4	50.5	4,231,146.5	21.0
660.8	0.1	376,892.4	5.3	52,798.8	4.1	-25,112.0	-100.0	-292,546.3	-12.3	45,114.7	2.3	501,505.8	2.5
		1,166.2	NS	-268,106.9	-21.0			7,007.9	0.3	-125,138.4	-6.3	352,276.9	1.8
571.3	0.1	118,420.8	1.7	19,008.6	1.5	11,651.4	46.4	809,829.8	34.0			1,005,084.0	5.0
				13,021.1	51.8	373,839.6	15.7			386,860.7	1.9		
64,223.4	5.4	1,679,500.0	23.7	-96,556.1	-7.6	23.6	0.1	1,012,969.6	42.5	822,209.1	41.4	4,312,489.6	21.4
1,180,489.2	100.0	7,096,595.8	100.0	1,012,442.6	79.4	100.0	0.0	2,091,902.4	87.7	1,863,037.2	93.7	20,105,845.0	100.0

Table 4-14. U.S. PRIMARY METAL INDUSTRIES 1974 ENERGY

Functional End Use \ Fuel Type	Coal		Coke		Distillate Fuel Oil		Residual Fuel Oil		Misc. Petro Products	
	Volume	%	Volume	%	Volume	%	Volume	%	Volume	%
Space Heating										
Space Cooling										
Space Conditioning, NSK/NEC										
Lighting										
Total Direct Heat	6,029.0	0.2	29,418.3	1.8	13,422.1	32.6	213,595.7	76.0	10,118.7	11.0
Direct Heat - below 600° F										
Direct Heat - 600°-1000° F										
Direct Heat - 1000°-1500° F										
Direct Heat - above 1500° F										
Direct Heat, NSK	6,029.0	0.2	29,418.3	1.8	13,422.1	32.6	213,595.7	76.0	10,118.7	11.0
Raw Material			1,402,469.0	87.1					82,289.2	89.0
Process Steam	65,197.6	2.5	1,689.4	0.1						
Electricity Generation	153,600.9	5.8	2,388.4	0.1			2,615.4	0.9		
Coke Production	2,363,105.0	89.5	-1,629,154.0	-97.0	3,397.1	8.3				
Machine Drive										
Electrolyte Processes										
Other Uses, NSK/NEC	51,222.4	1.9	82,639.2	4.9	24,290.4	59.1	64,933.0	23.1		
Total	2,639,154.9	100.0	50,549.5	3.0	41,109.6	100.0	281,144.1	100.0	92,407.9	100.0

Source: Energy and Environmental Analysis, Inc. (1978)

Table 4-15. U.S. CHEMICALS AND ALLIED PRODUCTS INDUSTRIES 1974

Functional End Use \ Fuel Type	Coal		Coke		Distillate Fuel Oil		Residual Fuel Oil	
	Volume	%	Volume	%	Volume	%	Volume	%
Space Heating								
Space Cooling								
Space Conditioning, NSK/NEC								
Lighting								
Total Direct Heat					31,337.7	26.1	41,869.8	25.4
Direct Heat - below 600° F					11,232.7	9.4	14,576.8	8.8
Direct Heat - 600°-1000° F								
Direct Heat - 1000°-1500° F					7,567.2	6.3	10,603.5	6.4
Direct Heat - above 1500° F					12,537.8	10.4	16,689.5	10.1
Direct Heat, NSK								
Raw Material								
Process Steam	230,449.3	71.5			49,419.3	41.2	76,311.9	46.2
Electricity Generation	26,991.0	8.4			4,728.3	3.9	7,743.6	4.7
Coke Production								
Machine Drive					7,075.7	5.9	9,453.8	5.7
Electrolyte Processes								
Other Uses, NSK/NEC	64,760.2	20.1	2,522.0	100.0	27,502.5	22.9	29,694.8	18.0
Total	322,200.5	100.0	2,522.0	100.0	120,063.5	100.0	165,073.9	

Source: Energy and Environmental Analysis, Inc. (1978).

CONSUMPTION BY PRIMARY FUEL AND FUNCTIONAL USE

LPG		Natural Gas		Other Gas		Hydro		Electricity		Other Energy		Total	
Volume	%	Volume	%	Volume	%	Volume	%	Volume	%	Volume	%	Volume	%
2,397.5	59.0	603,179.7	45.9	275,984.1	71.6	415.9	1.4	57,967.3	9.3	35,929.9	23.8	1,248,458.2	26.0
2,397.5	59.0	603,179.7	45.9	276,984.1	71.6	415.9	1.4	57,967.3	9.3	35,929.9	23.8	1,248,458.2	26.0
												1,544,758.2	32.1
				23,972.0	6.2							90,859.0	1.9
		114,762.6	8.7	34,037.7	8.8	-14,415.0	-50.0	-89,919.9	-14.4			203,070.1	4.2
		1,166.2	0.1	-263,106.9	-68.3			7,007.9	1.1	-125,138.4	-83.0	357,276.1	7.4
						954.4	3.3	18,107.2	2.9			19,061.6	0.4
						13,021.1	45.2	247,036.1	39.4			260,057.2	5.4
1,665.4	41.0	595,877.4	45.3	-96,556.1	-25.1	23.6	0.1	296,101.9	47.3	63,589.1	42.2	1,083,786.0	22.5
4,062.9	100.0	1,314,985.9	100.0	-25,669.5	-6.8	0.0	0.0	536,300.5	85.6	-25,619.7	-17.0	4,807,326.4	100.0

ENERGY CONSUMPTION BY PRIMARY FUEL AND FUNCTIONAL USE

Misc. Petro Products		LPG		Natural Gas		Electricity		Other Energy		Total	
Volume	%	Volume	%	Volume	%	Volume	%	Volume	%	Volume	%
				435,836.9	20.8	39,031.9	7.8	25,349.5	9.3	573,425.8	11.0
				87,099.8	4.2					112,909.2	2.2
				27,789.5	1.3					27,789.5	0.5
				194,739.2	9.2	36,049.7	7.2	25,349.5	9.3	274,309.0	5.3
				126,208.4	6.0	2,982.2	0.6			158,417.9	3.0
725,825.5	100.0	1,074,364.0	100.0	475,424.9	22.7			55,600.0	20.5	2,331,214.4	44.7
				850,888.4	40.7			115,180.7	42.4	1,322,249.6	25.4
				136,872.6	6.5	-63,484.7	-12.7	16,414.1	6.0	129,264.9	2.5
				98,407.8	4.7	334,573.6	66.9			449,510.9	8.6
						126,803.6	25.3			126,803.6	2.4
				95,155.2	4.5			58,916.6	21.7	278,551.3	5.3
725,825.5	100.0	1,074,364.0	100.0	2,092,585.8	100.0	436,924.4	87.3	271,460.9	100.0	5,211,020.5	100.0

Table 4-16. U.S. PETROLEUM REFINING AND RELATED INDUSTRIES 1974

Functional End Use \ Fuel Type	Coal Volume	Coal %	Distillate Fuel Oil Volume	Distillate Fuel Oil %	Residual Fuel Oil Volume	Residual Fuel Oil %	Misc. Petro Products Volume	Misc. Petro Products %
Space Heating								
Space Cooling								
Space Conditioning, NSK/NEC								
Lighting								
Total Direct Heat			36,558.9	90.7	200,447.8	71.2	372,100.1	99.5
Direct Heat - below 600° F			7,702.2	19.1	42,230.4	15.0		
Direct Heat - 600°-1000° F			28,856.7	71.6	158,217.4	56.2		
Direct Heat - 1000°-1500° F							372,100.1	99.5
Direct Heat - above 1500° F								
Direct Heat, NSK								
Raw Material								
Process Steam			1,848.1	4.6	70,470.5	25.0		
Electricity Generation			878.1	2.2	4,345.5	1.5	801.5	0.2
Coke Production								
Machine Drive			1,014.4	2.5	6,212.0	2.2	1,067.9	0.3
Electrolyte Processes								
Other Uses, NSK/NEC	5,321.5	100.0						
Total	5,321.5	100.0	40,299.4	100.0	281,475.7	100.0	373,969.5	100.0

Source: Energy and Environmental Analysis, Inc. (1978)

Table 4-17. U.S. PAPER AND ALLIED PRODUCTS INDUSTRIES 1974

Functional End Use \ Fuel Type	Coal Volume	Coal %	Distillate Fuel Oil Volume	Distillate Fuel Oil %	Residual Fuel Oil Volume	Residual Fuel Oil %	LPG Volume	LPG %
Space Heating								
Space Cooling								
Space Conditioning, NSK/NEC								
Lighting								
Total Direct Heat					66,899.2	13.7		
Direct Heat - below 600° F								
Direct Heat - 600°-1000° F								
Direct Heat - 1000°-1500° F								
Direct Heat - above 1500° F								
Direct Heat, NSK								
Raw Material								
Process Steam	161,807.1	77.5	11,944.4	47.4	330,365.8	67.6		
Electricity Generation	42,548.5	20.4	3,460.7	13.8	81,399.2	16.7		
Coke Production								
Machine Drive								
Electrolyte Processes								
Other Uses, NSK/NEC	4,490.8	2.1	9,773.2	38.8	9,916.5	2.0	62,558.0	100.0
Total	208,846.4	100.0	25,178.3	100.0	488,580.7	100.0	62,558.0	100.0

Source: Energy and Environmental Analysis, Inc. (1978).

ENERGY CONSUMPTION BY PRIMARY FUEL AND FUNCTIONAL USE

LPG		Natural Gas		Other Gas		Electricity		Other Energy		Total	
Volume	%	Volume	%	Volume	%	Volume	%	Volume	%	Volume	%
28,499.5	72.1	818,086.4	73.6	754,756.7	72.4					2,210,449.4	72.2
5,900.8	14.9	169,384.7	15.2	158,898.9	15.2					384,117.0	12.5
21,217.6	53.7	609,057.1	54.8	558,474.8	53.5					1,375,823.0	44.9
1,381.1	3.5	39,644.5	3.6	37,383.1	3.6					450,508.6	14.7
9,772.7	24.7	251,151.6	22.6	250,585.4	24.0			52,271.4	62.8	636,099.7	20.8
660.8	1.7	22,122.4	2.0	18,761.2	1.8	-15,225.6	-15.4			32,343.9	1.1
571.3	1.4	20,013.0	1.8	19,008.6	1.8	98,880.4	100.0			146,767.6	4.8
								30,915.5	37.2	36,237.0	1.2
39,504.3	100.0	1,111,373.0	100.0	1,043,111.9	100.0	83,654.8	84.6	83,186.9	100.0	3,061,897.6	100.0

ENERGY CONSUMPTION BY PRIMARY FUEL AND FUNCTIONAL USE

Natural Gas		Hydro		Electricity		Other Energy		Total	
Volume	%	Volume	%	Volume	%	Volume	%	Volume	%
2,295.6	0.6							2,295.8	0.1
79,547.0	19.5							146,446.2	6.6
209,207.8	51.2					836,520.3	93.8	1,549,845.4	69.9
77,875.7	19.1	-10,697.0		-111,744.9	-45.7	28,700.8	3.2	111,542.8	5.0
		10,697.0		215,345.1	88.1			226,042.1	10.2
39,384.2	9.6			29,081.2	11.9	26,395.5	3.0	181,599.2	8.2
408,310.3	100.0	0.0		132,681.4	54.3	891,616.6	100.0	2,217,771.7	

Table 4-18. U.S. STONE, CLAY, GLASS, AND CONCRETE PRODUCTS INDUSTRIES

Functional End Use \ Fuel Type	Coal		Coke		Distillate Fuel Oil	
	Volume	%	Volume	%	Volume	%
Space Heating					982.2	1.3
Space Cooling						
Space Conditioning, NSK/NEC						
Lighting						
Total Direct Heat	231,602.7	99.4			53,796.5	70.8
Direct Heat - below 600° F						
Direct heat - 600°-1000° F						
Direct Heat - 1000°-1500° F						
Direct Heat - above 1500° F						
Direct Heat, NSK	231,602.7	99.4			53,796.5	70.8
Raw Material						
Process Steam						
Electricity Generation	1,393.5	0.6			454.6	0.6
Coke Production						
Machine Drive					20,778.1	27.3
Electrolyte Processes						
Other Uses, NSK/NEC			16,047.9	100.0		
Total	232,996.2	100.0	16,047.9	100.0	76,011.4	100.0

Source: Energy and Environmental Analysis, Inc. (1978).

Table 4-19. U.S. FOOD AND KINDRED PRODUCT INDUSTRIES

Functional End Use \ Fuel Type	Coal		Coke		Distillate Fuel Oil	
	Volume	%	Volume	%	Volume	%
Space Heating	3,398.0	4.5			3,526.5	5.3
Space Cooling						
Space Conditioning, NSK/NEC						
Lighting						
Total Direct Heat					9,489.4	14.2
Direct Heat - below 600° F						
Direct Heat - 600°-1000° F						
Direct Heat - 1000°-1500° F						
Direct Heat - above 1500° F						
Direct Heat, NSK					9,489.4	14.2
Raw Material						
Process Steam	67,381.1	89.5			44,818.3	67.1
Electricity Generation	2,999.4	4.0			2,660.0	4.0
Coke Production						
Machine Drive						
Electrolyte Processes						
Other Uses, NSK/NEC	1,518.2	2.0	1,605.0	100.0	6,283.5	9.4
Total	75,296.7	100.0	1,605.0	100.0	66,777.7	100.0

Source: Energy and Environmental Analysis, Inc. (1978)

ENERGY CONSUMPTION BY PRIMARY FUEL AND FUNCTIONAL USE

Residual Fuel Oil		Natural Gas		Electricity		Other Energy		Total	
Volume	%	Volume	%	Volume	%	Volume	%	Volume	%
1966.4	3.4	6,921.7	1.0	711.6	0.7			10,581.9	0.8
46,505.6	94.3	667,946.5	95.9	5,692.5	5.6			1,005,543.7	77.2
46,505.6	94.3	667,946.5	95.9	5,692.5	5.6			10,005,543.7	77.2
295.8	0.6	4,164.5	0.6	-2,049.9	2.0			4,258.5	0.3
								20,778.1	1.6
540.8	1.1	17,304.3	2.5	95,948.4	93.7	130,890.0	100.0	260,731.4	20.0
49,308.6	100.0	696,337.0	100.0	100,302.6	98.0	130,890.0	100.0	1,301,893.7	100.0

ENERGY CONSUMPTION BY PRIMARY FUEL AND FUNCTIONAL USE

Residual Fuel Oil		Natural Gas		Electricity		Other Energy		Total	
Volume	%	Volume	%	Volume	%	Volume	%	Volume	%
3,143.4	4.8	20,549.6	4.3					30,617.5	3.3
				3,389.5	2.5			3,369.5	0.4
				31,163.0	23.0			31,183.0	3.3
9,304.5	14.2	75,348.1	15.7					94,142.0	10.0
9,304.5	14.2	75,348.1	15.7					94,142.0	10.0
45,453.8	69.4	323,115.2	67.5					480,768.4	51.3
2,608.2	4.0	18,945.2	4.0	-8,842.9	-6.5			18,370.0	2.0
				98,701.1	72.8			98,701.1	10.5
5,029.5	7.7	40,642.0	8.5	2,304.8	1.7	123,208.5	100.0	180,591.5	19.3
65,539.4	100.0	478,600.2	100.0	126,715.6	93.5	123,208.5	100.0	937,743.0	100.0

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SECTION 5.0

DEVELOPMENT OF INDUSTRIAL ENERGY CONSUMPTION AND COST DATA AT THE STATE LEVEL

5.1 INTRODUCTION

Review of existing industrial energy consumption data bases (Sec. 3.4) indicates that there are no consistent and realistic studies of past industrial energy-resource consumption by major sources, region, and industry. Important aspects of such a study include a detailed and comprehensive evaluation of demand, principal end uses, and cost of fuels and electric power in small geographic areas by large energy-consuming industries. This lack of detailed data on past and future energy demand, end uses, and cost represents the most critical constraint on characterizing typical energy applications and resultant services and assessing the potential for solar technologies in fulfilling regional industrial energy requirements.

This section develops the state 1974 and 1976 industrial sector energy demands and cost by 2-, 3-, and 4-digit SIC and primary fuel data. The research performed to develop these data are described in the following sections.

5.2 SELECTION OF STATES

Geographic regions defined by states were chosen for analysis because they represent the smallest division for which there is a reasonable probability of obtaining detailed energy data. The states considered to have the greatest potential for replacing conventional fuel with solar energy are Alabama, California, Illinois, Indiana, Louisiana, Michigan, Missouri, New Jersey, New York, Ohio, Oregon, Pennsylvania, Texas, West Virginia, and Wisconsin.

In selecting these states, the following criteria were applied:

- 4-digit SIC industries were identified as having the greatest potential for solar system applications located in the 13 major fuel consuming states (i.e., Texas, Louisiana, Ohio, Illinois, Pennsylvania, California, Michigan, Indiana, New York, Alabama, New Jersey, West Virginia, and Wisconsin);
- the total number of SIC industrial plants that have solar system potential were identified by location in each of the major energy consuming states;
- geographic distribution of industrial plants located in the 13 major fuel consuming states by primary energy (utilizing 4-digit SICs) was identified;
- major fuel consuming SIC industrial plants located in high insolation states were identified;
- primary fuel consuming SIC industries were ranked by number of industrial plants in high fuel consuming and high insolation states and identified by four temperature ranges (up to 212° F; 212°-350° F; 350°-550° F; 550°-1100° F).

These criteria have been successfully used in SERI IPH studies (Ketels and Reeve 1979 and 1980).

5.3 DISAGGREGATED STATE INDUSTRIAL ENERGY CHARACTERISTICS

Basic data sources on quantities and cost of fuels and electric energy used by state for heat and power by 2- and 3-digit SIC and primary fuel are described in Sec. 4.0; however, such data are not provided for the 4-digit SIC individual industries. The 4-digit SIC industries' data on quantities of fuels and electric energy used were estimated by multiplying the estimated energy intensity for 3-digit SIC level and 4-digit SIC level of the value added by manufacturing. This formula assumes that the 4-digit SIC individual industrial fuel intensity measured in the quantity of a given fuel required to produce one dollar of value added by manufacturing (in 1976 dollars) closely parallels that of the aggregate 3-digit SIC subgroup within a particular state. These quantities were converted to British thermal units and reported in billions of Btu. Table 4-1 provides Btu conversion factors.

The disaggregated data on value added by manufacturing at the state level by 2-, 3-, and 4-digit SIC were obtained from the 1974 and 1976 Annual Survey of Manufacturers (U.S. DOC 1974 and 1976) and expressed in constant 1976 dollars. For each state, the same specific manufacturing subsector energy service characteristics as those for the U.S. manufacturing subsector were developed. These are presented in the tables in Volume III. Practical application of these detailed state manufacturing subsector energy demands and cost data base is dictated by the conceptual and analytical framework of the energy-related task. Data on functional uses of energy disaggregated by hot water, steam, and hot air are summarized in Sec. 10.0.

SECTION 6.0

REVIEW OF STATE ENERGY MODELS

6.1 PURPOSE AND BACKGROUND

An evaluation of state energy models was undertaken to assess their applicability projecting state industrial energy demands to 1990. The 1978 OPEC oil embargo and later energy supply disruptions and price increases have caused state policy makers to think seriously about the long-term availability, use, and price of energy resources. In 1977, excess demand and reduced supply of natural gas caused major unemployment in the Northeast. In 1978, a coal strike caused utilities to burn more costly oil and to "wheel" power from other more plentiful sources of primary energy. In 1979, partly because of problems in the Middle East and partly because of reduced petroleum stocks, gasoline shortages and waiting lines became significant problems.

These events have encouraged state energy officials to increase their efforts in gathering and disseminating energy information and expeditiously weighing policy choices. The complex interaction of a state's economy, energy needs and flows, and environmental constraints necessitates more refined and careful assessments. The complexity of analyses is increasing as the policy concerns become more specific.

The tools available to policy makers range from simple extrapolation of trends that project the future to more sophisticated models using analytical methods that estimate overall relationships between demographic, economic, and energy variables. States face many complex issues requiring these methods, and many states have begun to develop models and analytical tools to satisfy federal requirements and evaluate energy options and futures. Models have been loosely defined as abstract simplifications of reality or what may be reality in the future, even though some models consist of many complex equations and assumptions. Models may be used to:

- predict the circumstances that a state may face as a result of variations in energy supply and demand,
- estimate the results of choices that may influence energy supply or demand,
- present the optimal method for implementing an energy policy,
- educate and provide better information in a timely way, and
- articulate policy preferences.

Even though models with various levels of sophistication are increasingly being used, their use has some limitations:

- a substantial gap exists between the expectations of what models can do and what they actually do in discerning policy implications;
- implementation costs are high for more detailed models;
- inadequate information often produces generalized results;
- policy variables are either inadequate or crude;
- the consequences of one policy option over another are difficult to distinguish; and
- the more complicated models are difficult to understand.

The following section discusses the evolution of state model development and use and reviews models of industrial energy demand.

6.2 EVOLUTION OF STATE ENERGY MODELS

The level of modeling effort among state governments varies greatly, from having no energy modeling at all to large staffs with million-dollar budgets. States that were first to have energy models have had considerable time to evolve their forecasting approach and refine their methods. With almost a decade of effort, in some cases, the more advanced state energy forecasting systems have acquired staggering complexity; indeed, some have been linked to the econometric forecasts of the well-known Wharton, Chase, or DRI models of the national economy.

In a recent examination of the modeling efforts of all the states (Synergic Resources Corp. 1980b), an evolutionary pattern was apparent. Genealogies of models evolve, and cross-breeding is well known. This has begun to occur in other areas of energy modeling (U.S. DOE 1978a). A representation of the hierarchy of complexity and level of effort in existing state energy models can be useful in renewing energy models, and such a hierarchy is shown in Table 6-1. The levels proceed from the simple to the complex. Construction of a data base has been placed in the first level. Although it is not mandatory to begin at level one and build a forecasting system by going through successive levels—and most state forecasting systems have not done this—the levels shown do follow a logical sequence of development.

The design of a forecasting system should rest on two principles: a data base and policy needs. Even the best model is useless without good quality input data, and many modeling efforts are over complex for their intended need. With a good data base at the first level, levels II, III, or IV could be considered. They are not consecutive in the sense that one needs to have an econometric model (Level II) before one can build an end-use model. They are hierarchical in that most states first attempt econometric models because they are easier to build, gather data for, and obtain a quick estimate of energy impacts related to prices and income. End-use models are relatively harder to build and have only recent priority policy topics (such as the effects of conservation on residential demand for home heating fuel).

Data on supply and prices needed for models in Level III are usually harder to come by. It may mean gathering primary data, such as records from retail fuel distributors, or deeper secondary efforts, such as tax records of gasoline sales. Supply and price models at the state level generally require some analysis of national data and policies.

Engineering end-use models are usually more data-intensive than Levels II and III, needing data on such items as intensity, appliance saturation, and energy flows.

Models involving combinations of econometric and end-use methods, but directed at one specific fuel or sector allowing examination of a range of different scenarios, are characterized as specific policy-oriented models (Level V). They allow for analysis of some energy policies but may not include all fuels, sectors, or types of policies.

Integrated energy and policy-oriented models, Level VI, involve several linked energy models covering most or all of the energy sectors. These models often are accompanied by an optimization model (usually a linear program) that studies different policy objectives. The integrated energy and policy-oriented class is different from specific policy-oriented models primarily in size, complexity, and broader range of objectives.

Table 6-1. HIERARCHY/EVOLUTION OF STATE ENERGY MODELING EFFORTS

	Hierarchical or Evolutionary Level	Description of Modeling Involved	State Example and Any Associated Model Names
I.	Secondary Data Base/ Information Systems	Data compiled from existing sources. Trend projections made from historical data. Computerized information system can be attached for contingency planning and supply regulation.	Minnesota: REIS Kansas: Energy Information System Use of FEDS, EIA, DRI, etc., by many states
II.	Aggregate Econometric Demand Estimation	Standard economic data (prices, income, output, etc.) used to estimate future demand. Sectors highly aggregated (residential, commercial, industrial).	Minnesota: Electric demand Oregon: Fuel demand models
III.	Supply and Price Analysis	Engineering process and more detailed econometric methods used to model supply. Often involves gathering primary data by survey. Seasonal fuel supply-demand using time series methods.	Texas: Electricity supply
IV.	Engineering End Use	More data-intensive than II or III, though still can be done with secondary sources. Can be used for policy analysis, usually for studying conservation effects.	Wisconsin: Commercial Energy Model and Residential Energy Model
V.	Specific Policy-Oriented Models	Includes supply-demand analysis but allows user-inputs for different impact analysis. Sometimes involves only extension of simple supply or demand model; e.g., emissions variable in demand-supply analysis.	California: Industrial Sector Model Ohio: OPCO
VI.	Integrated Energy and Policy-Oriented Models	Several forecasting models linked to cover most or all energy sectors. Sometimes including optimization model linked to energy model allowing study of policy objective impacts.	California: Peak Load Model Wisconsin: WISE
VII.	Energy-Economic Linkage Models	Energy models linked to models of state economy. Commonly, input/output or econometric model linked with energy submodels.	New York: EEFM New Mexico: SWEEP-LLP-FED Texas: TEFM
VIII.	Substate/County Level Models	Same as VII but with associated primary data base management at substate level.	Minnesota: MINTOM and REIS

Finally, energy-economic linkage models (Level VII) represent the largest and most complex class of models, covering the entire state economy and allowing a full range of policy impact analysis. These require either an input/output model or a large, disaggregated econometric model. Beyond this is a level where the model is improved only by the quality of the input data, and a substantial effort is made at gathering substate (county) data (Level VIII).

6.3 STATE LEVEL INDUSTRIAL ENERGY MODELS

A review of state energy models was conducted by the Synergic Resources Corporation (1980) for Pennsylvania and was updated by contacting state energy agencies in all 15 states under consideration. Nine states reported that they do not have any documented models for forecasting or evaluating industrial energy use and conservation. The other six states (California, New Mexico, New York, Oregon, Texas, and Wisconsin) do have formal models.

Information and documentation on the most recent versions of each model were obtained from all states except Oregon. The review of the Oregon model refers to an old version developed several years ago. Oregon recently has implemented a new model but despite repeated requests the documentation was not received and, therefore, could not be reviewed. The state models are described in Appendix B.

The review of available state energy models indicates that:

- all the models are primarily econometric and provide no end-use information;
- except for the California model, no explicit consideration of conservation or cogeneration is included; and
- the existing models are severely limited in their applicability to forecast industrial energy requirements at a level of detail necessary to analyze solar energy potential.

SECTION 7.0

METHODS FOR PRICE FORECASTING AT THE STATE LEVEL

7.1 PURPOSE AND BACKGROUND

This section evaluates the methods at the state level to develop a projection of state industrial energy prices to 1990. First, the alternatives for supply-demand balancing and price forecasting are reviewed. Then, the national energy model's applicability for analyzing state energy prices is assessed. Finally, the regional forecasts of energy prices from the 1978 Annual Report to Congress (ARC) are developed.

7.2 ALTERNATIVES FOR SUPPLY-DEMAND BALANCING AND PRICE FORECASTING

Different methods can be used for forecasting supply and fuel prices. These approaches can be classified as:

- intuitive or judgmental
- trend forecasting
- time series analysis
- econometric
- engineering
- combination.

The objective of these approaches is to develop a supply function for a particular type of energy that describes the quantity of energy supplied at specified prices. The choice of a forecasting technique for a particular application depends on several factors including:

- the purpose of the forecast,
- availability and quality of data,
- desired forecast accuracy, and
- resources available to develop the forecasts.

Intuitive or judgmental approaches estimate future supplies/prices without formally analyzing historical data or underlying relationships. Since they are primarily based on the forecaster's judgment, they have little value in public policy analysis and should be used only when there is no other alternative.

Trend forecasting estimates future supplies/prices by analyzing historical data over time and extrapolating the time trend into the future.

Time series analysis applies formal analytical procedures to investigate the structure and patterns in the historical data including seasonal and cyclical variations.

Econometric modeling estimates elasticity by analyzing historical data for relationships between the energy supplies and prices, and independent variables.

Engineering approaches analyze the physical factors affecting supply, taking into account the characteristics and costs of the supply facilities. For example, a coal supply function can be developed by analyzing typical new mines and developing production cost estimates for mines with specified characteristics. The engineering approach can be used even when limited or no historical data exist. For example, if coal gasification or solar electric generation is to be analyzed, econometric approaches cannot be used, and engineering estimates must be made. The disadvantage of the engineering approach is the limited response to policy variables such as changes in prices.

Balancing supply and demand to estimate prices can be obtained through an integrating model that accounts for the supply and demand functions and determines the price at which a market clearing is achieved. The approaches that have been used include:

- iterative,
- simultaneous equation,
- linear programming, and
- external balancing of supply and demand.

The iterative approach attempts to calculate successively demand, supply, and price until a balance is achieved. The simultaneous equation approach econometrically estimates the demand and supply equations simultaneously and solves them. Linear programming specifies a cost function to be minimized given a set of constraints, and then uses the iterative approach to determine the least-cost energy supply mix to meet calculated demands. The external balancing approach calculates supply and demand separately and shows a surplus or shortage. The user can then analyze alternative methods to eliminate the imbalance external to the model.

The Northwest Energy Policy Project (NEPP) (1978) used the iterative approach for supply and demand balancing. The MacAvoy-Pindyck Natural Gas Model utilized simultaneous equations (MacAvoy and Pindyck 1974), and the DOE Project Independence Evaluation System (PIES) model uses linear programming. The Ozarks Regional Energy Alternative Study used an approach with external balancing of supply and demand.

The simultaneous equation approach has the same advantages and disadvantages associated with econometric methods. Linear programming is comprehensive and flexible but can be expensive to develop and relatively expensive to operate. It may also be too sophisticated for the quality of data available. External balancing makes the development of the information system/model easier but reduces the flexibility of the tool and puts a greater burden on the user. The iterative approach is somewhat more complex and expensive to implement (not so much as linear programming) but provides greater flexibility than external balancing.

7.3 NATIONAL ENERGY MODELS FOR ANALYZING STATE LEVEL ENERGY PRICES

During the past decade, a vast array of models has been developed to analyze the nation's energy future that is so large it is impossible to develop an exhaustive list. In fact, it is difficult to even list all the indexes, reviews, and catalogues that have tried to organize the available information on national energy models.

In this section we summarize some of the more prominent models developed to analyze national energy issues. Most of these models have some disaggregation of fuels, sectors, and geographic regions; however, none is detailed enough to provide state-specific output or forecasts. Nevertheless, national energy models do provide some potential benefits, because the projections can be used at the regional level and simple disaggregation techniques can be developed to estimate state level data.

The more prominent national models are (Synergic Resources Corp. 1980; Energy Modeling Forum 1979):

- FOSSIL I: Developed at Dartmouth University and used by DOE for policy analysis, this model uses the systems dynamics approach.
- The SRI-GULF Energy Model: Developed by Stanford Research Institute and Gulf Oil Company, it analyzes synthetic fuel strategies and has since been revised and refined.
- The Livermore Energy Policy Model: It is an improved version of SRI-GULF.
- The Brookhaven Energy Systems Optimization Model (BESOM): Developed at Brookhaven National Laboratory, it performs detailed analysis of energy resource allocation and new technology implementation and also has been disaggregated to a regional level.
- ETA-MACRO Model: Developed by Professor Alan Manne of Stanford University, it studies the interactions among economic growth, conservation, and energy technologies.
- The DRI Energy Model: Developed by Data Resources, Inc. (DRI), it projects energy consumption using econometric and engineering approaches and is linked to the DRI U.S. macroeconomic model.
- The Chase and Wharton Models: Analogous to DRI, they are linked to their respective national macroeconomic models.
- PILOT Model: Developed by Stanford University, it analyzes the impact of various national policies on energy use and the standard of living primarily using linear programming.
- The DOE Long-Term Energy Analysis Package (LEAP): It analyzes the overall U.S. energy system to the year 2025.
- A model used by the Department of Commerce develops state energy forecasts of consumption and production by major fuel type. Unfortunately, this model used a disaggregate method and is not useful for policy analysis.
- The Total Energy Resource Analysis (TERA) Model: Developed for the American Gas Association, it analyzes policy issues relative to natural gas supply and demand.
- Midterm Energy Forecasting System (MEFS): Along with other models, it was developed by the Energy Information Administration and is discussed in more detail later.

These models are summarized in Table 7-1.

In addition to these national models, numerous studies have used quantitative techniques to develop national energy forecasts. These include:

Table 7-1. SUMMARY OF NATIONAL ENERGY MODELS

Model Name	Purpose/Objective	Coverage	Remarks
FOSSIL I	To serve as a simulation and policy tool to study the magnitude of the U.S. energy problem	National	Useful for policy analysis, but not a good forecaster.
SRI-GULF Energy Model	Analyze synthetic fuel strategy	Regional, National	Useful for long-term analysis of new energy technologies.
Livermore Energy Policy Model	Supply and demand for energy	Regional, National	Modification of SRI-GULF.
Brookhaven Energy System Optimization Model	Allow detailed analysis of energy resource allocation and technological implementation	National, but can be Regional	Provides useful tool for analyzing conservation and end use.
ETA-MACRO	To study the interrelationships between economic growth, conservation, and energy technologies	National	Primarily useful for macro-analysis.
DRI Energy Model	Project market-clearing demands from past trends and economic forecasts	Regional, National	Linked with DRI U.S. macro-economic model.
PILOT	Measure the impact on standard of living of various policy decisions	National	No geographic disaggregation.
Long-Term Energy Analysis Package	Simulate the energy-economic activity of the defined system	National	Useful for long-term analysis.
Midterm Energy Forecasting System	Forecast energy prices, supplies, demands, and conversion factors	National, by State	Actually, a large integrated set of models used by EIA.
Total Energy Resource Analysis (TERA)	Analyze natural gas policy issues	Regional, National	Used by American Gas Association for policy analysis.

- The Harvard Energy Project that performed a comprehensive analysis of national energy strategies;
- The Mellon Institute Study, The Least Cost Energy Strategy, that used several existing models to develop a high conservation scenario; and
- The National Academy of Science CONAES Study that developed several scenarios representing alternative energy futures for the United States.

The most useful national model for forecasting energy prices at the regional level is the Energy Information Administration (EIA) MEFS (U.S. DOE 1976). MEFS is the most detailed energy model and has undergone continued testing and refinement over the last 5-6 years. Other advantages of MEFS include:

- MEFS looks at all energy forms by sector and explicitly represents the market clearing mechanism.
- While it is not state-specific, its regional detail on the supply side is greater than any other national model.
- It is under constant scrutiny since it is continually being used by EIA. Its results are published in the EIA Annual Report to Congress and are very widely disseminated.
- The data base supporting MEFS is continually updated.
- Although documentation had been a problem earlier, considerable effort is now being devoted to comprehensive documentation of the model and data base.
- A number of detailed supporting models exist that also are being updated and refined.

MEFS is the revised, expanded, and refined version of the old PIES. It is a national energy forecasting system used to forecast regional energy prices, supplies, demands, and conversion activities. Thus, it is an analytical tool that can be used to examine the potential impacts of changes in federal policies by specifying alternative scenarios. It can be used to examine both differing resource and technological option assumptions (e.g., high compared with low discovery rates for oil and gas), and the comparative impacts of differing political, tax, and regulatory environments. To do this, scenarios are specified to reflect the appropriate world oil price, tax and regulatory conditions, and other parameters. MEFS contains both a data base and a modeling structure allowing a wide range of assumptions that can be analyzed and compared for their policy implications through the selection of scenario variables.

MEFS is a large-scale energy modeling system with three major components:

- a nonlinear demand function that calculates regional fuel quantities demanded at specified fuel prices;
- an integrated piece-wise linear supply function that calculates the fuel prices at which the energy market would be willing to produce and deliver specified quantities; and
- an equilibrating mechanism that integrates the supply function with a linear approximation of the demand function and iterates on quantities and prices, recursively solving the linear programming model until an equilibrium is reached.

Final demand for a particular fuel depends on the price of that fuel, the prices of substitute fuels, the general level of economic activity, and the nature and extent of energy conservation programs. Energy production, conversion, and distribution activities are dealt with individually for each fuel and each producing region in the integrated supply function. Resource base estimates, together with technological cost information, are used to construct supply functions that show the cost at which additional fuel supplies can be produced. The integrated supply function also includes the costs of refining petroleum into a slate of products, of generating electricity, of transporting final energy commodities to meet demand in each region, and of constructing new refining and electrical generation capacity as needed.

The equilibrating mechanism of MEFS matches energy demands with energy supplies by fuel and region by adjusting prices and iteratively resolving the linear program until a balance is achieved. This component is also used where modifications to prices and quantities are made, such as those required for modeling natural gas regulation and allocation, oil entitlements, and average cost pricing of electricity.

MEFS includes an integrating model called the Midterm Energy Market Model (MEMM) and a series of supporting models (see Fig. 7-1). The supporting models and their roles in MEFS are:

- National Coal Model—develops supply functions for coal.
- Midterm Oil Supply Model—develops supply functions for oil.
- Econometric Demand Models—develop demand functions by fuel, sector, and region.
- Conservation Models—analyze effects of conservation measures on demand.
- Macroeconomic Models—develop projections of economic variables affecting energy and analyze effects of energy strategies on the economy.
- Midterm Gas Supply Model—develops supply functions for gas.
- Synthetics Supply Model—analyzes availability and cost of synthetic fuel.
- Advanced Technologies Submodel—provides data on costs of advanced technologies.
- International Energy Evaluation System (IEES)—analyzes international production and transportation of fuels.
- Comprehensive Human Resources Data System (CHRDS)—analyzes distributional effects of energy policies on different socioeconomic groups.
- Refinery and Petrochemical Modeling System (RPMS)—analyzes the refinery and petrochemical sector.
- Electric Utility Models—analyze electricity generation by fuel type and region.
- Nuclear Power Models—develop supply forecasts for nuclear power.

MEFS provides forecasts of both national and regional market equilibrium levels and prices for major fuels and predicts fuel import levels and activity in each of the major energy industries, including electric utilities, oil- and gas-producers, coal plants, and refineries. MEFS has provided forecasts for the National Energy Strategy Study Analysis and for the EIA's 1978 Annual Report to Congress (ARC 1979). The system is being enhanced and updated with new operational versions available approximately every six months. MEFS is currently being used to develop projections for the EIA 1979 Annual

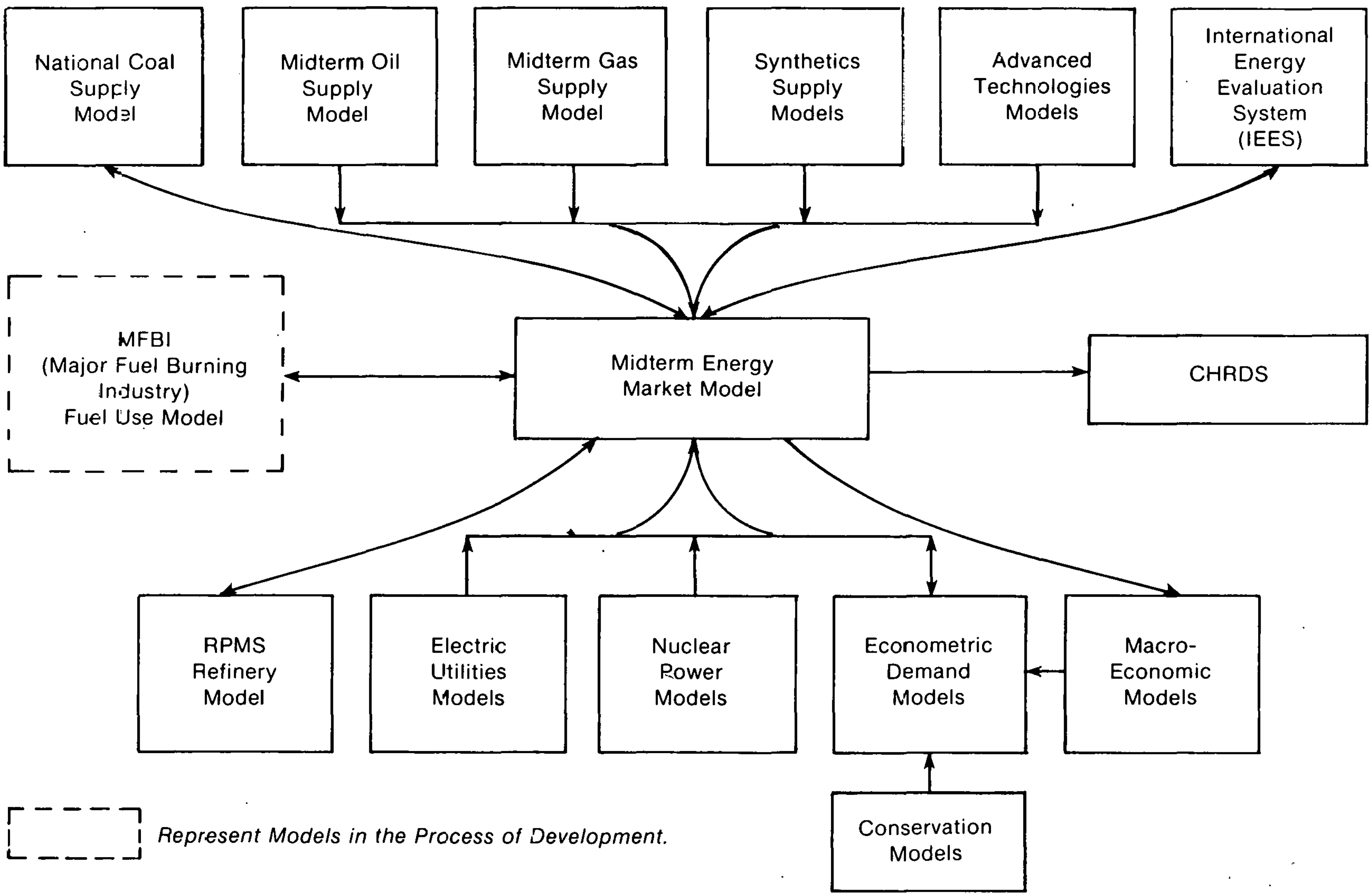

Figure 7-1. Overview of MEFS Structure

Report to Congress. It is also being used to evaluate the impacts of the recent increases in world oil prices.

There are some important limitations to the use of MEFS:

- it is highly complex and difficult to explain to decision makers;
- it is very difficult and expensive to use;
- being a successor to PIES, it suffers from some credibility problems; and
- many specific models and data items are of limited accuracy, which influences the results.

7.4 REGIONAL FORECASTS OF ENERGY PRICES FROM 1978 ARC

EIA's latest available published forecasts are from the 1978 ARC published in mid-1979. In developing these projections EIA assumed a world oil price of $23.50 per barrel (bbl) in 1990 (in 1978 dollars) for the C-High scenario. World events immediately following the publication of the 1978 ARC made the oil price assumptions obsolete. Current world oil prices indicate that EIA was far too optimistic in its assumptions regarding world oil prices. EIA currently is preparing the 1979 ARC. Price projections by region are not available; however, the world oil price assumptions are as shown in Table 7-2.

Table 7-2. WORLD OIL PRICE ASSUMPTIONS FOR EIA 1979 ANNUAL REPORT TO CONGRESS

(1979 $/bbl)

	Scenario		
Year	Low	Medium	High
1985	27.00	32.00	39.00
1990	27.00	37.00	44.00
1995	27.00	41.00	56.00

7.5 STATE-LEVEL PRICE PROJECTIONS

Using state level energy price data for the period 1960-1978 from the Federal Energy Data System (FEDS) price data base (EIA 1979), the 1978 ARC regional price forecasts, and the world oil price assumptions, the projections of 1990 prices for different energy forms for the 15 states under consideration in this study were prepared. These price projections are shown in Table 7-3 to 7-5.

Table 7-3. ENERGY PRICE PROJECTIONS: LOW PRICE SCENARIO[a]

(MBtu in 1979 Dollars)

	Energy Form			
State	Distillate Fuel	Residual Fuel	Natural Gas	Coal
New York	5.73	5.01	3.60	2.51
New Jersey	5.73	5.01	5.38	2.51
Pennsylvania	6.02	5.56	4.13	2.23
West Virginia	5.84	4.89	3.80	2.23
Ohio	5.50	4.84	4.73	2.00
Indiana	5.50	4.84	3.99	2.00
Illinois	5.50	4.89	5.03	2.00
Michigan	5.56	4.79	4.47	2.00
Wisconsin	5.50	4.84	4.82	2.00
Alabama	5.83	4.66	3.49	2.49
Louisiana	5.70	4.80	1.85	2.30
Texas	5.75	4.85	4.35	2.30
Missouri	5.39	4.73	4.77	1.79
California	5.39	4.76	4.77	2.89
Oregon	5.23	4.48	4.79	2.19

[a]Assumptions: World Oil Price in 1990 (1979 dollars): $27/bbl.

Table 7-4. ENERGY PRICE PROJECTIONS: MEDIUM PRICE SCENARIO[a]

(MBtu in 1979 Dollars)

	Energy Form			
State	Distillate Fuel	Residual Fuel	Natural Gas	Coal
New York	7.25	6.42	4.73	2.51
New Jersey	7.25	6.42	7.07	2.51
Pennsylvania	7.57	7.08	5.31	2.23
West Virginia	7.35	6.23	4.88	2.23
Ohio	7.02	6.29	6.32	2.00
Indiana	7.02	6.29	5.34	2.00
Illinois	7.02	6.35	6.73	2.00
Michigan	7.09	6.23	5.97	2.00
Wisconsin	7.02	6.29	6.44	2.00
Alabama	7.34	6.08	5.83	2.49
Louisiana	7.24	6.24	1.95	2.31
Texas	7.31	6.30	4.60	2.31
Missouri	6.40	6.14	5.37	1.80
California	6.64	5.84	5.04	2.90
Oregon	6.85	6.19	6.13	2.21

[a]Assumptions: World Oil Price in 1990 (1979 dollars): $37/bbl.

Table 7-5. ENERGY PRICE PROJECTIONS: HIGH PRICE SCENARIO[a]

($MBtu in 1979 Dollars)

	Energy Form			
State	Distillate Fuel	Residual Fuel	Natural Gas	Coal
New York	8.68	7.63	5.64	2.54
New Jersey	8.68	7.63	8.07	2.54
Pennsylvania	9.04	8.39	7.49	2.26
West Virginia	8.77	7.38	5.89	2.26
Ohio	8.46	7.49	6.32	2.01
Indiana	8.46	7.49	5.34	2.01
Illinois	8.46	7.57	6.73	2.01
Michigan	8.54	7.42	5.97	2.01
Wisconsin	8.46	7.49	6.44	2.01
Alabama	8.76	7.24	5.98	2.49
Louisiana	8.70	7.43	1.83	2.31
Texas	8.78	7.50	4.32	2.31
Missouri	8.32	7.31	6.11	1.80
California	8.29	7.40	7.11	2.91
Oregon	8.05	7.00	6.84	2.51

[a]Assumptions: World Oil Price in 1990 (1979 dollars): $44/bbl.

SECTION 8.0

FEDERAL AND STATE INDUSTRIAL ENERGY CONSERVATION PROGRAMS

8.1 PURPOSE AND BACKGROUND

This section assesses the extent to which federal and state industrial energy conservation programs will affect future state industrial energy demand. First, a brief review of the major federal legislation relevant to industrial energy conservation is provided. Then, the DOE energy conservation program is outlined, and the effects of federal conservation programs are estimated. Finally, state conservation programs are summarized.

8.2 MAJOR FEDERAL LEGISLATION RELEVANT TO INDUSTRIAL ENERGY CONSERVATION

The federal role in industrial energy utilization and conservation was initiated with the Federal Energy Administration Act of 1974 (PL 93-275) that was signed into law on 7 May 1974. This Act established the FEA and empowered it as follows:

> ... (a) The Administrator shall collect, assemble, evaluate, and analyze energy information by categorical groupings, established by the Administrator, of sufficient comprehensiveness and particularity to permit fully informed monitoring and policy guidance with respect to the exercise of his functions under this Act. (b) All persons owning or operating facilities or business premises who are engaged in any phase of energy supply or major energy consumption shall make available to the Administrator such information and periodic reports, records, documents, and other data, relating to the purposes of this Act, including full identification of all data and projections as to source, time, and methodology of development, as the Administrator may prescribe by regulation or order as necessary or appropriate for the proper exercise of functions under this Act.

This Act provided detailed reporting of energy-use data for the industrial sector.

The Nonnuclear Energy Research and Development Act of 1974 (PL 93-577) was signed into law on 31 December 1974. This Act directed the Administrator of ERDA (predecessor to DOE) to "formulate and carry out a comprehensive Federal nonnuclear energy research, development, and demonstration program. . . ." The first item of a long list of RD&D program elements and activities was:

> ... to advance energy conservation technologies, including but not limited to—
>
> (i) productive use of waste, including garbage, sewage, agricultural wastes, and industrial waste heat;
> (ii) reuse and recycling of materials and consumer products; . . . .

Since that time, there has been additional legislation relating to various aspects of industrial energy utilization and conservation. The federal acts considered likely to affect future state industrial energy demand are:

- The Energy Policy and Conservation Act of 1975 (P.L. 94-163)
- The Energy Conservation and Production Act of 1976 (P.L. 94-385)
- The National Energy Conservation Policy Act (P.L. 95-619)
- The Powerplant and Industrial Fuel Use Act of 1978 (P.L. 95-620)
- Natural Gas Policy Act of 1978 (P.L. 95-621)
- Energy Tax Act of 1978 (P.L. 95-618)
- Public Utility Regulatory Policy Act (P.L. 95-617)

A brief review of the most important provisions in each of these acts relevant to the sources and uses of energy by industry is given in Appendix C.

8.3. DOE INDUSTRIAL ENERGY CONSERVATION RD&D PROGRAM

The Federal Government has a variety of options for improving the efficiency of industrial energy use. As outlined below, some barriers may be alleviated by a federal RD&D program, although others may require economic or other incentives:

- Technology programs
  - research and development
  - demonstration
  - information
- Incentives
  - fuel use tax
  - tax deductions
  - investment tax credits
  - favorable loans
  - subsidies
- Regulations
  - fuel conversion
  - fuel pricing
  - efficiency targets
  - data reporting.

8.3.1 Method Used to Develop RD&D Program Plan

DOE (1978) has developed a strategic plan for industrial energy conservation through the following five major steps.

Selection of High-Potential Industry Targets. Industry groups were identified and assessed at the 3- and 4-digit SIC level. Twenty single-product industries were identified initially as high-potential targets based on the following:

- relative homogeneity within each group in technology use,
- total energy consumption,
- oil and natural gas consumption, and
- degree of inherent incentive to conserve oil and natural gas.

Assessment of Key Constraint and Identification of Possible Federal Strategies. Among the three major constraints—technological, financial, and institutional—technological was found to infringe significantly upon industry's ability to accelerate energy conservation. Technological constraints were identified by assessing the energy efficiency limits of today's best available technology as a measure of the current potential for energy conservation. In addition, constraints were identified in two areas:

- process technologies specific to individual industries (e.g., steelmaking), and
- generic technologies usable by several or all industries (e.g., heat exchangers and heat pumps).

On the basis of these findings, major federal program strategies were identified and assessed in terms of their respective impact on specific constraints.

Assessment of RD&D by Industry. Information concerning RD&D functions in each key industry was developed through interviews with industry technical executives and a review of public information.

Development of Major Strategies. Major strategies were identified to overcome key technology-related constraints in terms of three principal factors:

- degree to which constraints are overcome;
- degree to which industry RD&D is complemented; and
- coordination of federal programs for RD&D, economic incentives, and regulatory policy.

Ordering of RD&D Functions. Priorities were set as guidelines on RD&D functions in each industry for each type of technology on the basis of the following:

- probable impact on energy conservation in each industry,
- total energy conservation potential,
- effectiveness in accelerating energy conservation, and
- cost to implement.

8.3.2 Objectives and Goals of the Federal Industrial Energy Conservation RD&D Plan

The key objectives regarding industrial energy conservation are to:

- achieve expeditiously the maximum penetration of existing and new energy conservation technologies;
- substitute more plentiful energy sources for relatively scarce fuels; and
- minimize energy losses in waste streams by
  - minimizing unemployment,
  - reducing the rate of inflation
  - enhancing the competitive posture of U.S. industries in the international marketplace, and
  - avoiding excessive administrative burdens and costs.

The DOE industrial energy conservation RD&D program has three preliminary goals:

- to provide an advanced technological base for improved energy use efficiency in industry and agriculture;
- to accelerate the commercialization and adoption of emerging and advanced technologies; and
- to significantly decrease the growth rate of industrial energy consumption and, particularly, oil and natural gas consumption from 1977 to 2000. Specifically, the program has a savings goal of 3.2 quads by 1985 and 8.6 quads by 2000.

8.3.3 Program Philosophy

The overall philosophy of the DOE program centers on a focused RD&D program combined with appropriate economic incentives and related regulatory policy. This technical program attempts to work compatibly and synergistically with other program efforts. RD&D programs supply the push by providing advanced technology and proving economic and technological feasibility in operating environments. Regulatory programs supply the push by establishing requirements and motivation for action by industry. Incentive programs supply the economic pull by providing advantages for industrial actions in the national interest.

An extensive analysis has been conducted by DOE to address the key issues facing program management in developing a program strategy within the context of this philosophy and the program goals.

8.3.4 Scope of the Program Plan

The focus of the DOE program is the Division of Industrial Energy Conservation under the Assistant Secretary for Conservation and Solar Applications. The program is coordinated with the basic and applied research activities of the Offices of Energy Research and the Assistant Secretary for Energy Technology, as well as the information gathering and regulatory activities of the Economic Regulatory Administration and EIA.

The programs of the Division of Industrial Energy Conservation encompass the range of activities betweeen applied RD&D and technology transfer and consist of:

- establishing priorities for specific industries, technologies, and RD&D functions;

- verifying energy conservation potential and identifying RD&D opportunities;
- accelerating the adoption of improved industry-specific technologies;
- accelerating the adoption of improved generic technologies;
- accelerating the adoption of cogeneration systems; and
- enhancing technology transfer.

8.4 ESTIMATING THE EFFECTS OF FEDERAL INDUSTRIAL ENERGY CONSERVATION PROGRAMS

Industry has always been conscious of energy cost as an element of production costs and has attempted to increase the efficiency of energy use when real energy prices were decreasing. Before 1972, energy efficiency improvements approximated 1%/yr.

After 1972, in response to increased energy prices, industry devoted much greater efforts to conservation. Three types of conservation are possible:

- "housekeeping" measures to adopt better procedures to control energy use and reduce waste,
- low-cost retrofit to recover and reduce wasted energy and improve process efficiency, and
- major process changes.

Since 1972, industry has achieved some improvement in energy efficiency. DOE established targets for energy efficiency improvements by 1980 in the 10 major 2-digit industries. Progress toward these targets is measured by the reported performance of major companies in each industry group. By the end of 1978, six of these industries had already exceeded their 1980 goals as shown in Table 8-1.

Table 8-1. EFFICIENCY IMPROVEMENT IN INDUSTRY

SIC	Industry Group	1980 Target (%)	1978 Actual (%)
20	Food	12	17
22	Textiles	22	19
26	Paper	20	14
28	Chemicals	14	17
29	Petroleum	12	16
32	Stone, Clay & Glass	16	13
33	Primary Metal	9	9
34	Fabricated Metals	24	22
35	Nonelectrical Machinery	15	28
37	Transportation Equipment	16	21

Source: U.S. DOE, Office of Industrial Programs (1979).

The 1979 report of the DOE Industrial Energy Efficiency Program stated that the 1980 energy efficiency improvement goals for the industries listed should be achieved and that the total energy savings should be 2.85 quads per year, which is equivalent to 1.2 million barrels of oil per day (U.S. DOE 1979). The report also notes that housekeeping conservation measures typically used by industry to save energy are far from exhausted, and they will continue to be a dominant contribution in industrial energy conservation in the early 1980s. Beyond that, capital investment programs of increasing cost will become more important in achieving additional energy savings.

Although many energy periodicals frequently report the results of industrial energy conservation efforts by individual firms, the aggregate impacts of such efforts are difficult to determine for a state or nation. Even though DOE has a mandatory industrial reporting program for the 10 most energy-intensive industries, those consuming over 90% of the purchased energy used by the nation's manufacturers, it is very difficult to document which measures were actually taken by states and specific companies. Firms may either report directly or through their trade association on their progress in meeting voluntary targets for each industry 2-digit SIC group. DOE, however, only reports the energy savings for industries and not by plant or state to protect confidentiality of data.

The potential applications of conservation measures in specific industries are dependent on a number of technological, institutional, and economic factors. Numerous constraints to implementing energy conservation measures include:

- low rates of technological innovation,
- capital availability,
- uncertainty regarding future energy prices,
- conflicting federal regulations and policies,
- risk aversion to major process changes, and
- low asset turnover rates in some industries.

DOE estimates of the potential for improving energy efficiency by adopting technological options are given in Table 8-2. The estimated national energy savings for all industries by 1985 because of specific conservation measures in the industrial sector are shown in Table 8-3. Unfortunately, it is impossible to disaggregate these estimates to the state level because of the diversity of industries and conservation measures. Section 9.0 discusses state-specific industrial energy conservation programs.

Table 8-2. ESTIMATED TECHNOLOGICAL LIMITS TO INDUSTRIAL ENERGY CONSERVATION

Industry	Industry Estimates of Best Available Technology Improvement from 1979	Estimates of Theoretical Limits of Energy Efficiency Improvement
Steel	30%-35%	62%-82%
Petroleum Refining	10%-15%	90%
Paper	30%-40%	100%
Ammonia	N/A	N/A
Aluminum	15%-25%	88%
Cement	20%-30%	93%
Olcfins	20%-30%	59%
Textiles	15%-30%	95%
Chlor-Alkali	15%-25%	N/A
Glass	N/A	N/A

Source: U.S. DOE, Office of Industrial Programs (1979).

Table 8-3. POTENTIAL AND ESTIMATED ENERGY SAVINGS FROM RD&D PROGRAM

Activity	Potential Savings in 1985 (quads/yr)	Estimated Savings in 1985 (quads/yr)
Waste Heat Recovery	3.0-4.0	0.99
Improved Combustion	2.0-3.0	0.61
Alternative Fuels and Feedstocks	1.5-2.1	0.28
Industrial Cogeneration	2.0-3.0	0.48
High Temperature Processes	2.0	0.33
Low Temperature Processes	1.5-2.0	0.16
End Product Processes	0.2-0.3	0.19
Agriculture and Food	0.4-0.5	0.13
Total	12.6-17.9	3.20

Source: U.S. DOE, Division of Industrial Energy Conservation (1978).

8.5 STATE INDUSTRIAL ENERGY CONSERVATION PROGRAMS

This section reviews the state industrial energy conservation programs in the 15 selected states and attempts to estimate their impact on the future state industrial sector energy demand. The activities listed in the state energy conservation plans, U-535 annual reports, and other documents were used as references.

Activities at the state level relating to industrial energy conservation were initiated after the Energy Policy and Conservation Act (EPCA) was enacted. Initially, the states were essentially responding to federal requirements; however, many states have recently taken the initiative to adopt their own programs for promoting industrial energy conservation.

Most studies have found that states typically promote voluntary programs that encourage information transfer for public education as opposed to the mandatory or legislative approach. The industrial energy conservation programs for the 15 study states preferred this with only a few exceptions. All 50 states are now in their last year of the EPCA grant program. Presently Congress is considering a measure that will further amend EPCA and other acts to consolidate several energy planning and management activities in the states.

A review of federal and state industrial energy conservation programs indicates that there is little coordination or integration of the federal industrial energy efficiency improvement program and the state energy conservation programs. Recently, though, some effort has been made to plan workshops and seminars with federal/state cooperation. In many cases, the federal programs apply to large energy-intensive industries, while state-supported programs are directed toward smaller, less energy-intensive industries. In some cases, states were aware of the federal program and promoted it as part of their own energy conservation activities (Indiana and Alabama, for example). Each year the Industrial Energy Efficiency Program submits a report to Congress on the progress made in achieving the industrial targets. As indicated in Sec. 8.0, substantial progress has been made in reducing energy consumption. The interesting feature of the industrial program is that the targets are voluntary but the reporting requirements are mandatory. Unfortunately, only the names and addresses of the firms participating in the program in each state are available. No data can be obtained regarding the energy conservation achieved by a specific company located in a certain state, although some states have asked for the mailing list and conducted their own surveys to monitor the progress in reducing industrial energy consumption.

Each year, states are required to submit Form U-535 (Annual Report of State Energy Conservation Plan Savings: Source Book Report) to DOE, estimating the energy savings resulting from implementing specific program measures. These state reports correspond to the annual state energy conservation plans that are submitted as a result of funds received under EPCA and Energy Conservation and Production Act (ECPA). The annual state U-535 reports then comprise a source book of state conservation programs reflecting annual energy savings and expenditures. The program measures for a state sometimes consist of aggregated commercial/industrial activities or very specific programs. Nevertheless, the state conservation plans and DOE Source Book have been found to be a useful review of state energy conservation activities, which can then be compared to state modeling and forecasting efforts to project future industrial energy requirements.

Many states are now moving toward developing comprehensive energy plans that extend beyond the limited time frame of existing federal categorical grant programs. Since this is the last year of funding under existing EPCA/ECPA grants to states and because of the need to formulate comprehensive state energy programs, Congress plans to legislate comprehensive state and local energy planning. Such states as California, Missouri, New York, and New Jersey have already formulated or are now formulating long-term energy plans. For a description of individual conservation plans of the 15 selected states see Appendix D.

8.6 SUMMARY OF STATE PROGRAMS

After reviewing the energy conservation activities of the 15 selected states, information transfer, primarily by audits, workshops, and reference materials, was found to be the most common program affecting industry. These findings are consistent with the survey of the 50 states that was completed and released by Common Cause (1980) and Volume 8 of DOE's Source Book of State Energy Conservation Programs (U.S. DOE 1980).

The Common Cause survey noted that 32 states offer industrial on-site audits and 37 states have set up energy information clearinghouses. More than half the states surveyed have established state energy advisory committees and twelve states have established efficiency standards for boilers or other industrial equipment. Only two of the 15 states reviewed had such standards.

Cogeneration is a major item of interest in the states. Typically, states provided funding to support cogeneration feasibility studies. Only California was encouraging cogeneration through legislative/regulatory efforts.

Table 8-4 shows estimates of the projected 1980 energy savings as a result of implementing state energy conservation programs in the industrial sector, which is expected to be a total of 1.2 quads. These figures are presented mainly to show the variation in estimated energy savings. A problem in working with U-535 estimates of the impact of state energy programs is the occasional aggregation of industrial and commercial energy programs and the lack of control for intervening variables that may also affect the energy savings reported.

Table 8-4. 1980 ESTIMATED INDUSTRIAL ENERGY CONSERVATION SAVINGS FOR THE 15 STUDY STATES

(Trillion Btu)

States	1980 Energy Savings
Alabama	38
California	200[a]
Illinois	40
Indiana	111
Louisiana	185
Michigan	0.35
Missouri	2.76
New Jersey	23
New York	16.5
Ohio	115
Oregon	11[a]
Pennsylvania	158
Texas	283
West Virginia	1.8
Wisconsin	13
Total	1,198.41

Source: DOE Form U-535.

Two other findings are believed to be significant. The first relates to the lack of coordination and integration of the DOE Industrial Energy Efficiency Program with the state industrial energy conservation activities. After meeting with a representative of the DOE industrial program, it was disclosed that Argonne National Labs is under contract to develop a workshop for the states in DOE's Region V (Illinois, Indiana, Michigan, Minnesota, Ohio, and Wisconsin) and the DOE industrial program. It is hoped that the workshop results in a pilot program that provides increased cooperation between the states and the DOE program. A few state energy offices have taken the initiative and attempted to list which industries in their political boundaries were reporting to Washington; however, no energy savings information is available to the states.

The DOE program has been slowly moving toward greater state interaction in one other area. From November 1979 to March 1980, 10 industrial energy management workshops were held in New England. Over 1,500 industrial representatives attended. The workshops were a cooperative effort of the Washington office, regional DOE offices, and state energy offices. The actual impact of these programs is yet to be determined. However, there is relatively little interaction between the DOE Industrial Energy Efficiency program and the state energy offices.

The second finding relates to the uncertainty surrounding the future sources and uses of industrial energy. With a few exceptions, most states have a short planning horizon regarding policy and program development. Under the two major federal energy programs providing funds to the states (EPCA/ECPA), the states must submit annual state energy conservation plans. With the states in the last year of the EPCA/ECPA grant program and Congress now considering the Energy Management Partnership Act, which would consolidate EPCA/ECPA and the Energy Extension Service and also encourage comprehensive energy planning and management, it is unknown what programmatic changes are in the offing and how these will affect the implementation of state energy programs.

The most significant impact on industrial energy consumption will likely be the state of the economy and the supply and price of various energy resources. Provisions of the Public Utility Regulatory Policy Act (P.L. 95-617), the Natural Gas Policy Act (P.L. 95-621), and the Power Plant and Industrial Fuel Use Act of 1978 (P.L. 95-620), are likely to have major impacts on the sources and uses of energy in the industrial sector. Although many of the resulting federal rules and regulations are already issued, much uncertainty still surrounds these programs. State PUCs are now in the process of holding cost-of-service and rate design hearings; however, it is presently not known how they will judge the results of the load research now under way by major electric utilities. Phase I of incremental pricing is now being implemented under the Natural Gas Policy Act. There is currently a move in Congress to abolish incremental pricing.

With multiple programs directed to a target area, it is difficult to determine the independent impact of each program unless detailed and costly research designs are constructed. Also, because of the fragmented nature of federal and state energy policies, it is difficult to develop the understanding needed to estimate individual program impact. This is especially true since very few states are aware of the extent of local industry involvement and progress in industrial energy conservation.

Unless a significant effort is made to formulate complex methods that measure independent program impact on future industrial energy requirements, estimates of future conservation are likely to be unreliable and limited in validity. This leads to a number of additional problems for states. Policy analysis and program evaluation methods are developing fields. For the past few years, the DOE Office of Conservation and Solar Applications has been attempting to increase the sophistication with which states evaluate the impact of implementing program measures. To date, the Office has used private contractors to either develop and evaluate program evaluation methods or to develop the necessary data base for estimating the impact of program measures. In December 1979, the DOE Office of Conservation and Solar Applications held a meeting of state energy conservation officials, and much concern was expressed regarding the quality of state program evaluation methods and the need to control the independent effects of program measures.

In conclusion, after reviewing state activities impacting industrial energy use, it was impossible to assess the extent to which the state-initiated legislative/regulatory programs will affect future industrial energy requirements. The bulk of the legislative/regulatory efforts are at the federal level, and little is known about their state- and industry-specific impacts. This is largely because of the still evolving nature of the many pieces of legislation that in total compose the National Energy Act, and the lack of geographically disaggregated impact assessments. The typical state implementation strategy is information transfer. The estimated 1980 energy savings have been presented, but the post-1980 state-initiated energy activities impacting industry are unknown at this time.

SECTION 9.0

DEVELOPMENT OF INDUSTRIAL ENERGY PROJECTIONS AT THE 2-DIGIT SIC LEVEL

9.1 INTRODUCTION

To develop projections of industrial energy end uses by state, it was necessary to first develop aggregate projections of total energy requirements* by 2-digit SIC group. The method used to disaggregate the 2-digit projections to the 4-digit level and to estimate end uses is described in Sec. 10.0.

At the initiation of the project, it was expected that projections of state industrial energy requirements at the 2-digit level were expected to be available or be developed from existing state industrial energy demand models. The resources and time allocated to the development of such projections in this effort, therefore, were quite limited. Unfortunately, the review of state industrial energy demand models indicated that such projections could not be easily developed because:

- Nine of the fifteen states did not have any industrial energy demand models.
- Of the six that had models, two (New Mexico and Wisconsin) only addressed electricity consumption, and the New York model did not provide any disaggregation of total industrial energy demand by SIC.
- The energy models available for the three remaining states (California, Texas, and Oregon) had very significant differences in model structure, scope and coverage, assumptions and treatment of conservation, cogeneration, etc., and ability to address regulatory and policy issues.

Alternative approaches were considered to develop the required projections for the 15 states. These approaches included:

- using engineering-economic methods to estimate future energy utilization patterns taking into account conservation, fuel switching, substitution, etc.;
- using previously developed national or regional econometric models;
- estimating new models using data for the 15 states;
- estimating energy use and conservation from the federal industrial energy reporting system; and
- using estimates and projections of energy intensities.

Because of the significant time and resource constraints of the study, only a limited amount of research could be performed. The energy intensity approach was used for making the projections. A brief discussion of the alternatives and the selected procedure follows.

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*Energy requirements refer to total purchased fuels and exclude electric energy. This definition is used because the objective is to determine energy end uses potentially suitable for solar penetration.

9.2 ALTERNATIVE APPROACHES

9.2.1 Engineering and Economic Analysis of Energy Requirements

This approach involves performing an analysis of the major determinants of energy utilization in each 2-digit industrial group and, using engineering and economic approaches, projecting these determinants and their effects on energy requirements. Such analyses have been performed at the national level in the Drexel University Industrial Applications Study and the Industrial Sector Technology Use Model (ISTUM). Also, regional analyses are currently under way at the Oak Ridge National Laboratory (ORNL).

Unfortunately, the resources required to perform engineering-economic analyses of the major 2-digit groups for each state were far beyond the scope of this effort. The national studies could not be disaggregated to the state level, and the ORNL studies are not complete.

9.2.2 Use of National or Regional Econometric Models

Although a large amount of effort has recently been devoted to the estimation of econometric models of industrial energy use, only a few of these address disaggregation of the industrial sector by 2-digit SIC. Most of DOE's efforts in MEFS and the supporting models treat the industrial sector in aggregate only.

A quick review of existing industrial econometric models did not indicate any available models at the 2-digit level that could be readily adapted for the purposes of this study. One example of available econometric models at the 2-digit SIC level is shown in Table 9-1. These models were regional and not state level.

9.2.3 Estimation of New Models

An attempt was made to estimate energy use as a function of energy prices and value added using data at the 2-digit SIC level for the 15 states. Data were collected for 1971 and 1976, and cross-sectional analyses were conducted using the following model structure:

$$\log(\text{Energy Consumption}) = A + B \log(\text{Price}) + C \log(\text{Value Added})$$

The results of the cross-sectional analysis are summarized in Table 9-2. The table shows that the results were inconclusive, perhaps because of the small data sample. Further research along these lines could yield useful results, particularly after the 1977 Census of Manufacturers data are published. Time and resource constraints preclude additional data collection and analysis along these lines.

Table 9-1. ILLUSTRATIVE EQUATIONS FOR TOTAL ENERGY CONSUMPTION BY MAJOR 2-DIGIT SIC[a]

Serial No.	SIC	Industry	Coefficients and T Values C_0	C_1	C_2	Statistical Measures R^2	D.W.
1	20	Food	-3.92 (-6.32)	-0.88 (-3.99)	-0.97 (13.3)	0.89	2.38
2	22,23	Textiles	-6.52 (-4.55)	-0.43 (-0.27)	1.41 (5.4)	0.91	2.08
3	24,25	Lumber	-6.82 (-4.89)	-0.96 (-2.31)	1.34 (6.0)	0.89	1.60
4	26	Paper	-5.00 (-5.13)	-0.88 (-2.52)	1.30 (7.7)	0.95	1.94
5	28	Chemicals	-5.85 (-5.28)	-1.86 (-4.76)	1.20 (6.53)	0.95	2.22
6	29	Petroleum	-4.9 (-8.4)	-2.09 (-6.86)	1.11 (8.65)	0.93	1.33
7	30	Rubber	-7.96 (-3.24)	-0.276 (0.32)	1.63 (4.42)	0.74	2.16
8	32	Stone, Clay, Glass	-5.6 (-3.86)	-1.54 (-2.99)	1.34 (6.62)	0.90	2.27
9	33	Primary Metal	-6.01 (-7.78)	-1.36 (-5.03)	1.347 (13.9)	0.90	2.27
10	34	Fabricated Metals	-5.68 (-12.2)	-0.27 (-0.95)	1.21 (19.5)	0.95	2.64
11	37	Transportation Equipment	-6.09 (5.82)	-0.59 (-1.03)	1.13 (6.6)	0.92	1.84
Total of 11 Industries 1.59				-6.32	-1.88	1.19	0.92
			(-7.92)	(-8.54)	(15.9)		
Total of All Industries 2.20				-3.89	-1.74	0.94	0.89
			(-4.95)	(8.3)	(12.9)		

[a]Equation Form: log (Total Energy Consumption) = C_0 + C_1 log (Average Price) + C_2 log (Value Added) + Dummy Variables

Source: Limaye et al. (1975)

Table 9-2. RESULTS OF CROSS-SECTIONAL ANALYSIS OF 1971 AND 1976 DATA BY 2-DIGIT SIC[a]

SIC		1971 B	1971 C	1976 B	1976 C
20	Food & Kindred Products	0.10841	0.93924	0.08894	0.91066
26	Paper & Allied Products	-0.23588	0.28680	-0.69086	0.28692
28	Chemicals, Allied Products	-0.46190	0.80008	-0.58556	0.79741
29	Petroleum & Coal Products	-0.73625	0.94008	—	—
32	Stone, Clay, Glass Products	—	—	0.02716	0.83144
33	Primary Metal Industries	-0.22621	0.94108	-0.01991	0.81129
36	Electric, Electronic Equipment	—	—	-0.27700	0.97869

[a]Model Structure: $\log(E) = A + B \log(P) + C \log(VA)$

where

E = Energy (Purchased Fuel)
P = Price
VA = Value Added

9.2.4 Use of Data from Federal Industrial Energy Reporting System

This approach involves the utilization and extrapolation of energy use and conservation data from the Federal Industrial Energy Reporting System. DOE is closely monitoring the energy consumption of major firms by 2-digit SIC to determine progress toward the 1980 targets for energy conservation.

However, the DOE program provides data at the national level only with no regional or state disaggregation. Also, no indication of additional conservation potential beyond the 1980 targets is available.

9.2.5 Use of Energy Intensities

Energy intensities that can be measured by the ratio of energy consumption to value added can be used for analyzing industrial energy use. An analysis of the energy consumption (purchased fuels) to value added (in constant 1972 dollars) ratio for each major 2-digit group in each state was performed. The results for six of the SIC industries are shown in Figs. 9-1 through 9-6.

These figures generally indicate a consistent trend across the states in the decline of the energy to value added ratios. Statistical analyses were conducted to examine this decline.

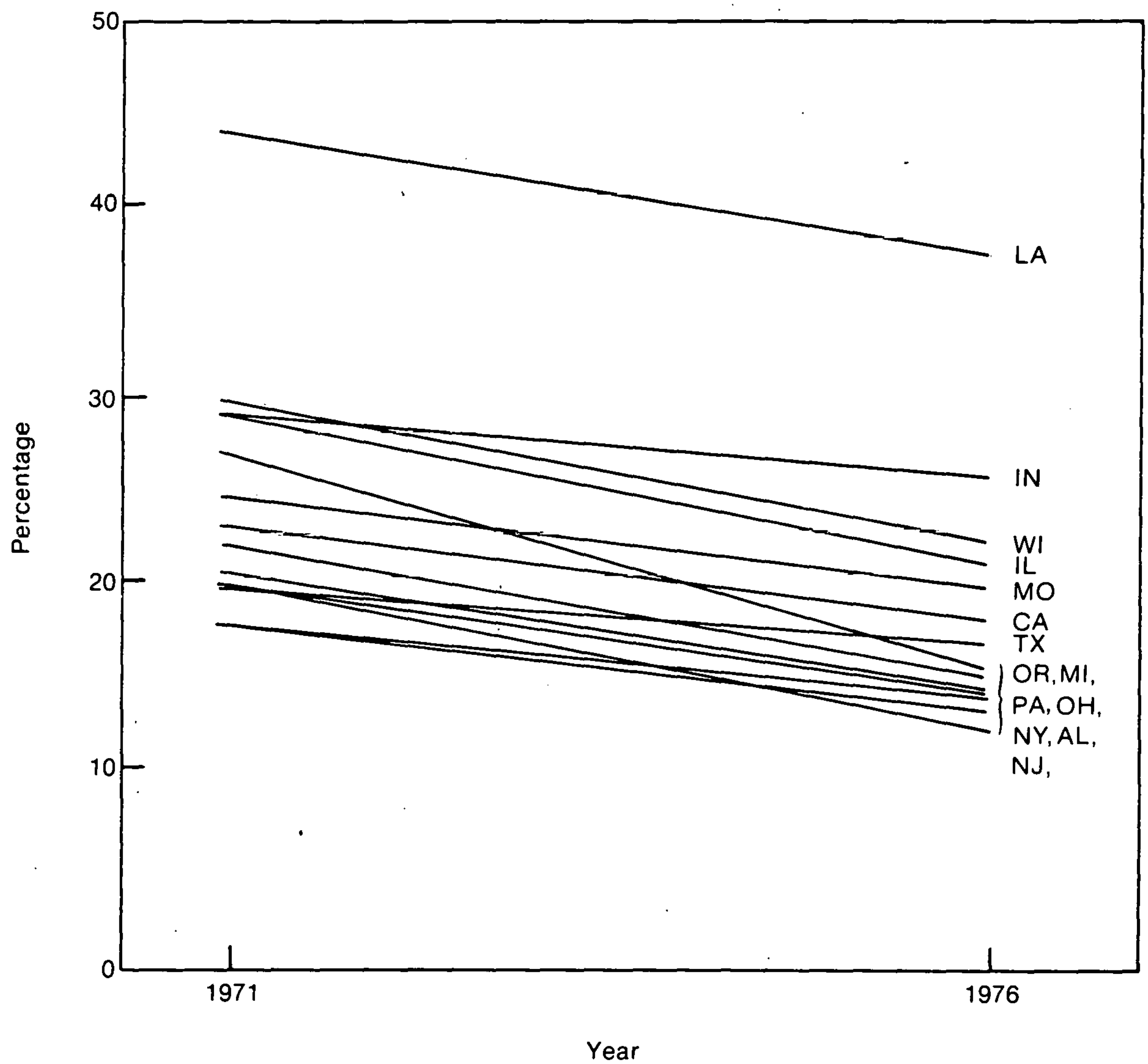


Figure 9-1. Trends in the Ratio of Purchased Fuel to Value Added by State, 1971 to 1976: SIC 20

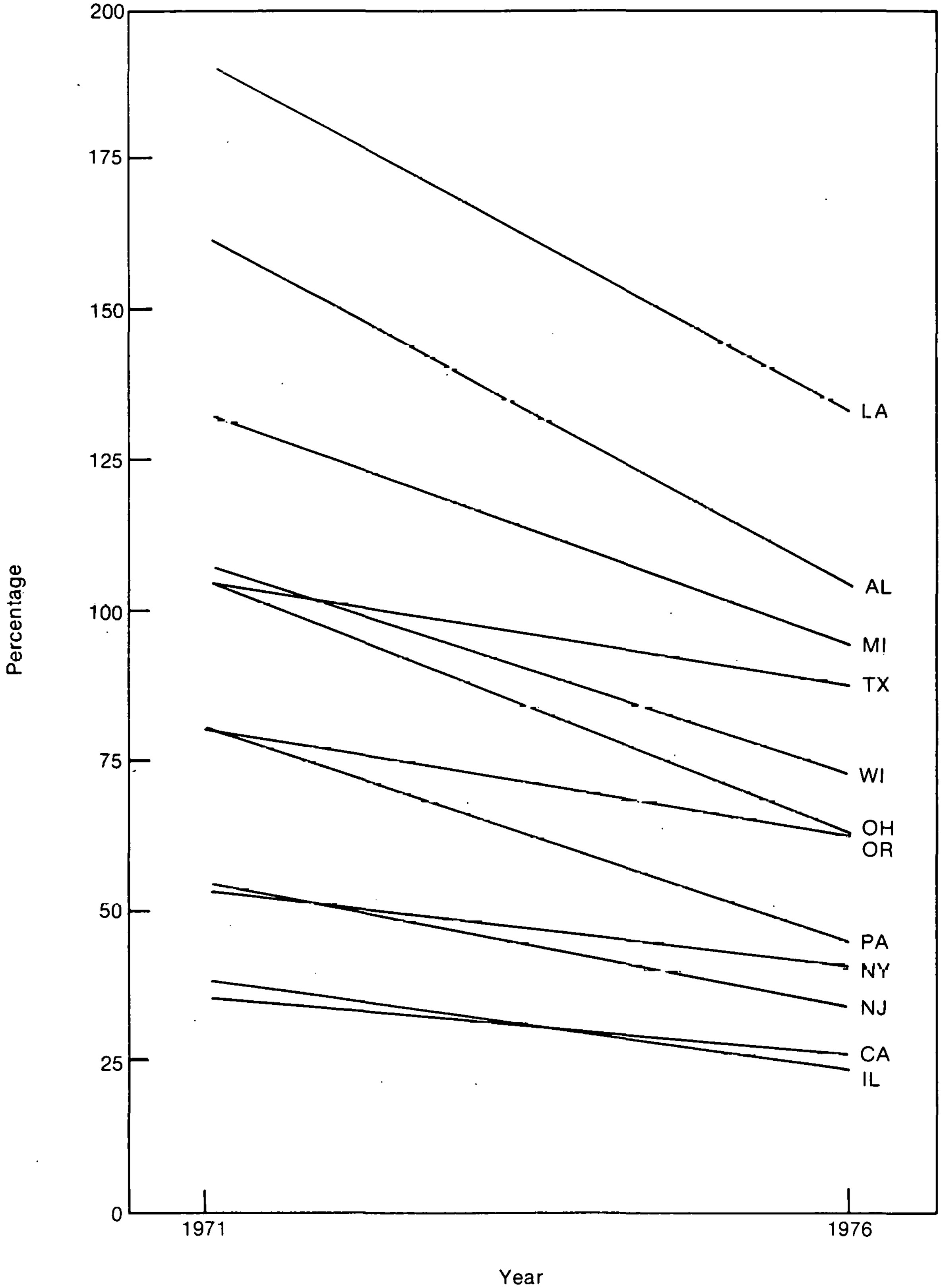


Figure 9-2. Trends in the Ratio of Purchased Fuels to Value Added by State, 1971 to 1976: SIC 26

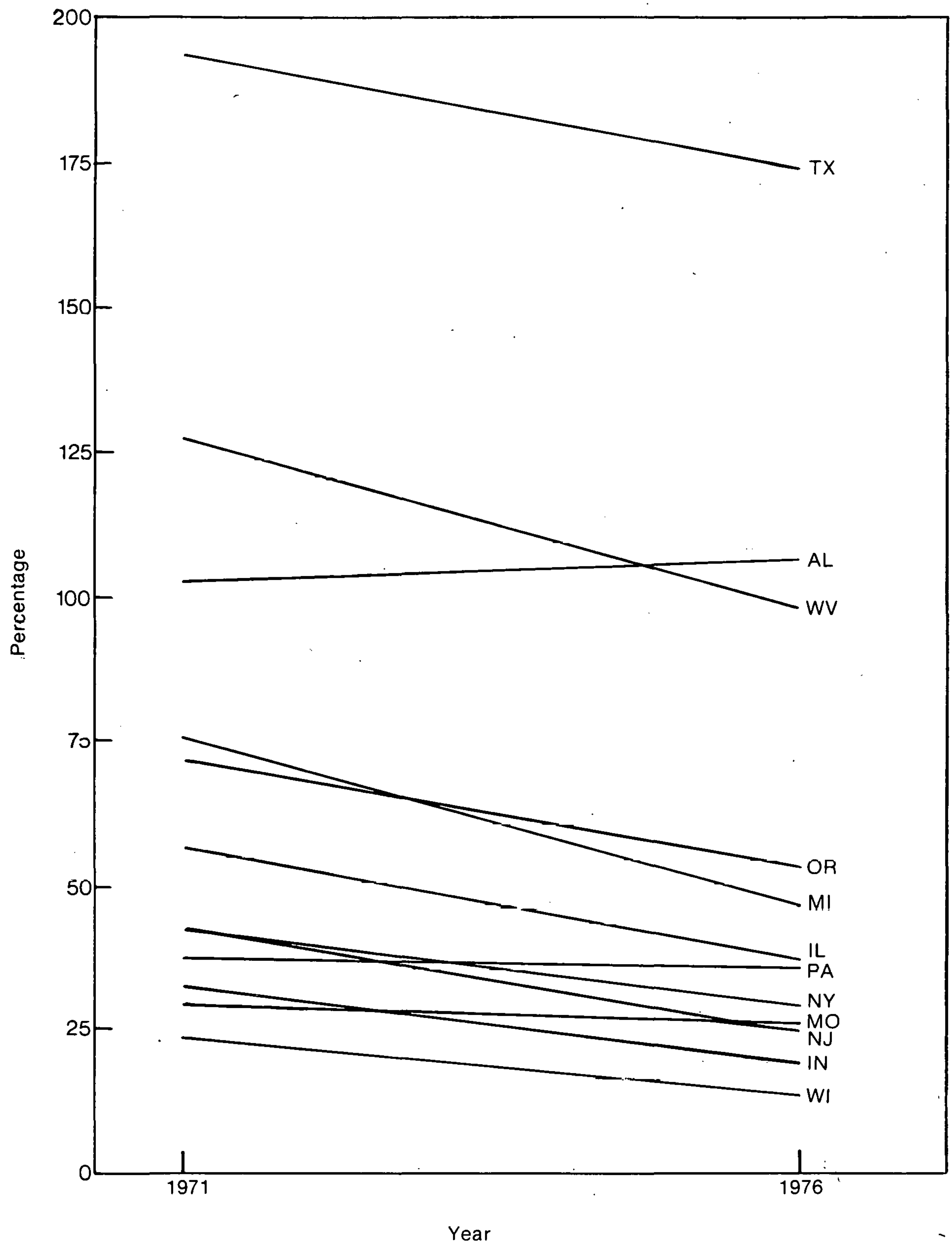


Figure 9-3. Trends in the Ratio of Purchased Fuel to Value Added by State, 1971 to 1976: SIC 28

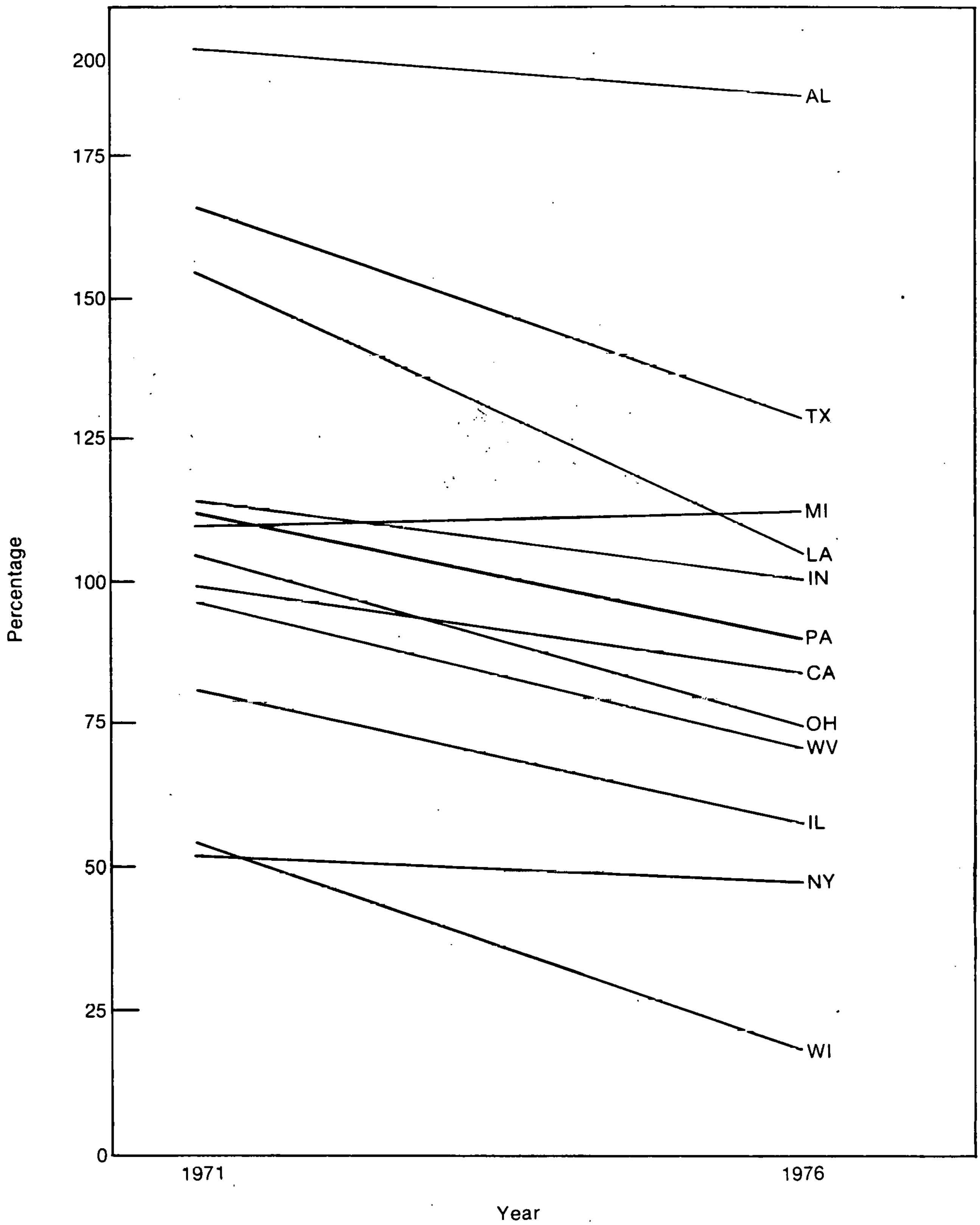


Figure 9-4. Trends in the Ratio of Purchased Fuel to Value Added by State, 1971 to 1976: SIC 32

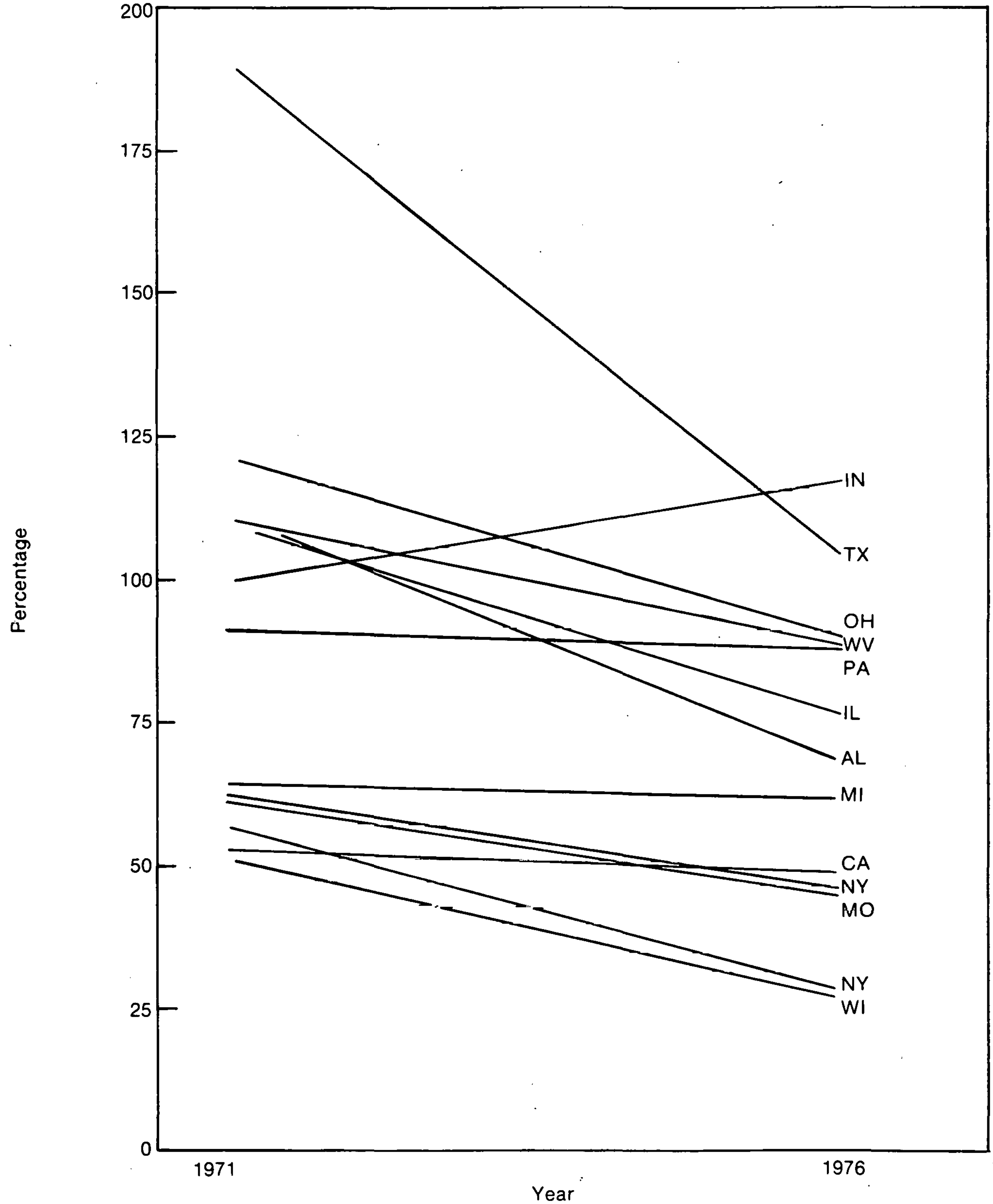


Figure 9-5. Trends in the Ratio of Purchased Fuel to Value Added by State, 1971 to 1976: SIC 33

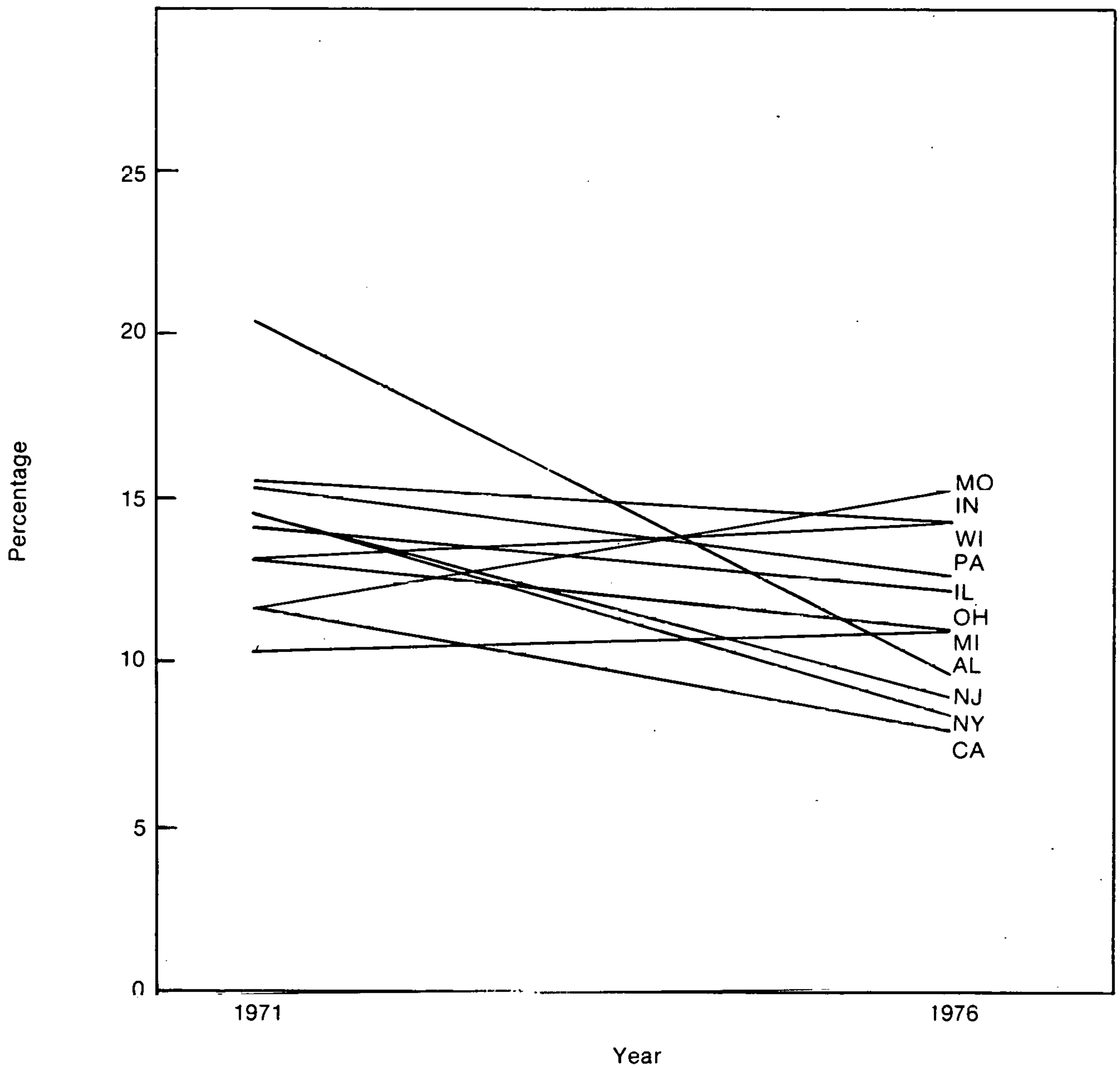


Figure 9-6. Trends in the Ratio of Purchased Fuel to Value Added by State, 1971 to 1976: SIC 34

9.3 ANALYSIS AND PROJECTION OF ENERGY INTENSITIES

Data on energy intensities and energy prices for 1971 and 1976 were compiled for each major 2-digit SIC by state. A simple statistical analysis was conducted to develop estimates of price elasticity of the energy intensity ratio. It was assumed that this elasticity essentially captured the past effects of energy conservation. The estimated elasticities are shown in Table 9-3.

Table 9-3. PRICE ELASTICITIES OF ENERGY INTENSITY RATIO ESTIMATED FROM 1971 AND 1976 DATA

SIC		Estimated Elasticity
20	Food & Kindred Products	-0.321
22	Textile Mill Products	-0.342
24	Lumber & Wood Products	-0.837
26	Paper & Allied Products	-0.351
28	Chemicals, Allied Products	-0.283
29	Petroleum & Coal Products	-0.834
30	Rubber, Miscellaneous Plastics	-0.461
32	Stone, Clay, Glass Products	-0.265
33	Primary Metal Industries	-0.328
34	Fabricated Metal Products	-0.357
35	Machinery, Except Electrical	-0.649
37	Transportation Equipment	-0.145
38	Instruments, Related Products	-0.220

Energy price projections developed in Sec. 7.0 indicated significant real price increases between 1976 and 1990. An assumption was made that the application of the price elasticities shown in Table 9-3 would essentially capture the effects of future conservation. This is a very strong assumption with little justification. However, under the constraints of this study, it was necessary to make some general assumptions because, as discussed in Secs. 8.0 and 9.0, analyses of energy conservation programs do not provide any explicit data regarding effects of future conservation programs.

Energy intensity ratios for each major SIC in each state were calculated using the price projection for the medium price scenario. No projections of state level value added by 2-digit SIC were available for all the states from any single source. The U.S. Department of Commerce, Office of Business Economics, provided projections of earnings (in real dollars) by 2-digit SIC and state from their OBERS system. The projected average annual growth rates for earnings were applied to value added to develop projections in real dollars. The product of projected value added and projected energy intensity provided the needed energy demand projections.

Appendix E shows the results of the analysis.

SERI

SECTION 10.0

DISAGGREGATION OF INDUSTRIAL ENERGY PROJECTIONS BY END USE

10.1 INTRODUCTION

As indicated in Sec. 2.0, the analysis of the potential of solar energy in IPH requires information on end uses of energy in the industrial sector. The end uses that are best suited for the application of solar energy are hot water, low-temperature process steam, and low-temperature hot air applications. The performance of various types of solar thermal systems for industrial applications varies significantly relative to the temperature of the application. Therefore, one of the main objectives of this study was to develop a distribution of end uses by temperature level. The end uses and temperature levels of industrial energy requirements vary from process to process and have to be investigated at a disaggregated level by SIC. As indicated in the review of existing industrial data bases in Sec. 3.0, the availability and quality of data on industrial energy end uses is severely limited.

An approach was developed to work with existing data bases and data sources to disaggregate projections of energy requirements by 2-digit SIC, end use (and temperature level), and 4-digit SIC. The end-use projections were then integrated over the industrial mix in each state to obtain the temperature distribution for industrial energy utilization at the state level in 1990.

The time and resource constraints of this study required a reliance on existing data bases despite their limited accuracy and reliability. Judicious use of various existing data bases was made in performing the analysis and developing the projections.

10.2 SUMMARY OF APPROACH

Based on the review and evaluation of industrial data bases, the Drexel University Industrial Applications Study data base was used as the principal source of data on end use (Hamel et al. 1979). This data base contains detailed process and unit operations level information for 108 processes representing 60 energy intensive 4-digit SIC industrial groups. Since the 60 SIC industries did not cover the entire list of relevant industries in all the states, the Drexel data were supplemented with information from the ITC study of solar applications for industrial process steam (1977).

Using these two data sources, end-use profiles for each 4-digit industrial group were prepared. The end uses examined were:

- hot water,
- steam (212°-300° F, each 100° F interval from 300°-1000° F, and 1000° F), and
- hot air (100° F intervals).

Table 10-1 shows examples of data for two industry groups.

The energy-use patterns for each of the 15 states under evaluation were examined from the 1972 Census of Manufacturers (reporting 1971 data), and the 1976 Annual Survey of Manufacturers. For each state, the major 2-digit industry groups were identified, and

Table 10-1. ILLUSTRATIVE DATA ON INDUSTRIAL END USE

End Use	Purchased Fuel Use (Btu/lb of product) SIC 2821	Purchased Fuel Use (Btu/lb of product) SIC 3321	% of Purchased Fuel SIC 2821	% of Purchased Fuel SIC 3321
Hot Water				
Steam (°F)				
212-300	187.5		11.83	
301-400	250.0		17.11	
401-500	194.5		13.31	
501-600	19.7		1.36	
601-700				
701-800				
Hot Air (°F)				
<150	196.7	7.5	13.46	0.14
151-200				
201-300				
301-400				
401-500	90.2	650.0	6.17	12.14
501-600		1,950.0		36.43
601-700				
701-800				
801-900				
901-1000				
>1000		2,740.0		47.26
Other	523.0	5.5	36.84	0.11
Total	1,461.6	5,353.0	100.00	100.00

any group consuming more than 2% of the total industrial energy consumption was included. Table 10-2 shows the 2-digit SIC industries by state included in the analysis.

For each 2-digit SIC group, the major 3-digit SIC groups were identified. The criterion for selecting the 3-digit group was that each consumed at least 2% of the total energy consumed by the respective 2-digit SIC. The state level data did not report energy consumption below the 3-digit level. The disaggregation of 3-digit groups to the 4-digit level was accomplished by using national energy consumption data. For each 3-digit SIC group at the U.S. level, the major 4-digit groups were identified, again using the criterion that any group consuming at least 2% of the total was to be included. The result of this analysis provided a list of major industry groups to be analyzed in each state (Table 10-2).

The 2-digit industrial energy projections (Sec. 9.0) were disaggregated to the 4-digit level using appropriate shares for each 4-digit group as a function of the relevant 2-digit groups. The 4-digit SIC group energy consumption was then disaggregated to the end-use level by using data similar to that in Table 10-3. The end-use data were aggregated to the 2-digit level. Finally, the 2-digit end-use data were aggregated for all the 2-digit groups to obtain state level totals. The distribution of state level end uses was then developed.

10.2.1 Disaggregation of 2-Digit SIC to 3-Digit and 4-Digit Levels

For illustrative purposes, the state of Pennsylvania is used. Figure 10-1 shows the composition of the major 3-digit groups in SIC 20 (food) and SIC 28 (chemicals) and the major 4-digit SIC groups as a percentage of 3-digit totals (developed from U.S. figures) in Pennsylvania.

10.2.2 Calculation of Energy Consumption by End Use

Tables 10-4 and 10-5 show the percentage distribution of end-use energy consumption for 4-digit SIC groups composing SIC 20 and SIC 28 in Pennsylvania. Table 10-6 shows the energy consumption by end use in 1976 for these 4-digit groups and for the total of SIC 20 in Pennsylvania, and Fig. 10-2 shows a bar graph of the percentage distribution for SIC 20.

Similar calculations were performed for all relevant industries in all 15 states. The results of these calculations are shown in Tables 10-7 through 10-21.

The summary of results showing end uses of energy in Btu for the 15 states is shown in Table 10-22. Table 10-23 shows the same data as a percentage of total consumption, thus providing the temperature distribution at the state level.

Table 10-2. MAJOR 2-DIGIT SIC GROUPS INCLUDED IN ANALYSIS

State	SIC Groups 20	22	24	26	28	29	30	32	33	34	35	37	38	% of Total Energy Represented by These SICs
New York	X			X	X			X	X	X	X	X	X	84.5
New Jersey	X	X		X	X	X	X	X	X	X	X			63.0
Pennsylvania	X			X	X	X		X	X	X				89.2
West Virginia					X	X		X	X					94.7
Ohio	X			X	X	X		X	X	X	X			87.3
Indiana	X				X			X	X	X	X	X		89.2
Illinois	X			X	X			X	X	X	X			86.3
Michigan	X			X	X			X	X	X	X	X		93.5
Wisconsin	X			X	X			X	X	X	X	X		89.9
Alabama	X	X	X	X	X		X	X	X	X				96.4
Louisiana	X			X	X	X		X	X					98.4
Texas	X			X	X	X		X	X					96.7
California	X		X	X	X	X		X	X	X		X		93.4
Oregon	X		X	X	X			X						81.9
Missouri	X				X			X	X	X		X		86.8

Table 10-3. ILLUSTRATION OF SELECTION OF 4-DIGIT SIC GROUPS FOR ANALYSIS

(State: Pennsylvania; Industry Group: SIC 20—Food and Kindred Products)

SIC	Description	1976 Energy Consumption (Billion Btu)	Energy Consumption as % of: 2-Digit SIC	3-Digit SIC
20	Food & Kindred Products	31,900	100.00	—
201	Meat Products	2,600	8.15	—
2011	Meatpacking	1,690	5.30	65.43
2013	Sausages	402	1.26	15.49
2016	Poultry Dressing	402	1.26	15.49
202	Dairy Products	3,700	11.60	—
2022	Cheese	638	2.00	26.11
2023	Condensed Milk	925	2.90	25.03
2026	Fluid Milk	1,439	4.51	38.90
203	Preserved Fruits & Vegetables	4,300	13.47	—
2032	Canned Specialties	734	2.31	17.16
2033	Canned Fruits & Vegetables	1,215	5.12	38.06
2034	Dehydrated Fruits & Veg.	453	1.42	10.54
2037	Frozen Fruits & Vegetables	970	3.04	22.57
204	Grain Mill Products	4,300	13.47	—
2046	Wet Corn Milling	2,625	8.23	61.09
2048	Prepared Feeds	726	2.28	16.89

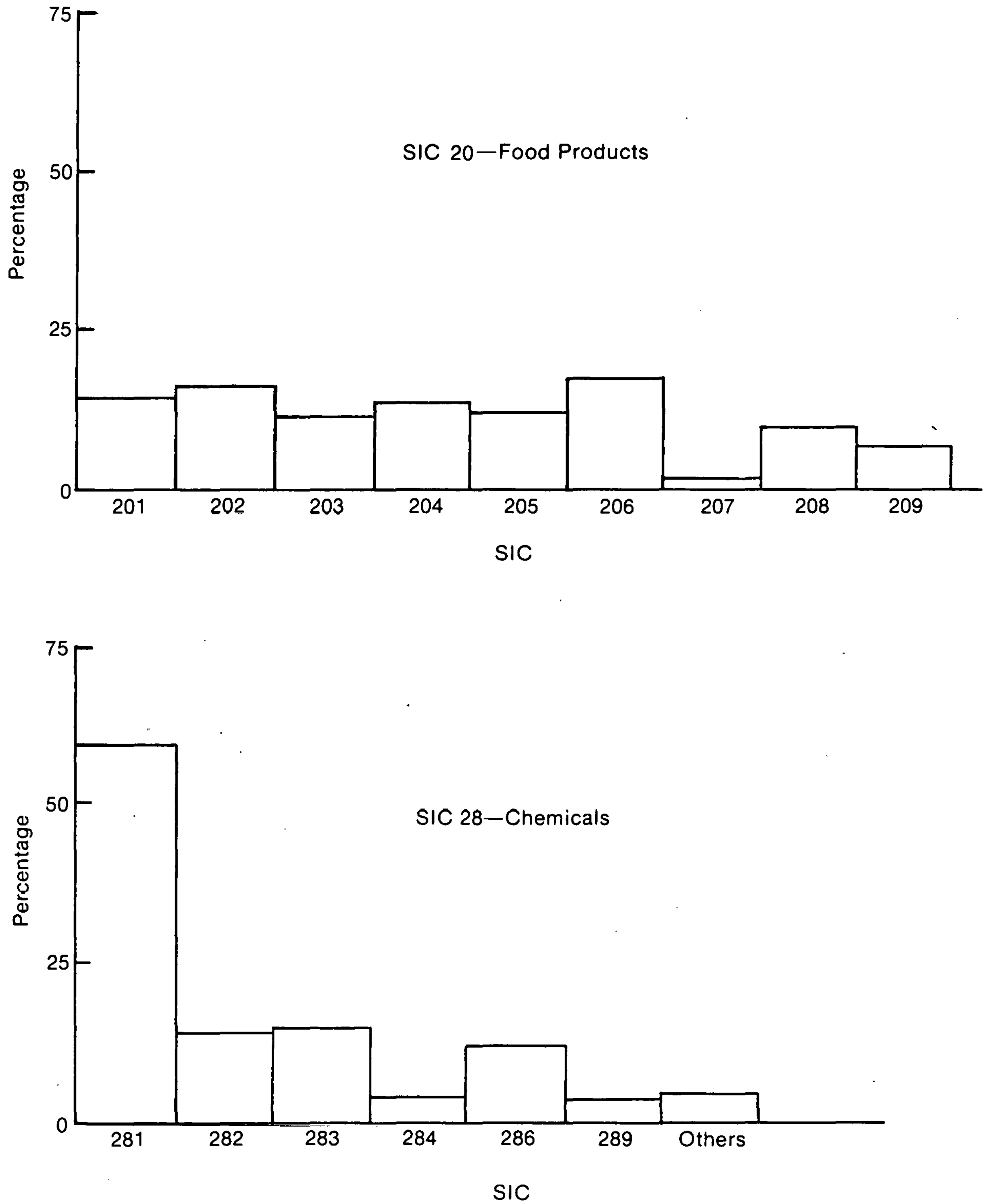
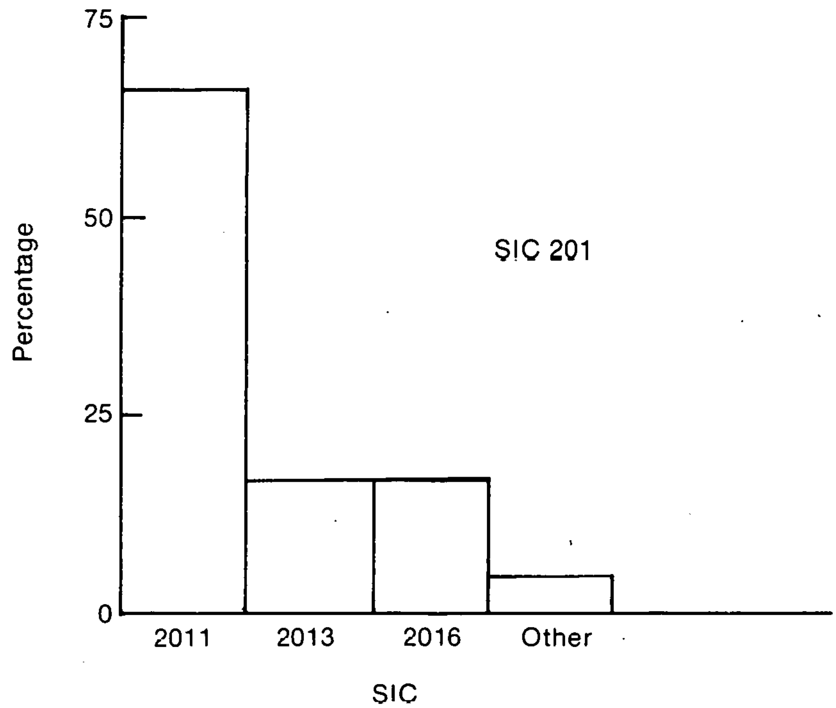


Figure 10-1. Illustration of Disaggregation of 2-Digit to 3-Digit SIC for Pennsylvania



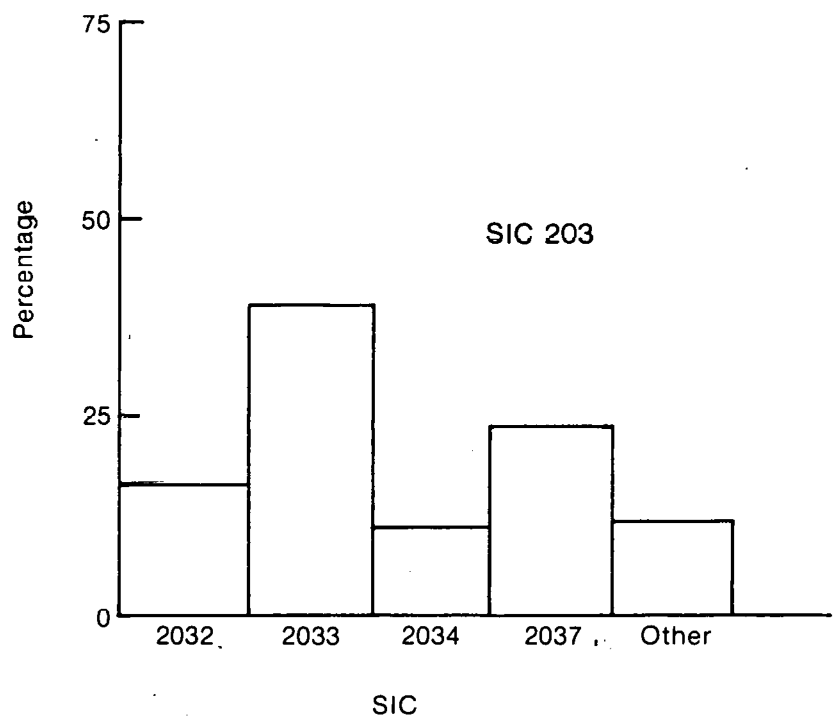


Figure 10-1. Illustration of Disaggregation of 2-Digit to 3-Digit SIC for Pennsylvania (concluded)

Table 10-4. ILLUSTRATIVE END-USE DATA SHOWING PERCENTAGE OF 2-DIGIT TOTAL ENERGY CONSUMPTION: PENNSYLVANIA (SIC 20)

End Use	Standard Industrial Classification																						
	2011	2013	2016	2022	2023	2026	2032	2033	2034	2037	2046	2048	2051	2062	2063	2075	2077	2079	2082	2085	2086	20XX[a]	Total
Hot Water (°F)																							
< 212	1.14	0.27	0.92	0.21				0.91	0.07	0.58			0.16	1.60		0.07		0.03	1.54		1.37	2.54	11.41
Steam (°F)																							
212-300	2.22	0.53		1.71	1.66	2.22	1.73	3.03	0.11	1.70	4.62	0.26	1.30	2.09	6.25	0.68		0.28	0.72	0.54		9.05	40.70
301-400									0.15								0.52	0.22		0.26		0.33	1.48
401-500																							
501-600																							
>600																							
Hot Air (°F)																							
<150	0.07	0.02	0.02								0.03		0.44		2.74							0.95	4.27
151-200				0.47	0.69	0.02			0.82		0.22											0.63	2.85
201-300											0.78					0.21			1.01			0.57	2.57
301-400												1.93								0.08		0.57	2.58
401-500													1.93									0.55	2.48
501-600									0.15													0.04	0.19
601-700																							
701-800																							
801-900																							
901-1000														0.62								0.18	0.80
Other	1.90	0.44	0.32	0.64	0.55	2.27	0.58	1.19	0.12	0.76	2.58	0.09	5.29	1.74	3.03	0.27	0.17	0.17	1.02	0.27	0.45	6.82	30.67
Total	5.33	1.26	1.26	3.03	2.90	4.51	2.31	5.13	1.42	3.04	8.23	2.28	9.12	6.05	12.02	1.23	0.69	0.70	4.29	1.15	1.82	22.23	100.00

[a]Refers to all other 4-digit groups within SIC 20.

Table 10-5. **ILLUSTRATIVE END-USE DATA SHOWING PERCENTAGE OF 2-DIGIT TOTAL ENERGY CONSUMPTION: PENNSYLVANIA** (SIC 28)

	Standard Industrial Classification														
End Use	2812	2813	2816	2819	2821	2822	2823	2824	2834	2841	2865	2869	2899	28XX[a]	Total
Hot Water (°F)															
< 212						0.10	0.09	0.17						0.04	0.40
Steam (°F)															
213-300	0.43	0.24	0.48	5.16	1.58	0.67	2.63	1.76	2.21	1.96	0.26	0.89		1.88	20.16
301-400	1.63	0.16	0.09		2.29						1.25	0.22	1.22	0.71	7.57
401-500					1.78						0.17	0.24	0.12	0.24	2.55
501-600					0.18			0.81				0.48		0.15	1.62
>600															
Hot Air (°F)															
<150		1.01	0.65	0.03	1.80	0.16	0.23	0.32			0.26	10.92	0.04	1.59	17.01
151-200				0.23		1.86	0.03	1.57	1.70			0.34		0.59	6.32
201-300						0.10									0.10
301-400								0.41		0.71				0.12	1.24
401-500					0.83			1.05		0.05	0.06			0.21	2.20
501-600								0.97						0.10	1.07
601-700	0.44													0.05	0.49
701-800															
801-900											0.21	0.66		0.09	0.96
901-1000															
>1000	0.58	0.38	1.61							0.35	8.82		1.21	12.95	
Other	2.67	0.58	0.34	3.57	4.92	0.57	2.26	3.38	1.09	0.66	1.06	1.44	0.46	2.36	25.36
Total	5.17	2.58	1.94	10.60	13.38	3.46	5.24	10.44	5.00	3.38	3.62	24.01	1.84	9.34	100.00

[a]Refers to all other 4-digit groups within SIC 28.

Table 10-6. PURCHASED FUEL BY 4-DIGIT SIC FOR PENNSYLVANIA 1976

(Billion Btu)

	Standard Industrial Classification																						
End Use	2011	2013	2016	2022	2023	2026	2032	2033	2034	2037	2046	2048	2051	2062	2063	2075	2077	2079	2082	2085	2086	20XX	Total
Hot Water (°F)																							
< 212	364	86	294	67				290	22	185			51	510		22		10	491		437	810	3,639
212-300	708	169		545	530	708	552	967	35	542	1,474	83	415	667	1,994	217		89	230	172		2,887	12,984
301-400									48								166	70		83		105	472
401-500																							
501-600																							
601-700																							
701-800																							
Hot Air																							
< 150	22	6	6								10		140		874							303	1,361
151-200				150	220	6			262		70											201	909
201-300											249					67			322			182	820
301-400												616								26		182	824
401-500													616									175	791
501-600									48													13	61
601-700																							
701-800																							
801-900																							
901-1000																							
>1000														198								57	255
Other	606	141	102	205	175	725	185	379	38	243	822	28	1,687	555	966	86	54	54	326	86	144	2,177	9,784
Total	1,700	402	402	967	925	1,439	737	1,636	453	970	2,625	727	2,909	1,930	3,834	392	220	223	1,369	367	581	7,092	31,900

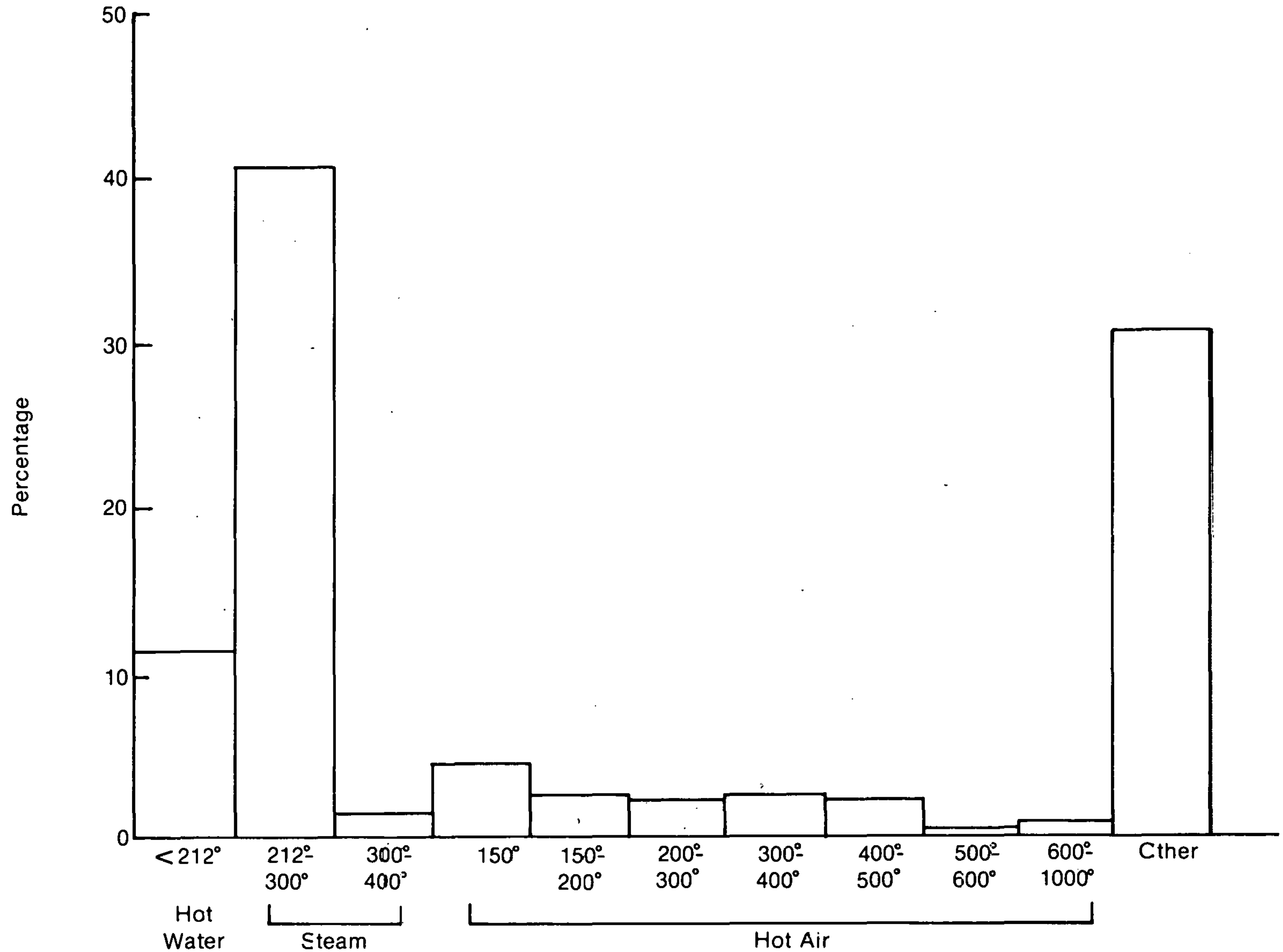


Figure 10-2. Energy Consumption by End Use for SIC 20 in Pennsylvania

Table 10-7. ENERGY REQUIREMENTS BY 2-DIGIT SIC AND END USE—1990: ALABAMA

(Billion Btu)

	SIC Group								
End Use	20	22	24	26	28	30	32	33	Total
Hot Water (°F) <212	584		45		556		133		1,318
Steam (°F)									
212-300	1,827	4,180	1,393	56,306	18,299		179		82,184
301-400	409		47		5,958	1,871	946	606	9,837
401-500					2,971				2,971
501-600			103		1,628				1,731
601-700									
701-800									
Hot Air (°F)									
<150	38	1,665	366		6,090		61	266	8,486
151-200	58	329	1,072		2,709		15		4,183
201-300	281	913	340		162	2,391		7	4,094
301-400	84	306	363		695		2,234	116	3,798
401-500	177				3,079		1,438	783	5,477
501-600	2				1,598		57	2,219	3,876
601-700					517			10,532	11,049
701-800									2,778
801-900									
901-1000									4,405
>1000				10,797	3,002		30,744	42,346	86,889
Other	1,290	3,407	2,931	43,517	29,916	698	2,323	4,022	88,104
Total	4,750	10,800	6,660	110,620	77,180	4,960	38,130	68,080	321,180

Table 10-8. ENERGY REQUIREMENTS BY 2-DIGIT SIC AND END USE—1990: CALIFORNIA

(Billion Btu)

End Use	SIC Group 20	24	26	28	29	32	33	34	37	Total
Hot Water (°F) <212	8,901	1,216		45		41			387	10,590
Steam (°F)										
212-300	32,434	748	15,850	9,610		506	2,900			62,048
301-400	2,121	307		3,719	73	1,457	496		746	8,919
401-500				624	10,115					10,739
501-600		281		429						710
601-700										
701-800				1,186						1,186
Hot Air (°F)										
<150	6,586	960		8,926	45	217	60	823	3,036	20,653
151-200	2,229	2,804		1,192	10,650	413	20		2,884	20,192
201-300	1,330	182		11		1,344	1,484	1,372	1,942	7,665
301-400	525	993		1,175	569	6,429	194			9,885
401-500	561			356	625	2,749	650			4,941
501-600	316			468		21	1,697			2,502
601-700				284			8,649			8,933
701-800					18,248		576			18,824
801-900				568	6,844			3,691		11,103
901-1000	769				982		2,392		601	4,744
>1000			3,412	15,932		86,337	32,114	4,525	3,536	146,856
Other	16,128	2,809	19,208	10,155	7,669	3,846	1,288	1,249	1,218	63,570
Total	71,900	10,300	38,470	55,680	55,820	103,360	49,620	14,560	14,350	414,060

Table 10-9. ENERGY REQUIREMENTS BY 2-DIGIT SIC AND END USE—1990: ILLINOIS

(Billion Btu)

	SIC Group							
End Use	20	26	28	32	33	34	35	Total
Hot Water (°F) <212	4,233		171	707				5,111
Steam (°F)								
212-300	24,347	11,348	15,623	733		3,189		55,240
301-400	4,769	345	5,424	799	1,925		17,629	30,891
401-500			1,523					1,523
501-600			874					874
601-700								
701-800			1,397					1,397
Hot Air (°F)								
<150	740		16,308	241	315	3,006		20,610
151-200	1,067		3,388	518				4,973
201-300	3,572		45	681	18	5,016		9,332
301-400	5,991		1,892	1,312	280			9,475
401-500	568		5,109	2,582	945			9,204
501-600	25		487	20	2,643			3,175
601-700			198		33,851			34,049
701-800					3,256			3,256
801-900			865			4,057		4,922
901-1000	111				5,741			5,852
>1000		1,109	24,183	41,079	112,194	16,548		195,113
Other	16,277	10,018	12,613	2,568	13,862	2,074	7,031	64,443
Total	61,700	22,820	90,100	51,240	175,030	33,890	24,660	459,440

Table 10-10. ENERGY REQUIREMENTS BY 2-DIGIT SIC AND END USE—1990: INDIANA

(Billion Btu)

	SIC Group							
End Use	20	28	32	33	34	35	37	Total
Hot Water (°F) < 212	2,242		42				914	3,198
Steam (°F)								
212-300	8,005	6,191	531		1,950			16,677
301-400	1,184	1,498	667	3,353		6,241	1,760	14,703
401-500		113						113
501-600		93						93
601-700								
701-800		803						803
Hot Air (°F)								
<150	77	3,116	135	162	1,354		7,161	12,005
151-200	867	1,460	302				6,802	9,431
201-300	1,289		542		2,257		4,575	8,663
301-400	1,406	6	2,870	189				4,471
401-500	127	12	1,969	649				2,757
501-600	28		10	1,947				1,985
601-700		206		58,327				58,533
701-800				1,758				1,758
801-900		170			2,482			2,652
901-1000				2,434			1,418	3,852
>1000		9,522	40,951	182,148	7,445		8,338	248,404
Other	4,975	6,660	4,061	19,443	382	2,539	2,872	40,932
Total	20,200	29,850	52,080	270,410	15,870	8,780	33,840	431,030

Table 10-11. ENERGY REQUIREMENTS BY 2-DIGIT SIC AND END USE—1990: LOUISIANA

(Billion Btu)

	SIC Group						
End Use	20	26	28	29	32	33	Total
Hot Water (°F) < 212	1,850		227		35		2,112
Steam (°F)							
212-300	10,821	30,493	69,178		473		110,965
301-400	694		36,708		294	558	38,254
401-500			8,477	21,535		182	30,194
501-600			8,780				8,780
601-700							
701-800			13,624				13,624
Hot Air (°F)							
<150	2,992		194,970		75	42	198,079
151-200	100		11,580	22,681	176		34,537
201-300	272		76		203		551
301-400	179		378		1,370	91	2,018
401-500			2,498	1,332	961	449	5,240
501-600			757			1,286	2,043
601-700			2,649			10,933	13,582
701-800				38,853		394	39,247
801-900			14,608	14,573			29,181
901-1000	675			2,097		910	3,682
>1000		8,485	280,420		19,600	35,431	343,936
Other	6,257	49,872	111,940	14,769	3,513	10,394	196,745
Total	23,840	88,850	756,870	115,840	26,700	60,670	1,072,770

Table 10-12. ENERGY REQUIREMENTS BY 2-DIGIT SIC AND END USE—1990: MICHIGAN

(Billion Btu)

	SIC Group								
End Use	20	26	28	32	33	34	35	37	Total
Hot Water (°F) <212	2,604		131	33				3,290	6,058
Steam (°F)									
212-300	7,974	18,464	9,594	435		1,568			38,035
301-400	568	80	6,782	767	1,451		8,768	6,336	24,752
401-500			1,458						1,458
501-600			1,341						1,341
601-700									
701-800									
Hot Air (°F)									
<150	151	88	14,303		53	3,432		25,783	43,810
151-200	715		2,060	11				24,492	27,278
201-300	741		46	539		5,726		16,474	23,526
301-400	763		190	4,605	80				5,638
401-500	416		876	1,845	2,423				5,560
501-600	50		419		7,282				7,751
601-700			412		20,722				21,134
701-800					506				506
801-900			896			1,997			2,893
901-1000								5,106	5,106
>1000		3,325	11,877	41,182	86,361	18,895		29,805	191,445
Other	5,938	17,914	15,016	5,013	14,252	1,671	3,442	10,564	73,810
Total	19,920	39,870	65,400	54,430	133,130	33,290	12,210	121,850	480,100

Table 10-13. ENERGY REQUIREMENTS BY 2-DIGIT SIC AND END USE—1990: MISSOURI

(Billion Btu)

	SIC Group						
End Use	20	28	32	33	34	37	Total
Hot Water (°F) <212	2,990		54			313	3,357
Steam (°F)							
212-300	5,880	4,506	700		2,039		13,125
301-400	700	2,432	450			602	4,184
401-500		201		189			390
501-600		65					65
601-700							
701-800		572					572
Hot Air (°F)							
<150	79	2,383	49	24		2,450	4,985
151-200	472	517				2,328	3,317
201-300	1,142		136			1,566	2,844
301-400	1,063	348	4,486				5,897
401-500	273	35	2,127	463			2,898
501-600			43	1,389			1,432
601-700		174					174
701-800				206			206
801-900					2,595		2,595
901-1000		119		413		485	1,017
>1000		8,356	41,935	10,261		2,853	63,405
Other	3,461	5,162	4,270	8,785	686	983	23,347
Total	16,060	24,870	54,250	21,730	5,320	11,580	133,810

Table 10-14. ENERGY REQUIREMENTS BY 2-DIGIT SIC AND END USE—1990: NEW JERSEY

(Billion Btu)

End Use	SIC Group										
	20	22	26	28	29	30	32	33	34	35	Total
Hot Water (°F) <212	3,056			122			573				3,751
Steam (°F)											
212-300	6,418	1,337	14,306	19,280		130	433		948		42,852
301-400	1,286			6,942		255	2,031	141		4,676	15,331
401-500				1,769		819		87			2,675
501-600				1,457							1,457
601-700											
701-800											
Hot Air (°F)											
<150	289	1,902		27,779		1,159	433	31	949		32,542
151-200	390	376		6,030			1,038				7,834
201-300	966	979		33		2,977	1,719	4	1,582		8,260
301-400	129	493		1,869			783	28			3,302
401-500	615			968			3,216	19			4,818
501-600	53			367				17			437
601-700				312				443			755
701-800								338			338
801-900				1,991					1,207		3,198
901-1000	28							640			668
>1000			2,662	22,806			50,517	6,439	5,220		87,644
Other	5,680	1,843	14,502	19,525		930	2,937	3,683	754	1,744	51,798
Total	18,910	6,930	31,470	111,250	N.A.[a]	6,270	63,680	12,070	10,660	6,420	267,660[a]

[a]1990 energy requirements for SIC 29 unavailable.

Table 10-15. ENERGY REQUIREMENTS BY 2-DIGIT SIC AND END USE—1990: NEW YORK

(Billion Btu)

End Use	SIC Group									Total
	20	26	28	32	33	34	35	37	38	
Hot Water (°F) < 212	2,890		46	20				356	11,009	14,321
Steam (°F)										
212-300	9,320	14,793	11,244	266		2,183			2,307	40,113
301-400	191		2,995	519	1,065		11,070	685		16,525
401-500			450		43					493
501-600			1,012							1,012
601-700										
701-800										
Hot Air (°F)										
<150	707		8,699	59	102	667		2,787	1,634	14,655
151-200	1,003		2,387	148			418	2,793	506	7,255
201-300	637		15	444	11	1,112		1,781	3,505	7,505
301-400	299		56	2,067	102					2,524
401-500			419	1,180	409					2,008
501-600	114		695		1,118					1,927
601-700			542		9,071					9,613
701-800					1,065					1,065
801-900			486		2,065	2,102				4,653
901-1000	156							552		708
>1000		2,391	3,275	22,128	34,257	3,670		3,245		73,966
Other	5,713	12,556	13,789	6,029	4,462	246	3,712	971	7,139	54,617
Total	21,030	29,740	51,110	32,860	53,770	9,980	15,200	13,170	26,100	252,960

Table 10-16. ENERGY REQUIREMENTS BY 2-DIGIT SIC AND END USE—1990: OHIO

(Billion Btu)

	SIC Group								
End Use	20	26	28	29	32	33	34	35	Total
Hot Water (°F) <212	3,424		148		83				3,655
Steam (°F)									
212-300	11,690	18,397	17,734		1,153		1,783		50,757
301-400	1,689	168	8,081	173	2,285	4,194		15,032	31,622
401-500			991	3,029					4,020
501-600			565						565
601-700									
701-800			2,051						2,051
Hot Air (°F)			—						
<150	510		9,219	105	374	102	4,120		14,430
151-200	886		2,198	3,191	530				6,805
201-300	1,166		35		1,900		6,872		9,973
301-400	724		1,408	1,288	3,832	239			7,491
401-500	502		912	187	5,172	2,080			8,853
501-600	63		417		156	6,275			6,911
601-700			721			72,806			73,527
701-800				5,465		750			6,215
801-900				2,050			1,810		3,860
901-1000	76		382	294		1,637			2,389
>1000		3,344	20,437		80,536	228,920	22,682		355,919
Other	5,410	18,181	21,591	3,708	7,829	24,007	1,493	5,608	87,827
Total	26,140	40,090	86,890	19,490	103,850	341,010	33,760	20,640	676,870

Table 10-17. ENERGY REQUIREMENTS BY 2-DIGIT SIC AND END USE—1990: OREGON

(Billion Btu)

End Use	SIC Group 20	24	26	28	32	Total
Hot Water (°F) <212	784	463			32	1,279
Steam (°F)						
212-300	3,385	3,684	15,788	141	426	23,424
301-400	206	111		1,377	187	1,881
401-500				167		167
501-600		245		58		303
601-700						
701-800						
Hot Air (°F)						
<150	37	742		1,404		2,183
151-200	372	2,138		42		2,552
201-300	90	902				992
301-400	109	864			761	1,734
401-500	102			8	1,202	1,312
501-600	47					47
601-700						
701-800						
801-900				106		106
901-1000						
>1000			2,745	1,121	4,698	8,564
Other	1,988	6,651	14,697	1,046	2,544	26,916
Total	7,120	15,790	33,230	5,470	9,850	71,460

Table 10-18. ENERGY REQUIREMENTS BY 2-DIGIT SIC AND END USE—1990: PENNSYLVANIA

(Billion Btu)

End Use	SIC Group 20	26	28	29	32	33	34	Total
Hot Water (°F) < 212	3,204		214		55			3,473
Steam (°F)								
212-300	11,429	23,915	10,776		711		3,095	49,926
301-400	416	202	4,046	92	1,118	4,736		10,610
401-500			1,363	2,731		194		4,288
501-600			866					866
601-700								
701-800								
Hot Air (°F)								
<150	1,199		9,092	56	240		2,262	12,849
151-200	800		3,378	2,876	360			7,414
201-300	722		53		951		3,773	5,499
301-400	724		663	681	5,431	272		7,771
401-500	696		1,176	169	2,873	970		5,884
501-600	53		572		46	2,950		3,621
601-700			262			82,178		82,440
701-800				4,927				4,927
801-900			513	1,848			3,940	6,301
901-1000	224			265		311		800
>1000		3,175	6,922		75,716	260,430	12,452	358,695
Other	8,613	19,748	13,554	2,735	4,869	36,139	1,798	87,456
Total	28,080	47,040	53,450	16,380	92,370	388,180	27,320	652,820

Table 10-19. ENERGY REQUIREMENTS BY 2-DIGIT SIC AND END USE—1990: TEXAS

(Billion Btu)

End Use	SIC Group 20	26	28	29	32	33	Total
Hot Water (° F) <212	5,058		597		81		5,736
Steam (° F)							
212-300	14,791	23,003	83,192		1,138		122,124
301-400	2,361		63,190		1,436	837	67,824
401-500			15,922	73,258		429	89,609
501-600			15,126				15,126
601-700							
701-800			4,180				4,180
Hot Air (° F)							
<150	626		320,727		1,503	686	323,542
151-200	514		18,708	77,159	176		96,557
201-300	1,839		199		948		2,986
301-400	1,430		995		10,564	4,891	17,880
401-500	510		5,772	4,532	4,212	590	15,616
501-600	54		2,090		81	1,780	4,005
601-700			2,786			14,575	17,361
701-800				131,383			131,383
801-900			23,584	49,574			73,518
901-1000	131			7,133		193	7,477
>1000		4,871	299,332		109,048	65,326	478,577
Other	11,326	31,306	138,720	51,031	6,243	17,943	256,569
Total	38,640	59,180	995,120	394,070	135,430	107,250	1,729,690

Table 10-20. ENERGY REQUIREMENTS BY 2-DIGIT SIC AND END USE—1990: WEST VIRGINIA

(Billion Btu)

	SIC Group			
End Use	28	32	33	Total
Hot Water (°F) <212		12		12
Steam (°F)				
212-300	7,109	161		7,270
301-400	4,429	1,069		5,498
401-500	860			860
501-600	975			975
601-700				
701-800				
Hot Air (°F)				
<150	24,257			24,257
151-200	874	113		987
201-300		932		932
301-400	7	279	42	328
401-500	129	1,514	37	1,680
501-600			110	110
601-700	330		11,799	12,129
701-800				
801-900	1,784			1,784
901-1000			10	10
>1000	20,767	18,645	35,630	75,042
Other	10,139	1,345	4,532	16,016
Total	71,660	24,070	52,160	147,890

Table 10-21. ENERGY REQUIREMENTS BY 2-DIGIT SIC AND END USE—1990: WISCONSIN

(Billion Btu)

End Use	SIC Group 20	26	28	32	33	34	35	37	Total
Hot Water (°F) <212	5,665		11	15				278	5,969
Steam (°F)									
212-300	13,291	49,611	1,803	206		583			65,494
301-400	405		1,320	137	75		8,921	535	11,393
401-500			189						189
501-600			48						48
601-700									
701-800									
Hot Air (°F)									
<150	103		464		21	2,217		2,175	4,980
151-200	1,901		124	2				2,066	4,093
201-300	1,370		3	146		3,699		1,390	6,608
301-400	345		553	368	4				1,270
401-500	189		104	750	1,843				2,886
501-600	56		32		5,528				5,616
601-700					1,311				1,311
701-800									
801-900			27			742			769
901-1000					595			431	1,026
>1000		6,871	283	3,077	11,117	12,204		2,533	36,085
Other	9,845	34,398	1,479	1,399	446	935	3,559	872	52,933
Total	33,170	90,880	6,440	6,100	20,940	20,380	12,480	10,280	200,670

Table 10-22. STATE ENERGY REQUIREMENTS BY END USE—1980

(Trillion Btu)

	NJ	NY	PA	AL	MI	IL	IN	OH	CA	WV	LA	MO	OR	TX	WI	Total
Hot Water (°F) <212	3.75	14.32	3.47	1.32	6.06	5.11	3.20	3.66	10.59	0.01	2.11	3.36	1.28	5.74	5.97	69.95
Steam (°F)																
212-300	42.85	40.11	49.93	82.18	38.04	55.24	16.68	50.76	62.05	7.27	110.97	13.13	23.42	122.12	65.49	780.24
301-400	15.33	16.53	10.61	9.84	24.75	30.89	14.70	31.62	8.92	5.50	38.25	4.18	1.88	67.82	11.39	292.21
401-500	2.68	0.49	4.29	2.97	1.46	1.52	0.11	4.02	10.74	0.86	30.19	0.39	0.17	89.61	0.19	149.69
501-600	1.46	1.01	0.87	1.73	1.34	0.87	0.09	0.57	0.71	0.98	8.78	0.07	0.30	15.13	0.05	33.96
601-700																
701-800						1.40	0.80	2.05	1.19		13.62	0.57		4.18		23.81
Hot Air (°F)																
<150	32.54	14.66	12.85	8.49	43.81	20.61	12.01	14.43	20.65	24.26	198.08	4.99	3.19	323.54	4.00	738.08
150-200	7.82	7.06	7.41	4.18	27.28	4.97	9.43	6.81	20.19	0.99	34.54	3.32	2.55	96.56	4.09	237.41
201-300	8.26	7.51	5.50	4.09	23.53	9.33	9.66	0.07	7.07	0.93	0.55	2.84	0.99	2.99	6.61	99.43
301-400	3.30	2.52	7.77	3.80	5.64	9.48	4.47	7.49	9.89	0.33	2.02	5.90	1.73	17.88	1.27	83.49
401-500	4.82	2.01	5.88	5.48	5.56	8.20	2.76	8.85	4.94	1.68	5.24	2.90	1.31	15.62	2.89	79.14
501-600	0.44	1.93	3.62	3.88	7.76	3.18	1.99	6.91	2.50	0.11	2.04	1.43	0.05	4.01	5.62	45.46
601-700	0.76	9.61	82.44	11.05	21.13	34.05	58.53	73.53	8.93	12.13	13.58	0.17		17.36	1.31	344.58
701-800	0.34	1.07	4.93	2.78	0.51	3.26	1.76	6.22	18.82		39.25	0.21		131.38		210.53
801-900	3.20	4.65	6.30		2.89	4.92	2.65	3.86	11.10	1.78	29.18	2.60	0.11	73.16	0.77	147.17
901-1000	0.67	0.71	0.80	4.41	5.11	5.86	3.85	2.39	4.74	0.01	3.68	1.02		7.46	1.03	41.74
>1000	87.64	73.97	358.70	86.89	191.44	195.11	248.40	355.92	146.86	75.04	343.94	63.41	8.56	478.58	36.09	2750.55
Other	51.79	54.60	87.45	88.09	73.80	64.44	40.94	87.81	63.57	160.1	196.75	23.32	26.93	256.55	52.92	1184.97
Total	267.66	252.96	652.82	321.18	480.10	459.44	431.03	676.87	414.06	147.89	1072.77	133.81	71.46	1729.69	200.67	7312.41

Table 10-23. ENERGY REQUIREMENTS BY STATE AND END USE—1990

(Percentage of State Purchased Energy)

	AL	CA	IL	IN	LA	MI	MO	NJ	NY	OH	OR	PA	TX	WV	WI	Total
Hot Water (°F) <212	0.41	2.56	1.11	0.74	0.19	1.26	2.51	1.40	5.66	0.54	1.79	0.53	0.33	0.01	2.98	0.96
Steam (°F)																
212-300	25.59	14.99	12.02	3.87	10.34	7.92	9.81	16.01	15.86	7.50	32.77	7.65	7.06	4.92	32.64	10.67
301-400	3.06	2.15	6.72	3.41	3.57	5.16	3.12	5.73	6.53	4.67	2.63	1.63	3.92	3.72	5.68	4.00
401-500	0.92	2.59	0.33	0.03	2.81	0.30	0.29	1.00	0.19	0.59	0.24	0.66	5.18	0.58	0.09	2.05
501-600	0.54	0.17	0.19	0.02	0.82	0.28	0.05	0.55	0.40	0.08	0.42	0.13	0.87	0.66	0.02	0.46
601-700																
701-800		0.29	0.30	0.19	1.27		0.43			0.30			0.24			0.33
Hot Air (°F)																
<150	2.64	4.99	4.49	2.79	18.46	9.13	3.73	12.16	5.80	2.13	3.05	1.97	18.71	16.40	2.48	10.09
150-200	1.30	4.88	1.08	2.19	3.22	5.68	2.48	2.93	2.87	1.01	3.57	1.09	5.58	0.67	2.04	3.25
201-300	1.27	1.85	2.03	2.01	0.05	4.90	2.12	3.09	2.97	1.47	1.39	0.84	0.17	0.63	3.29	1.36
301-400	1.18	2.39	2.06	1.04	0.19	1.17	4.41	1.23	1.00	1.11	2.42	1.19	1.03	0.22	0.63	1.14
401-500	1.71	1.19	2.00	0.64	0.49	1.16	2.17	1.80	0.79	1.31	1.83	0.80	0.90	1.14	1.44	1.08
501-600	1.21	0.60	0.69	0.46	0.19	1.61	1.07	0.16	0.76	1.02	0.07	0.55	0.23	0.07	2.80	0.62
601-700	3.44	2.16	7.41	13.58	1.27	4.40	0.13	0.28	3.80	10.86		12.63	1.00	8.20	0.65	4.71
701-800	0.87	4.54	0.71	0.41	3.66	0.11	0.16	0.13	0.42	0.92		0.76	7.60			2.88
801-900		2.68	1.07	0.61	2.72	0.60	1.94	1.20	1.84	0.57	0.15	0.97	4.23	1.20	0.38	2.01
901-1000	1.37	1.14	1.28	0.89	0.34	1.06	0.76	0.25	0.28	0.35		0.12	0.43	0.01	0.51	0.57
>1000	27.05	35.47	42.47	57.63	32.06	39.88	47.39	32.74	29.24	52.58	11.98	54.95	27.67	50.74	17.98	37.61
Other	27.44	15.36	14.04	9.49	18.35	15.38	17.43	19.34	21.59	12.99	37.69	13.43	14.85	10.83	26.39	16.21

SECTION 11.0

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APPENDIX A

A REVIEW OF SELECTED DATA BASES

APPENDIX A

A.1 DOE'S END-USE ENERGY CONSUMPTION DATA BASE

The End-Use Energy Consumption Data Base (ECDB) was developed for DOE by various contractors and is documented in a series of contractor reports (Energy and Environmental Analysis, Inc. 1978). The numbers in the data base were compiled from secondary sources. The data base contains consumption estimates (not actual) for 1967, 1971, and 1974 at the national, census division, and state levels.

The industrial data are disaggregated at the 2-digit SIC level for agriculture, mining, and manufacturing. The manufacturing sector is represented by 24 groups, mostly at the 2-digit level (Table A-1). Only two industrial groups—Pulp and Paper, Primary Metals—are disaggregated further. The data base represents about 10 major fuel types.

Table A-1. LIST OF MANUFACTURING INDUSTRIES REPRESENTED IN ECDB

Food and Kindred Products	Rubbberr and Miscellaneous Plastics
Tobacco Manufacturers	Leather and Leather Products
Textile Mills	Stone, Clay, Glass, Concrete (total)
Apparel	Primary Metals
Lumber	Iron and Steel
Furniture	Aluminum
Paper (total)	Other Primary Metals
Pulp/Paper/Paperboard/Building Paper and Board Mills	Fabricated Metal Products
	Machinery (except electrical)
Other Paper Products	Electrical and Electronic Machinery
Printing and Publishing	Transportation Equipment, etc.
Chemicals (total)	Miscellaneous Manufacturing Industries
Petroleum Refining	

The end uses represented in the data base are:

- process steam,
- direct heat,
  - total,
  - below 600° F,
  - 600°-1000° F,
  - 1000°-1500° F,
  - above 1500° F, and
  - nsk (not specifically known),
- raw material,
- electricity generation,
- coke production,
- machine drive, and
- electrolyte processes.

The ECDB thoroughly investigates the energy consumed in some SIC industries documenting in separate volumes analyses of such high energy users as chemicals; petroleum refining; steel; stone, clay, and glass; paper; metal mining; and agriculture. The ECDB does not provide the same level of detail for energy consumption in some of the less energy-intensive industries, such as apparel manufacture (SIC 23).

The ECDB expresses all fuel consumption in terms of British thermal units (Btu). Secondary fuels have Btu values reflecting their actual values instead of the energy content of their inputs. Thus, the ECDB converts 1 kWh of electricity consumption into 3,412 Btu of energy consumption, rather than the 10,500 Btu of fossil fuel used to make that electricity.

The ECDB has been used to support a number of DOE studies; however, no information is available regarding any validation or verification.

A.2 INDUSTRIAL SECTOR TECHNOLOGY USE MODEL

The Industrial Sector Technology Use Model (ISTUM) was developed for DOE by Energy and Environmental Analysis, Inc. Designed to analyze and project the penetration of different technologies in the industrial sector, the model has a detailed data base on various cost elements of different energy-using technologies. This data base is used, together with information on energy demands by industry type, end use, and fuel prices, to calculate market shares for different technologies.

The ISTUM data base includes over 100 different technologies classified as conventional, fossil energy, conservation, cogeneration, solar, and geothermal, and has been used for evaluating the commercial viability of energy technologies in the industrial sector.

Figure A-1 shows a schematic of the model structure. The key characteristics and assumptions of the model are summarized here.

- Technology selection is based on its relative cost: for each application, the technology that has the least cost is selected. Calculating least-cost technologies is based on probabilistic cost functions that include not only the direct capital, fuel, maintenance, and operating costs but also reliability and ability to meet environmental regulations.
- An attempt was made to represent the decision-making behavior in the industrial sector. Energy users are disaggregated to the maximum extent feasible with available data, using characteristics likely to have the greatest impact on the costs of alternative technologies—type of energy, size of combustor, load factor, location, etc.

The model logic follows:

- Cost frequency distributions for each cost element are aggregated to obtain the cost of each technology on a comparable basis.
- The "nominal" market share of each technology is calculated by determining the applications for which it has the lowest cost.
- The "actual" market share is calculated from the nominal by incorporating a "behavioral lag" model that allows for the time-phasing of new technology adoption.

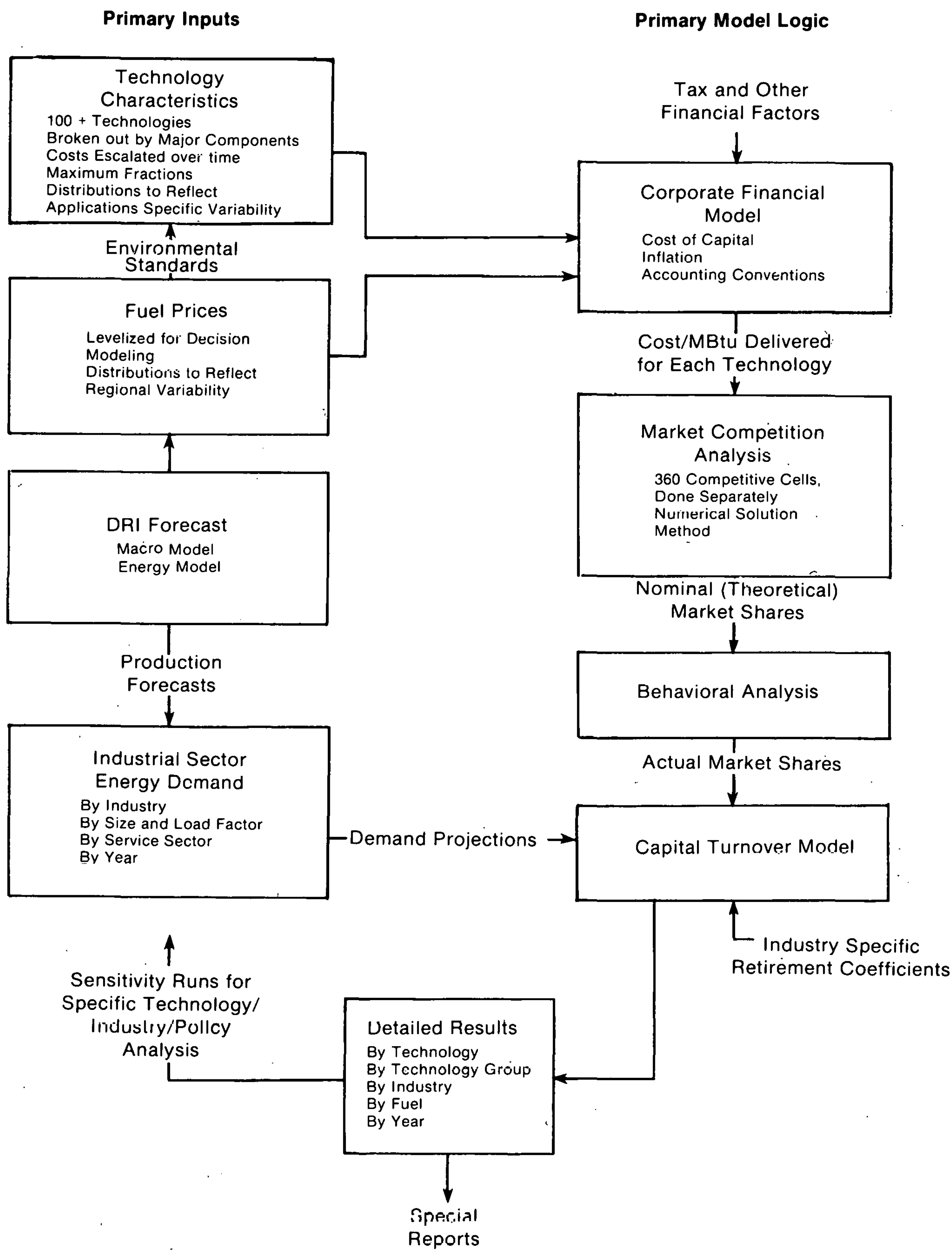

Figure A-1. Schematic of Industrial Sector Technology Use Model

- A "capital turnover model" calculates the demand due to retirement of capital stock of energy-using equipment.

To perform these calculations, an industrial data base has been developed at the following disaggregated level:

- industry type—26 SICs
- service sector or type of energy—23 types
- size of combustor
- combustor load factor
- year—1980, 1985, 1995, 2000.

The cornerstone of the ISTUM is its data base on energy use technologies and energy demands. It essentially represents a national probability distribution of the total costs of each technology disaggregated into seven major elements.

The energy demand data was derived from ECDB. ECDB's energy consumption was allocated into industry classifications used in ISTUM. Fuel consumption quantities were also translated into "service demand" quantities. A service demand is the amount of useful energy product required by an energy-using industrial process. ISTUM allocates energy demand to 23 service sectors, 13 of which are actually computed to determine which technologies will "win" the service demand. Service sectors analyzed in ISTUM are:

- steam*
- direct heat (intermediate)*
- direct heat (dirty)*
- indirect heat (coal capable)*
- machine drive*
- electrolytic*
- liquid feedstock
- natural gas feedstock
- LPG feedstock
- metallurgical coal
- miscellaneous energy and lubes
- space heat*
- indirect heat (not coal capable)*
- calcining*
- glass melting*
- brick and clay firing*
- ironmaking*
- steelmaking
- steel reheating*
- internal generation
- captive electricity
- captive direct heat
- coke consumption.

ISTUM divides energy demand among 26 SICs, of which 22 are at the 2-, 3-, or 4-digit level, depending on energy consumption patterns. The other four classifications represent mining and agriculture energy uses.

The third set of data in the model is fuel prices. Fuel price inputs were obtained from the Data Resources, Inc. (DRI) macroeconomic model. They correspond to the solution of DRI's "trend-long" macroforecast for the U.S. economy and a coordinated solution of

*Indicates service sectors in which technologies compete in ISTUM. The remaining keep an accurate account of the total industrial energy consumption.

the DRI energy model that actually forecast the basic fuel prices. The fuel prices were forecast for 13 regions from which a distribution of national prices for each fuel was generated. Prices were calculated to the year 2000 to match the model's solution horizon. In the actual technology competition, the prices were levelized to give a more accurate analysis.

A.3 GENERAL ENERGY ASSOCIATES INDUSTRIAL PLANT ENERGY PROFILES DATA BASE

General Energy Associates (GEA) (1979) developed the Industrial Plant Energy Profiles (IPEP) data base by integrating the Drexel data base with the Dunn and Bradstreet plant file. The integration software and correlations necessary to combine these data bases were developed using electric utility billing information on more than 5000 plant sites and detailed information on actual plant sites from trade associations and publications. In addition, hundreds of processes not in the Drexel/ DOE file were analyzed and added to the IPEP data base. The actual energy consumption figures reflected in each plant are checked against control sums for each SIC sector, state, and Standard Metropolitan Statistical Area (SMSA) as given by the Census Bureau and modified by data from the Bureau of Mines and Edison Electric Institute. In this way, local variations in intensity are accounted for in developing correlation coefficients in the model. To ensure that coefficients are not overconstrained, utility control sums from over 400 utilities were used to check totals.

GEA claim that IPEP can provide plant-specific data for 400,000 industrial plants. An example of the output possible is shown in Fig. A-2. Although GEA reports that a validation study is being circulated by a survey research firm, no documentation of the data base or validation tests have been published. Also, the differences between the IPEP and Drexel data bases cannot be examined or verified.

A.4 EPA NATIONAL EMISSIONS DATA SYSTEM DATA BASE

EPA has compiled the National Emissions Data System (NEDS) file over the past 10 years as part of the Aerometric and Emissions Reporting System (AEROS) that collects, processes, and reports pollution data. NEDS compiles complete fuel consumption and emissions data on all boilers and burners in the United States. The original NEDS file contained numerous errors; e.g., the state of New York is left out. Because of such errors, most analysts have avoided using NEDS; however, the EPA has updated and improved the original NEDS data.

NEDS data is reported for point and area sources. A point source is generally defined as any major stationary source with a potential for emitting more than 100 tons per year of any criteria pollutants. The point source data file contains information on more than 94,000 sources at nearly 34,000 facilities, including large utility boilers, industrial boilers, process heaters, etc. The information is primarily related to pollutants, emission levels, control equipment, etc.
NEDS also provides some energy-related information including:

- plant name,
- plant location,
- source type (boiler, process, etc.),

PLANT REFERENCE PROFILE

TRI STATE BREWERY
15 PARK PL.
MILWAUKEE, WISCONSIN 53211

WISCONSIN ELECTRIC POWER - 145

PRIMARY SIC 2082

FOSSIL FUEL USE (BTU/YR)
9.05×10^{11}

ELECTRICITY USE (KWH/YR)
36.2×10^{6}
ON SITE ELECTRIC 0%

PROCESS ENERGY PROFILE

UNIT OPERATIONS	TEMPERATURE (°F)	STEAM (LBM/HR)	FURNACE (BTU/HR)	ELECTRIC (KW)
GRINDING	*	*	*	420
COOKER	250°F	14,000 (40% HW)	*	*
FILTER	180°F	4,700 (HW)	*	570
FEEDSTUFF DRYER	700°F	*	38×10^{5}	160
BREWING	250°F	9,100	*	*
COOLER	REFRIG.	*	*	2930
CLEAN	160°F	12,000 (HW)	*	*
PASTEURIZE	180°F	34,000 (HW)	*	*
PACKAGE	*	*	*	480
OTHER	*	8,700	*	1480
		82,500 #/HR	38×10^{6}	6040

WASTE ENERGY PROFILE

SOURCE	TEMPERATURE (°F)	FLOW (LBM/HR)
BOILER STACK	450°	116×10^{3}
DRYER STACK	650°	200×10^{3}
NON RET. COND.	180°	25×10^{3}
CONTAM. WATER	150°	270×10^{3}

Figure A-2. Sample Industrial Plant Energy Information Available from GEA Industrial Plant Energy Profile (IPEP)

- fuel type,
- fuel quantity,
- operational rate,
- design capacity,
- stack temperature and flow rate, and
- percentage of fuel used for space heat.

The data file identifies the major processes within the plant. Some of the data can be very useful in understanding industrial energy use patterns, but the data base suffers from several significant weaknesses as reported by previous users:

- The data base is not updated systematically and, therefore, may contain data from different years;
- Small natural gas users are underreported;
- No age data on individual combustors are collected;
- No formal validation has been conducted for completeness or data quality; and
- Some site-specific data is sensitive due to "confidentiality."

Because of inconsistencies in the data quality reported by different states, NEDS information is of limited value for national studies. The accuracy and validity of data for specific states needs to be examined to determine its usefulness for specific applications.

A.5 ULTRASYSTEMS FACILITY ENERGY UTILIZATION DATA SYSTEM

Ultrasystems addresses some of NEDS problems in developing its Facility Energy Utilization Data System (FEUDS). FEUDS uses NEDS as the baseline but has added other data, such as combustor ages and mailing addresses.

In FEUDS, all point source related data are entered into the system via magnetic files on a semiannual basis. Any fluctuation in the configuration of a plant that affects an emission point source will be recorded by FEUDS, including additions to or modifications of a plant's operation or equipment and the use of different fuels. The following describes those key elements in FEUDS relevant to market segmentation or other applications.

- Plant Identification—name and address, county code, state code, ownership type, Universal Transverse Mercator zone with horizontal and vertical coordinates, and the 4-digit SIC.
- Plant Configuration—source classification code, boiler design capacity, percentage of annual throughput, normal operating schedule, average annual fuel consumption, maximum design rate, fuel heat content, emission control equipment, pollutants emitted annually, and source code.

A complete list of data elements in FEUDS is given in Table A-2.

Although Ultrasystems claims to have addressed a number of the problems in NEDS and has added data from other sources to the NEDS file, the FEUDS data base nevertheless is dependent on the quality of the raw data from the various states, which leads to inconsistencies in accuracy and reliability.

Table A-2. DATA ELEMENTS IN FUEDS

SYSTEM	FACILITY ENERGY USE DATA SYSTEM		SECTION 1			
FILE	FEUDS-1		PAGE 1 of 4			
RECORD	OWNER/MEMBER		DATE 5-30-79			

ITEM	LABEL	ITEM DESCRIPTION	DATA PIC	POS.	FROM	TO
1	POINT REC	Code = 3 for Data Record	9	1	1	1
2	FILLER	Not Used	X	7	2	8
3	RECORD TYPE	Code = P for point	X	1	9	9
4	STATE	2-Digit State Code	X	2	10	11
5	COUNTY	4-Digit County Code	X	4	12	15
6	FILLER	Contains 999	X	3	16	18
7	PLANT	4-Digit Plant Code	X	4	19	22
8	POINT	2-Digit Point Code	X	2	23	24
9	SCC	Source Classification Code (Fuel)	X	8	25	32
10	FILLER	Not Used	X	1	33	33
11	AQCR	Air Quality Control Region	X	3	34	36
12	YR-PL-REC	2-Digit Year Date Plant Last Updated	X	2	37	38
13	CITY	4-Digit City Code	X	4	39	42
14	UTM-ZONE	2-Digit UTM Zone	X	2	43	44
15	PL-N/A	Plant Name/Address	X	40	45	84
16	PL-CT	Plant Contact Responsible for NEDS Forms	X	12	85	96
17	OWNER	Ownership of Plant	X	1	97	97
18	YR-PT-REC	2-Digit Year Date Point Last Updated	X	2	98	99
19	SIC	4-Digit Standard Industrial Classification	X	4	100	103
20	FILLER	Not Used	X	2	104	105
21	UTM-EAST	UTM-East X Coord. (Kilometer) 9(3)V9	9	4	106	109
22	UTM-NORTH	UTM-North Y Coord. (Kilometer) 9(4)V9	9	5	110	114
23	STK-HEIGHT	Stack Height in Feet	9	4	115	118
24	STK-DIA	Stack Diameter in Feet 9(2)V9	9	3	119	121
25	STK-TEMP	Stack Temp in Degrees (F)	9	4	122	125
26	FLOW-RATE	In Cubic Feet/Minute	9	7	126	132
27	PLUME HEIGHT	Plume Height in Feet	9	4	133	136
28	MULT/BOIL-F	First and Last Point Codes	X	2	137	138
29	MULT/BOIL-L	Which Feed a Common Stack	X	2	139	140
30	YR-REC-CONT	Year Control Info Last Updated	X	2	141	142
31	BOILER-CAP	Boiler Design Capacity (MMBTU/HR)	X	5	143	147

Table A-2. DATA ELEMENTS IN FUEDS (continued)

SYSTEM	FACILITY ENERGY USE DATA SYSTEM			SECTION 1		
FILE	FEUDS-1			PAGE 2 of 4		
RECORD	OWNER/MEMBER			DATE 5-30-79		

ITEM	LABEL	ITEM DESCRIPTION	DATA PIC	POS.	FROM	TO
32	CONT-EQUIP	Emission Control Equip. 3-Digit Codes				
	PRIM-PART	Primary Control Particulates	9	3	148	150
	SEC. PART	Secondary Control Particulates	9	3	151	153
	PRIM-SO_x	Primary Control SO_x	9	3	154	156
	SEC-SO_x	Secondary Control SO_x	9	3	157	159
	PRIM-NO_x	Primary Control NO_x	9	3	160	162
	SEC-NO_x	Secondary Control NO_x	9	3	163	165
	PRIM-HC	Primary Control HC	9	3	166	168
	SEC-HC	Secondary Control HC	9	3	169	171
	PRIM-CO	Primary Control CO	9	3	172	174
	SEC-CO	Secondary Control CO	9	3	175	177
33	CONT-EFF	Control-Efficiency (Percent)				
	PART	Particulates (99V9)	9	3	178	180
	SO_x	SO_x (99V9)	9	3	181	183
	NO_x	NO_x (99V9)	9	3	184	186
	HC	HC (99V9)	9	3	187	189
	CO	CO (99V9)	9	3	190	192
34	YR-REC-PROD	Year Production Info Last Updated	X	2	193	194
35	ANN-THRUPUT	Percent of Annual Production Which Occurs in Each of Four Quarters				
		Winter	9	2	195	196
		Spring	9	2	197	198
		Summer	9	2	199	200
		Fall	9	2	201	202
36	OPER-SCH	Operating Schedule				
		Hours/Day	9	2	203	204
		Days/Week	9	1	205	205
		Weeks/Year	9	2	206	207
37	EST-PT-EM	Estimated Point Emissions				
		Part	9	7	208	214
		SO_x	9	7	215	221
		NO_x	9	7	222	228
		HC	9	7	229	235
		CO	9	7	236	242

Table A-2. DATA ELEMENTS IN FUEDS (continued)

SYSTEM	FACILITY ENERGY USE DATA SYSTEM	SECTION 1
FILE	FEUDS-1	PAGE 3 of 4
RECORD	OWNER/MEMBER	DATE 5-30-79

ITEM	LABEL	ITEM DESCRIPTION	DATA PIC	POS.	FROM	TO
38	EST-METHOD	Estimation Method				
	PART	Part	9	1	243	243
	SO_X	SO_X	9	1	244	244
	NO_X	NO_X	9	1	245	245
	HC	HC	9	1	246	246
	CO	CO	9	1	247	247
39	SPACE-HT	Percent-Space Heat (99V9)	9	3	248	250
40	YR-REC-REG	Year Regulatory Info Last Updated	X	2	251	252
41	ALL-EMS	Allowable Emissions				
	PART	Part	9	7	253	259
	SO_X	SO_X	9	7	260	266
	NO_X	NO_X	9	7	267	273
	HC	HC	9	7	274	280
	CO	CO	9	7	281	287
42	COMP-STAT	Compliance Status	X	1	288	288
43	COMP-DATE	Date for Plant to be in Compliance (Yr., Mo.)	X	4	289	292
44	DATE-REC-COMP	Date Compliance Info Last Updated				
		Year	X	2	293	294
		Month	X	2	295	296
		Day	X	2	297	298
45	EM-CONT-STAT	Emergency Control Status	X	1	299	299
46	CONT-REG	Control Regulations				
		REG-1	X	4	300	303
		REG-2	X	4	304	307
		REG-3	X	4	308	311
47	YR-REC-EM	Year Emissions Info Last Updated	X	2	312	313
48	OPER-RATE	Operating Rate in SCC Units per Year	9	7	314	320
49	MAX-RATE	Maximum Design Rate in SCC Units per Hour 9(4)V9(3)	9	7	321	327
50	SUL-CONT	Sulfur Content of Fuel (Percent) (9V99)	9	3	328	330
51	ASH-CONT	Ash Content of Fuel (Percent) (99V9)	9	3	331	333
52	HEAT-CONT	Heat Content in MMBTU's/SCC Unit	9	5	334	338

Table A-2. DATA ELEMENTS IN FUEDS (concluded)

SYSTEM	FACILITY ENERGY USE DATA SYSTEM			SECTION 1		
FILE	FEUDS-1			PAGE 4 of 4		
RECORD	OWNER/MEMBER			DATE 5-30-79		

ITEM	LABEL	ITEM DESCRIPTION	DATA PIC	POS.	FROM	TO
53	CD-6-CT	Card 6 Comment	X	20	339	358
54	SC-CODE	Source Code	X	1	359	359
55	CONF-CODE	Confidentiality Code	X	1	360	360
56	PL-COMT	Plant-Comment	X	36	361	396
57	PT-COMT	Point-Comment	X	36	397	432
58	CP-PT-EM	Computed Point Emission				
	PART	Part 9(7)V9(3)	9	10	433	442
	SO_X	SO_X 9(7)V9(3)	9	10	443	452
	NO_X	NO_X 9(7)V9(3)	9	10	453	462
	HC	HC 9(7)V9(3)	9	10	463	472
	CO	CO 9(7)V9(3)	9	10	473	482
59	SCC-COMT	SCC Comment	X	36	483	518
60	FILLER	Not Used	X	34	519	552

A.6 MAJOR FUEL BURNING INSTALLATIONS DATA BASE

The Federal Energy Administration compiled the Major Fuel Burning Installations (MFBI) survey in 1975 (U.S. DOE 1975). The survey includes fuel consumption data on all installations that consume at least 100 million Btu of fuel per hour. The primary purpose was to identify large combustors capable of firing coal but currently using oil or natural gas. The MFBI data deal with specific plants and combustors, with plants identified by company name, street address, state, and zip code. The total number of boilers and the number of other combustors are specified for the entire plant as well as the total design firing rate for all combustors. The following information was collected:

- kind of combustor (boiler, burner, other);
- combustor capacity;
- date installed and manufacturer;
- primary and alternate energy sources (coal, residual, distillate, gas, other);
- information about current and historical coal burning capability;
- 1974 and 1973 fuel use (Btu content and physical quantity of coal, residual, distillate, and gas consumed);
- percentage of combustor output devoted to electric generation, space heating, process steam, other; and
- information about air pollution control equipment and removal efficiencies.

The MFBI survey does not completely cover the industrial sector's energy usage, in that it focuses on large boilers, burners, and other combustors and detailed fuel usage information is not available for any combustor that uses less than 100 million Btu/hr. Even for a plant with several large combustors, the data do not give information about all of that plant's energy demands, since much of the fuel could have been burned in smaller units or used for nonfuel purposes (i.e., chemical feedstocks).

FEA has not published the MFBI data, which are considered confidential because of the information provided on individual companies. Aggregated summaries by SIC and state have been prepared for FEA's 1975 Natural Gas Task Force.

The data base has several anomalies that detract from its reliability: most burners show capacity uses greater than 90% or less than 10%; the correlation between boiler size and fuel consumption was less than 0.6; and large burners and boilers were used primarily for space heating. The MFBI statistics are probably invalid since most firms use 30%-80% of their burner capacity; boiler size and fuel consumption are highly correlated; and large burners and boilers are used for direct heat and process steam.

A.7 INTERTECHNOLOGY CORPORATION INDUSTRIAL PROCESS ENERGY DATA BASE

Intertechnology Corporation (ITC) examined direct heat processes in seventy-nine 4-digit industries for their report Analysis of the Economic Potential of Solar Thermal Energy to Provide Industrial Process Heat (ITC 1977). The ITC report is a primary source of industrial energy consumption data at the 4-digit SIC level, representing the first significant attempt to include temperature ranges, types of heat, and amount of heat in specific applications and processes.

To obtain the detailed information and data on process operating conditions and use of process heat, many different sources and methods were used. First, ITC made a thorough search of previous industrial energy studies performed for government agencies such as the Environmental Protection Agency (EPA), National Science Foundation (NSF), and Energy Research and Development Administration (ERDA). However, these studies were primarily concerned with gross energy consumption rather than process details. Then, information and data were obtained from technical literature, trade associations, industrial consultants, and—most importantly—from industrial contacts.

The information and data developed by ITC have been organized into a flow sheet containing important processes within a 4-digit SIC group; the flow sheet indicates individual operations with typical operating conditions such as temperature, source of heat, and amount of heat used per unit of product. In addition, current production and estimated future production data were obtained for estimating the total amount of heat required and the potential market for solar thermal energy systems particular application. Finally, because geographical location influences the performance of solar thermal energy systems and thus their impact for a particular application, production data were broken down where possible by states, for analysis with respect to solar climatic region.

The survey data were analyzed to identify process heat application and production processes in which solar thermal energy could be expected to have an impact. The variables considered in this assessment for a particular process include climatic region, geographical distribution of production, process heat requirements, competing fuels, and time frame of reference. The particular years included in the ITC analysis were 1976, 1985, and 2000.

The data base is, of course, only a sample of the total use of process heat by industry. The analysis of the potential for solar process heat for the subindustries included in the data sample has been scaled up to develop an overall estimate for the total potential of solar process heat. This scale-up was accomplished with the aid of estimates of the total use of process heat by industry, for the years 1976, 1985, and 2000.

Examples of data from the ITC study are shown in Table A-3.

A.8 BATTELLE INDUSTRIAL PROCESS HEAT DATA BASE

Battelle Memorial Institute also performed a study of potential industrial applications of solar energy (Hamel 1979). One specific objective was to identify and characterize process heat requirements. Battelle's approach consisted of the following steps:

- define the industry to be analyzed;
- identify major processes;
- prepare flow sheets for each process;
- identify process heat inputs;
- determine the quantity of heat required per unit of output, e.g., Btu/ton;
- determine the energy form; (hot water, steam, or direct heat/hot air) required for each process heat input;
- determine the temperature required for each process heat input;
- calculate the total process heat requirement for the industry or industry segment by multiplying the Btu-per-unit output by the annual production.

Table A-3. EXAMPLE OF DATA FROM ITC DATA BASE

Industry - SIC Group	Application Temperature Requirement °F	°C	Process Heat Used for Application 10^{12} Btu/Yr.	10^{12} kJ/Yr
11. Condensed & Evaporated Milk-2023				
Stabilization	200-212	93-100	2.93	3.09
Evaporation	160	71	5.20	5.48
Spray Drying	350-400	177-204	3.58	3.78
Sterilization	250	121	0.54	0.57
12. Fluid Milk-2026				
Pasteurization	162-170	72-77	1.44	1.52
13. Canned Specialities-2032				
Beans				
Precook (Blanch)	180-212	82-100	0.40	0.42
Simmer Blend	170-212	77-100	0.24	0.25
Sauce Heating	190	88	0.20	0.21
Processing	250	121	0.38	0.40
14. Canned Fruits and Vegetables-2033				
Blanching/Peeling	180-212	82-100	1.88	1.98
Pasteurization	200	93	0.15	0.16
Brine Syrup Heating	200	93	1.02	1.08
Commercial Sterilization	212-250	100-121	1.67	1.76
Sauce Concentration	212	100	0.44	0.46
15. Dehydrated Fruits and Vegetables-2034				
Fruit and Vegetable Drying	165-185	74-85	5.84	6.16
Potatoes				
Peeling	212	100	0.33	0.35
Precook	160	71	0.47	0.50
Cook	212	100	0.47	0.50
Flake Dryer	350	177	1.09	1.15
Granule Flash Dryer	550	288	1.09	1.15

These steps were followed for each industry, unless it appeared that the result would not justify a detailed analysis. For example, many processes in the ceramics industry use kiln firing. Since these high-temperature processes do not represent potential near-term applications of solar heat, detailed analyses were not performed and the gross process heat requirement for the processes was simply estimated. On the other hand, gypsum, concrete block, and brick segments employ relatively low-temperature processing, and these were analyzed separately in detail.

A key requirement in the analysis was determining the process heat required per unit of output. This is not a single value for any process; energy efficiencies vary from plant to plant because of age, state of equipment repair, or minor variations in procedure. The values used in each analysis represent average or typical values so that the industry total for a process, obtained by multiplying Btu-per-unit output by total output, is a reasonable representation of the overall sum of plants employing that process.

The industries covered by Battelle are:

- aluminum
- automobiles and trucks
- cement
- ceramics
- concrete block and brick
- gypsum
- chemicals (inorganic)
- coal mining and cleaning
- copper
- food processing
- glass
- lumber
- mining (Frasch sulfur)
- paper and pulp
- petroleum refining
- plastics/selected polymers
- rubber/SBR manufacture
- steel and iron
- textiles

The end uses were defined as:

- hot water (<212° F),
- steam,
  - 212°-350° F,
  - >350° F,
- direct heat/hot air,
  - <212° F,
  - 212°-350° F, and
  - >350° F.

Battelle compiled the information based on historical data and projected future process heat requirements to 1985 and 2000.

A.9 OAK RIDGE NATIONAL LABORATORY INDUSTRIAL DATA BASE

Oak Ridge National Laboratory (ORNL) is currently developing an industrial energy analysis model using the engineering end-use approach. A data base is being developed at the 2- and 3-digit SIC level. The industries represented include:

- food;
- paper;
- petroleum;
- stone, clay, and glass;
- industrial chemicals;
- primary iron and steel;
- nonferrous metals;

- durable manufacturing; and
- miscellaneous manufacturing.

Energy use is represented by 24 service types for steam, consisting of combinations of size, type of operation, and feasibility of coal conversion. The data base is disaggregated by 10 DOE regions and 11 vintages of capital stock.

The model develops generalized capital energy substitution (CES) functions that allow an evaluation of the trade-offs among capital, labor, and energy.

The data base could be very useful because of its regional and capital stock vintage disaggregation; however, no data on energy quality are included. The model and data base are currently under development and have not been completely documented.

A.10 INSTITUTE FOR ENERGY ANALYSIS CHARACTERIZATION OF INDUSTRIAL PROCESS ENERGY DATA

The Institute for Energy Analysis (IEA) of Oak Ridge Associated Universities analyzed industrial process heat (1979). The characteristics of heat that determine its potential in a particular manufacturing process are the temperature at which the heat is supplied and the heat transfer medium. IEA found that a complete data base specifying the heat transfer agents or media, temperatures, and uses of the energy consumed by manufacturers is not available in sufficient detail to allow requirements to be matched with suitable sources. Because of the wide variation in the temperatures and the forms of process heat required, detailed comprehensive information was sought for each of the 450 SIC industries at the disaggregated 4-digit level.

Since suitable matching of energy sources and requirements is a major portion of a study of alternative energy uses, a temperature spectrum of process heat requirements was attempted. A search of the literature revealed many studies with varying degrees of detail and completeness; however, IEA found no comprehensive study for appropriately matching energy services with alternative sources. Thus, data from a large number of studies, including some current studies, were synthesized by IEA.

An example of the data compiled by IEA is shown in Tables A-4 and A-5. Most of the data were synthesized from data bases described earlier in this section.

A.11 SERI'S INDUSTRIAL PROCESS HEAT DATA BASE

For the end-use matching study, SERI developed an Industrial Process Heat Data Base (IPHDB) (Brown et al. 1979) from information gathered from six U.S. cities—Fresno, Calif.; Denver, Colo.; El Paso, Tex.; Bismarck, N.D.; Brownsville, Tex.; and Charleston, S.C. To determine a good thermal and economic match between IPH requirements and solar equipment, some information is required: the industry and process type as identified by SIC, energy sources and heat transfer fluids used in the process, temperature and pressure, heat rate, and operating schedule.

IPHDB information categories are shown in Table A-6. Complete information on a particular industry makes it easier to size a solar IPH system and determine the resultant system cost. Certain solar IPH system characteristics have not been evaluated, such as thermal storage requirements.

Table A-4. EXAMPLE OF DATA COMPILED BY INSTITUTE OF ENERGY ANALYSIS: PROCESS HEAT REQUIREMENTS BY 2-DIGIT SIC, 1974

(Expressed IN 10^{15}J)

		Hot Water	Steam		Direct Heat or Heated Gas						Total Fuels Consumed
	SIC	<100°C	100-200°C	200-350°C	<100°C	100-200°C	200-350°C	350-550°C	550-1000°C	>1000°C	
Food	20	118.1	38.1	--	206.8	309.4	124.9	20.2	--	--	817.2
Tobacco	21	--	2.9	--	--	7.6	--	--	--	--	10.5
Textile	22	127.0	34.7	--	--	68.8	--	--	--	--	230.5
Lumber, Wood	24	3.0	13.4	--	--	147.2	--	--	--	--	163.6
Furniture	25	--	--	--	43.1	--	--	--	--	--	43.1
Paper	26	175.4	727.3	77.6	--	157.2	--	--	--	95.7	1,233.2
Chemicals	28	31.5	1,105.2	429.7	168.9	265.7	205.3	--	276.9	63.9	2,549.1
Petroleum	29	--	56.4	178.5	--	99.2	128.6	614.8	378.4	--	1,455.9
Rubber, Plastics	30	--	--	68.3	--	119.8	--	--	--	--	188.1
Leather	31	2.3	--	--	14.7	--	--	--	--	--	17.0
Stone, Clay, Glass	32	19.8	30.6	24.6	--	46.9	12.9	28.6	247.6	824.5	1,234.5
Primary Metals	33	86.1	40.8	--	3.0	--	46.0	--	0.7	1,968.3	2,144.9
Fabricated Metal	34	--	--	--	141.6	--	--	180.2	--	--	321.8
Machinery	35	44.6	4.8	73.1	--	35.3	37.4	--	--	78.1	273.2
Electric	36	--	--	--	4.5	14.0	--	146.6	--	--	165.1
Transportation	37	46.6	5.0	76.4	--	36.9	39.1	--	--	81.6	285.6
Total including SIC 29		654.1 5.9%	2,059.2 18.5%	928.8 8.3%	581.6 5.2%	1,308.0 11.8%	594.2 5.3%	990.4 8.9%	903.6 8.1%	3,112.1 28.0%	11,131.4 100%
Total excluding SIC 29		654.1 6.8%	2,002.8 20.7%	749.7 7.7%	581.6 6.0%	1,208.8 12.5%	456.6 4.8%	375.6 3.9%	525.2 5.4%	3,112.1 32.2%	9,675.5 100%

Table A-5. EXAMPLE OF DATA DEVELOPMENT BY INSTITUTE OF ENERGY ANALYSIS: MANUFACTURING PROCESS HEAT CHARACTERIZATION, 1974

Fuels for Heat and Power (Total)	11.2738 EJ
SIC 23, 27, 38, 39	0.1424 EJ
Identified Process Heat	11.1314 EJ

Heat Transfer Medium	Process Temperature Range	Energy Used to Provide Process Heat (EJ)	Percentage of Identified Process Heat
Hot Water	<100°C	0.6541	5.9
Steam	100-200°C	2.0592	18.5
	200-350°C	0.9282	8.3
Direct Heat or Heated Gas	<100°C	0.5816	5.2
	100-200°C	1.3080	11.8
	200-350°C	0.5942	5.3
	350-550°C	0.9904	8.9
	550-1,000°C	0.9036	8.1
	>1,000°C	3.1121	28.0
Total		11.1314	100.0

Table A-6. INDUSTRIAL PROCESS HEAT DATA BASE INFORMATION CATEGORIES

Categories[a]	Description/Comments
Process Code	
by SIC*	Standard Industrial Classification describing process
Process Data	
Fluid Used*	1 - Air 2 - Water 3 - Steam 4 - Other
Direct Heat*	0 - Direct (collector fluid direct to process) 1 - Indirect (intermediate heat exchanger)
Process Description	Description of process (cooking, washing, etc.)
Temperature Data	
Temperature*	Maximum temperature required for process
Tolerance	Tolerance of temperature
Supply temperature	Minimum supply temperature
Heat Rate Data	
Heat rate*	Heat rate required for process
Tolerance	Tolerance of heat rate
Energy use*	Average annual energy required for process in a plant of "standard" size
Energy use-unit output	Average amount of energy required per unit of industrial output
Pressure Data	
Pressure	Pressure required for process
Tolerance	Tolerance of pressure
Electrical Data	
Peak electricity	Peak electrical power required for process
Average electricity	Average electrical power required for process

[a]Data items collected for current IPHDB are indicated by asterisks.

Table A-6. INDUSTRIAL PROCESS HEAT DATA BASE INFORMATION CATEGORIES (concluded)

Categories[a]	Description/Comments
Operation Schedule	
Operation code*	0 - Continuous 1 - Batch or other
Seasonal Operation	
Season beginning	Week season begins (0 if year-round)
Season ending	Week season ends (0 if year-round)
Weekly Operation	
Monday-Friday shifts Saturday shifts Sunday shifts	0 - No shift 1 - Shift 1 2 - Shift 2 3 - Shifts 1 + 2 4 - Shift 3 5 - Shifts 1 + 3 6 - Shifts 2 + 3 7 - Shifts 1 + 2 + 3
Daily Operation	Military time when each shift starts or ends (to nearest hour)
Shift 1 start Shift 1 end Shift 2 start Shift 2 end Shift 3 start Shift 3 end	
System Applicability	Possible systems in order of applicability:
1st applicable system* 2nd applicable system* 3rd applicable system*	1 - Direct hot water 2 - Heat exchanger/hot water 3 - Direct hot air 4 - Indirect hot air 5 - Flashed steam 6 - Steam generator
Process Name	
Process name*	Name of process

[a]Data items collected for current IPHDB are indicated by asterisks.

In compiling information, previous studies of IPH requirements were used to avoid duplication and to make best use of existing resources. The first step in the data collection process was to determine which industries were in the six cities under study and to classify each industry according to a 4-digit SIC.

Next, several sources were consulted to determine IPH requirements. The information, usually given as annual energy use for the total industry, was revised to indicate IPH requirement for an average-sized plant by normalizing the total annual energy use by the number of plants in the industry. To use the IPHDB, a SIC industry located in a particular city is chosen; corresponding IPH data for an average-sized plant within that industry is then obtained from the IPHDB.

Certain limitations must be kept in mind. First, the IPHDB is based entirely on previous IPH studies. SERI did not survey industrial trade associations, process heat engineering firms, or other potential sources of IPH data. Second, the IPH data were redefined to describe a hypothetical, average-sized plant for each industry. A case study with site-specific information would be required to determine if an actual plant could economically use a solar IPH system.

The IPHDB could be extended to additional cities and more industries. Also, verification of the end-use matching approach and a more detailed evaluation of the industrial application of solar energy require more detailed process information. Both of these needs are being considered.

A.12 COOPERATIVE EFFORT FOR INDUSTRIAL ENERGY DATA COLLECTION

In the past few years, several studies have been carried out to accumulate plant-specific data. These studies originated in several federal programs, including those for industrial energy conservation, environmental assessments, geothermal energy, and solar energy (industrial process heat, small power systems, and cogeneration). Although the studies were largely independent of one another, much of the data collected were similar enough to be useful for multiple programs.

To compile detailed data on specific industrial processes and to eliminate multiple contacts with individual plants, a cooperative effort to collect and centralize industrial energy use data was organized in 1978 by several solar research organizations. The primary agreement was that all contacts with industrial plants or trade associations would be entered on a master list and distributed to all IEDC members. All available data would be compiled in a common format and submitted to a central data file made available to all members. It was agreed that SERI would be the central point for assembly and distribution of the information. Following the organizational meeting, each member was asked to submit any further comments on the proposed data format. From these inputs, a SERI committee, which included engineers, market analysts, and computer scientists, prepared the data format. This format, along with the first edition of the Contacts Lists, was distributed to all interested parties in January 1979. The format is shown in Table A-7.

The agreements are that:

- IEDC members will gather as much information as time and resources will allow;

Table A-7. DATA FORMAT: INDUSTRIAL PROCESS ENERGY DATA

1.0 Plant Identifiers		
1.1	SIC code	
1.2	City	
1.3	State	
1.4	Zip code	
1.5	Company name	
1.6	Plant name	
1.7	Plant contact	
1.8	Phone number	
1.9	Interviewer/firm	
1.10	Phone number	
2.0 Process Heat Requirements		**Units**
Individual Processes (up to five)		
2.1	Name of process	
2.2a	Supply temperature (temperature at which heat transfer fluid is delivered to the process)	°F
2.2b	Return temperature (temperature at which heat transfer fluid leaves process)	°F
2.3	Material temperature	°F
2.4	Flow rate	lb/h
2.5	Pressure	psi
2.6	Steam quality	%
2.7	Heat transport medium (code)[a]	
2.8	Process medium (code)[a]	
2.9	Daily start hour	
2.10	Daily end hour	
2.11	Days per week	
2.12	Scheduled downtime (code)[b]	
2.13	Unscheduled downtime	weeks/yr
2.14	Process line condition (excellent, good, average, fair, or poor)	
Plant Totals		
2.15	Unscheduled downtime	weeks/yr
2.16	Fuel type (code)[c]	
2.17	Annual fuel usage	MBtu/yr
2.18	Cost	$/MBtu
2.19	Utility supply schedule (interruptible or continuous: I or C)	

Table A-7. DATA FORMAT: INDUSTRIAL PROCESS ENERGY DATA (continued)

Discuss:

2.20 Backup fuel

2.21 Substitutability

3.0 Electrical Requirements		Units
Each Process (up to five)		
3.1	Peak power	kW
3.2	Peak/average ratio	
3.3	Supply voltage	V
Each On-Site Turbine-Generator Unit (up to five)		
3.4	Fuel type (code)[c]	
3.5	Turbo-generator type (diesel, steam, gas turbine, or other: D,S,G, or O)	
3.6	Rated capacity	kVA
3.7	Inlet temperature	°F
Steam Systems Only		
3.8	Inlet pressure	psi
3.9	Flow rate	lb/h
3.10	Extraction temperature	°F
3.11	Extraction pressure	psi
Plant Totals		
3.12	Utility company	
3.13	Rate schedule (utility-designated rate code if available)	
3.14	Total annual purchased power	MWh
3.15	Total annual self-generated power	MWh
3.16	Estimated unit cost of self-generated power	mills/kWh

4.0 Economic Factors		Units
4.1	Discount rate	%
4.2	Payback period	yr
4.3	Number of employees	
4.4	Value of shipments	$10⁶/yr
4.5	Age of plant	yr
4.6	Percentage of operating cost for energy	%
4.7	Total available adjacent land (own, lease, purchase)	acres
4.8	Total available roof area	10^3 ft²
4.9	Urban or rural location (U or R)	

Discuss

4.10 Shape, terrain, and suitability of available land

4.11 Plant environment (dust, air pollutants, local micro-climate, etc.)

4.12 Other considerations (if any)

Table A-7. DATA FORMAT: INDUSTRIAL PROCESS ENERGY DATA (concluded)

5.0 Institutional Factors	
5.1	Perspectives on fuel availability
5.2	Perspectives on fuel costs
5.3	Environmental impact problems
5.4	Necessary conditions before use of solar energy is considered
5.5	Does an energy management program/committee exist?
5.6	Preferred incentives (tax credit, low-interest loans)
5.7	Who is responsible for energy-related investment?
5.8	Preferred methods of information dissemination (trade journals, technical meetings, trade associations, briefings, or other)
5.9	Energy conservation measures implemented (since 1974)
5.10	What alternatives have been considered?

[a]A = air S = steam
W = water O = other

[b]NN-NN (last week of operation - week operation resumes)
Example: If plant closes from Christmas to New Year's Day, the code is: 51-01.

[c]C = coal G = natural gas
R = residual oil P = propane
D = distilled oil B = biomass

- The data will be submitted to SERI in the appropriate format and edited as necessary; and
- SERI will compile a central data file of all contributions and make it available to all interested parties.

From the beginning, IEDC has been recognized as a voluntary effort. There are no binding agreements; its success depends entirely on the cooperation of the members.*

The main function of IEDC in past months has been to maintain an updated Contacts List. The list, now in its third revision, contains entries from five organizations representing seven different studies. There are 39 entries for trade associations and 150 entries for industrial plants. No data are yet on file.

Nearly a year after its inception, IEDC continues to interest many individuals. Presently, nearly 30 organizations are on its distribution list. Clearly, IEDC has the potential to meet a great need for information in the field of industrial process energy analysis.

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*A member, then, is any interested group doing work related to industrial energy use and willing to abide by IEDC agreements.

SERI

APPENDIX B

A DESCRIPTION OF SIX STATE MODELS

APPENDIX B

This appendix describes the six states' formal energy models reviewed for this study.

B.1 CALIFORNIA

The California Energy Commission (CEC) (1979) developed the most detailed and sophisticated energy demand models, which are used to support CEC's biennial report to the California legislature. The detailed documentation of these models is available from the CEC Publications Office.

Model Overview. The Industrial Demand Model evaluates the potential for energy conservation of new, energy-efficient industrial processes and the role of cogeneration, in addition to providing a baseline forecast for the biennial report. The structure of the model is shown in Fig. B-1. The energy demand is calculated by major industry group based on the level of activity and the prices of labor, energy, and capital. The energy demand by fuel type is passed on to a conservation model where the effects of industrial audits and Title 24-mandated building standards are added. In addition, projections of industry-specific cogeneration and the implications of environmental pollution control regulations are considered in developing the final energy demands.

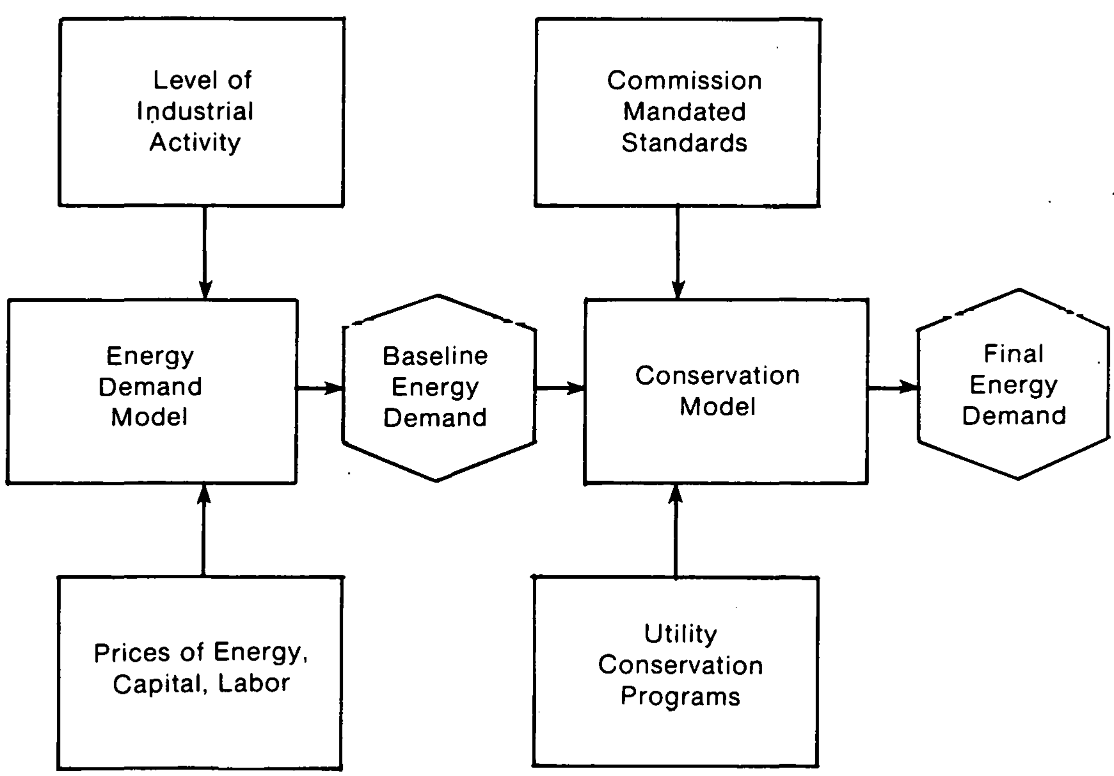

Figure B-1. Structure of California Industrial Energy Demand Model

Scope and Coverage. The Industrial Demand Model covers the manufacturing, mining, and agriculture sectors by 2-digit SIC. The breakdown by SIC is shown in Table B-1.

Table B-1. INDUSTRIAL CLASSIFICATIONS IN CALIFORNIA INDUSTRIAL ENERGY DEMAND MODEL

SIC	Description
(11, 12, 14)	Metal Mining
13	Oil and Gas Extraction
(16, 17)	Building Construction
20-39	Total Manufacturing
29	petroleum refining
37	transportation equipment
20	food and kindred products
28	chemical and allied products
33	primary metal industries
36	electrical and electric machinery
32	stone, clay, glass, and concrete products
35	machinery (except electrical)
34	fabricated metals
30	rubber and plastics products
26	paper and allied products
24	lumber and wood products
38	instruments
27	printing and publishing
23	apparel and textile products
22	textile mill products
25	furniture and fixtures
39	miscellaneous
31	leather and leather products
21	tobacco

Since CEC is primarily interested in forecasting and analyzing utility demands, electricity and natural gas are the principal energy types addressed. Oil is included in the analysis to allow for effects of interfuel competition. The model is disaggregated by major electric utility service territories. The service territories considered are:

- Pacific Gas and Electric Company,
- Southern California Edison Company,
- Los Angeles Department of Water and Power,
- Sacramento Municipal Utility District, and
- San Diego Gas and Electric Company.

The model does not have any end-use information on such energy uses as space heating, process steam, and feedstock.

Structure and Techniques. Among the 20 SIC industries that make up manufacturing, some use more energy than others; 12 of the 20 used nearly 97% of the manufacturing sector electricity in 1976. Several separate models have been tailored to these differences in energy consumption among manufacturing industries. All the models are based on historical data concerning changes in consumption resulting from changes in the costs of energy, capital, and labor as reported in EIA's Annual Survey of Manufacturers for the years 1958-1976.

In the first stage of the analysis, the model considers all types of energy—gas, electricity, and all other fuels—as a single factor. Each type of energy is treated separately in a later stage.

Future energy consumption in the 12 largest manufacturing industries is calculated by analyzing a combination of factors—capital (equipment and structures), labor, and energy. Mathematical equations have been developed based on the principle that firms seek to minimize the costs of each unit of production by selecting the least expensive combination of production factors. As energy prices rise, energy consumption tends to slow; if labor costs rise more rapidly than energy costs, then, all other things being equal, energy consumption increases. For each 2-digit SIC industry, energy consumption is determined by the firm's output and by the shifting costs of labor, capital, and energy. Thus, the model reflects the economic substitution of labor for capital equipment, energy for labor, and so on, as firms respond to the changing prices of these factors.

For each 2-digit SIC, the model calculates how much energy consumption will increase or decrease on the basis of 19 years of historical evidence on the relationship between energy consumption and other factors. For example, past data may indicate that for every one-cent increase in the cost of gas, energy consumption per unit of production fell by 100 mcf. This basic relationship is assumed to hold true in the future. The relationships between energy, capital, labor, and units of production are calculated separately for each of the 2-digit SIC industries. For consistency, value added is used to measure production.

Using the relationship between energy consumption, value added, and the costs of labor, capital, and energy for each of the 12 largest 2-digit SIC industries; and projections of value added and prices in the future; the model predicts future statewide energy consumption for each 2-digit SIC industry. The next step is to separately forecast electricity, natural gas, and other fuel consumption. A second mathematical model describes the relationship between a firm's choice of energy—gas, electricity, or other (mainly oil)—and their prices and the firm's historical patterns of energy use. The model equations were determined by analyzing data from the same historical period, 1958-1976, that was used for the energy consumption model. The model predicts fuel splits, which are percentages of each of three heat and power sources. As with the energy consumption model, the fuel split model makes statewide forecasts.

The models described above are used for the 12 largest SIC industries except for petroleum refining, food products, and pulp and paper. The models for these three industries are very similar. For petroleum refining, the model forecasts electricity usage directly, rather than starting with total energy usage. Electricity intensities (Btu of electricity per dollar of value added) are projected as a function of the prices of electricity, gas, other fuels, capital, and labor. This approach is used because it apparently best matches the petroleum industry's historical response to price and output changes. Projections for electricity demand in the pulp and paper industries closely follow the two-model approach, except that a simpler total energy equation is used.

Along the same lines, electricity, gas, and other fuel consumption is forecast separately for the food industry.

The eight smallest energy consumers are the printing, textile, instruments, apparel, miscellaneous manufacturing, furniture, leather, and tobacco industries. The approaches are all similar to the models used for the 12 largest SIC industries. The first predicts total energy consumption as a function of the level of an industry's output. Total energy consumption is then distributed among the three energy sources, electricity, natural gas, and other fuels based on historical trends. The second approach ascertains the need for each energy source based on the industry's historical responses to changes in its level of production and to energy prices. The third approach uses an energy intensity indicator that measures the quantity of energy required to produce a dollar of output or the quantity of energy consumed per employee.

The next step is to translate statewide energy consumption forecasts into utility service area totals. The U.S. Bureau of the Census provided historical data on the percentage of statewide sales in each 2-digit SIC attributable to each utility in 1976. These percentages were then used in the forecast years and modified to reflect the changing percentages of value added for each 2-digit SIC industry in each service area.

Data Sources. The data for developing the equations came from the Census of Manufacturers. Value added and price projections are obtained from the Center for the Study of the California Economy..

Treatment of Conservation Measures. The model explicitly represents two conservation programs in the industrial forecast. Both are ongoing efforts and therefore should continue in the forecast period. The programs are (1) the Energy Commission's energy efficiency standards for new buildings and (2) energy audits and surveys conducted by the utilities.

Calculation of future conservation savings is very complex. In general, the model calculates the savings as follows:

- For the building standards, the square footage of new industrial buildings is forecast for each service area and SIC. These figures are multiplied by a service-area savings rate to obtain yearly savings. The savings rate is derived by examining the climate in each service area and comparing the energy efficiency of old buildings and buildings that conform to the standards.
- For utility customer audits, the number of audits expected to be performed per year is multiplied by the average savings expected per audit.

The model also considers the impacts of new cogeneration facilities of 50 MW or less. (Facilities larger than 50 MW are considered generation facilities.) Cogeneration estimates can be made in two ways. The first method is a generic assessment in which projections are based on industrial heat requirements and assumptions about the rate at which the potential can be realized using surveys of utilities and industrial firms. This method can more accurately identify the potential electricity supplies that could be supplied by cogenerators but cannot analyze the behavioral factors that determine how much potential can reasonably be developed at any particular time. The second method assesses cogeneration potential on a project-by-project basis. Each potential project presently identified by interested utilities and industrial customers is examined to determine the likelihood of implementation. The forecast includes those considered "reasonably likely to occur."

Regulatory/Policy Considerations. The model can explicitly address any regulatory or policy issues that affect fuel prices since prices are included in the forecasting equations. To some extent, the model can address regulatory and policy considerations relative to cogeneration. Also, mandatory building standards and other current CEC conservation programs are included.

The model, however, does not represent renewable energy resources; thus, it cannot analyze the potential for solar energy in IPH. Also, the model does not represent industrial energy end uses (such as hot water steam at different temperature levels, etc.) and therefore is limited in evaluating new conservation measures such as waste heat recovery or process efficiency improvement.

The model structure that uses transcendental logarithmic production functions is very complex and difficult to explain to policy makers. It relies primarily on econometric methods that assume past trends and relationships will continue. It cannot, therefore, easily address new technologies.

Because of the lack of end-use detail and the difficulty in addressing renewable energy technologies, its value for forecasting and analyzing solar energy for IPH is extremely limited.

B.2 NEW MEXICO

Model Overview. New Mexico has developed linked models of the state's economy, demographics, and energy resources, resulting in a comprehensive energy management system (EMS) that captures the various interactions (New Mexico Energy Institute 1979). The principal objectives of EMS are:

- an improved understanding of the current energy system in New Mexico,
- the capability of finding solutions to short-term problems, and
- the capability for long-range planning.

Scope and Coverage. Currently, the model only includes electricity demand and supply. Other fuels are to be added later.

Model Structure and Techniques. The EMS currently consists of several linked components that provide a consistent method for evaluating the consequences of alternative energy policies and for developing strategies for the economy and population.

Three major components make up the current version of EMS.

- Southwest Water, Economy, Energy, and Population (SWEEP) Model,

- Econometric Electrical Demand (EED) Model, and
- Linear Programming Processing (LPP) Model.

Inputs into the entire EMS are alternative scenarios of future development with emphasis on energy. EMS outputs include projections of population, output, and resource use at high levels of detail for the period 1980-2000.

SWEEP is the core of the system and represents the various impacts of new energy developments. It is composed of two major modules: (1) the economic module and (2) the demographic module. The economic module uses multiregional I-O tables for seven planning regions in New Mexico and the four surrounding states. Regional I-O tables are derived from national 5-year I-O tables developed by Clopper Almon and used by DOE for energy and environmental impact projections.

The demographic module employs the cohort-survival method to age regional populations by year. Base year population estimates by age and sex distribution are constructed for each region. Labor force participation, fertility, and survival rates are also constructed for each region plus trend factors that are derived separately for most of these rates.

The EED model is a system of econometric equations to project the residential, commercial, industrial, and public demand for electricity and electricity prices. Key inputs include projections of population per capita income and alternative fuel prices. Some of these inputs are derived from the SWEEP model; others from the LPP model.

The LPP model is an engineering-economic model of fossil-fuel electrical generation processes. Under a given set of electricity demand requirements, fuel prices and availabilities, and effluent limitations, the model will operate existing plants and build new capacity to meet the demand in the least-cost manner.

Limitations. Since the model does not currently address fossil fuels, it has no potential applications for the analysis of solar energy in IPH.

B.3 NEW YORK

Model Overview. A comprehensive econometric model has been developed for New York State (Greene et al. 1979). The quantities of major fuels demanded (e.g., electricity, oil, natural gas, coal, and gasoline) by the state's residential, commercial, industrial, and transportation sectors are predicted in one component of the model. Energy demand is related not only to the functioning of the state's economy as a whole, but also to the state's changing demographic characteristics. These relationships are treated in the economic and demographic model, which is shown in Fig. B-2.

The two-way flow of information between the economic and demographic modules indicates they are fully integrated and that the values of the predicted variables are jointly determined. The one-way flow of information from the economic and demographic components to the energy demand component indicates that the models are linked to each other rather than being fully integrated. One feedback effect from the energy demand component to the economic component (represented by the dashed arrow) has been developed that reduces the amount of money available for other goods and services as the total cost of energy to the consumer increases. Since other potential feedback effects, such as the relationship between energy use and employment, have not been developed at this time, the energy demand and economic components are only partially integrated.

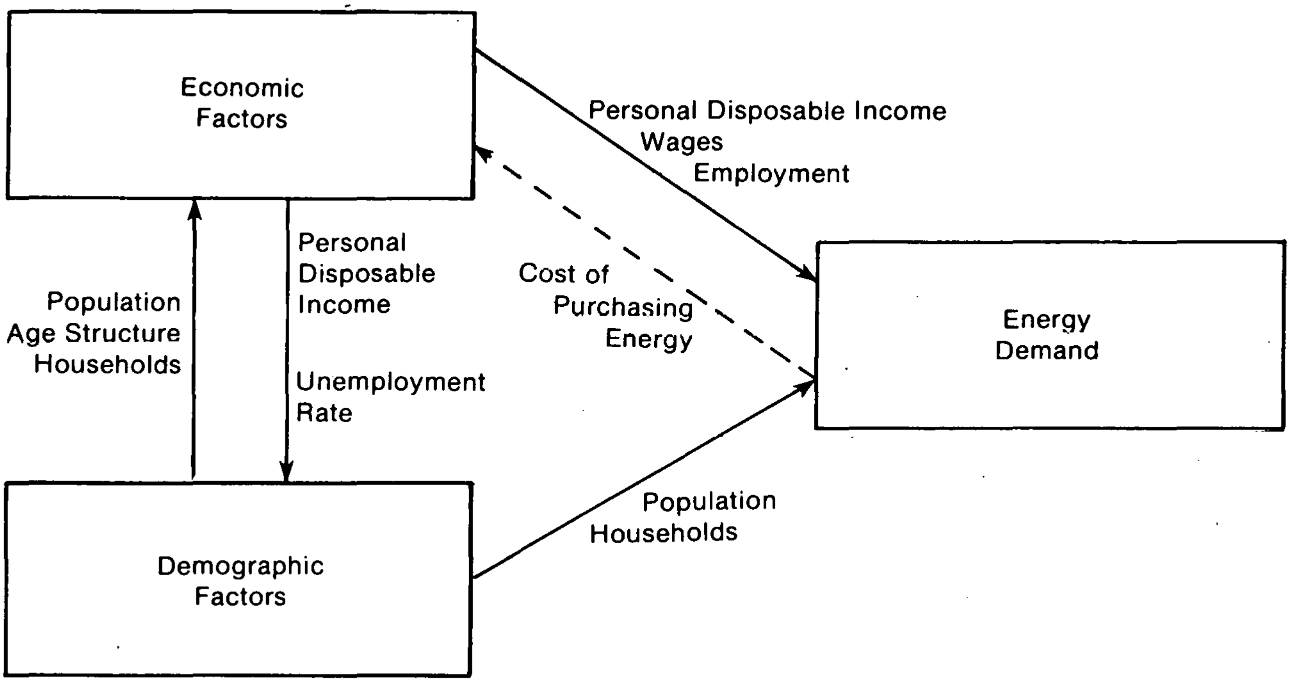

Figure B-2. Overview of New York State Macroeconometric Model.

The macroeconometric model treats the state on an aggregate basis in that virtually all the variables represent the state as a single spatial unit. Each of the three major components of this model (i.e., economic, demographic, and energy demand) consists of a system of multiple regression equations that are estimated from data from their own respective sample periods. The economic component treats the economy within a consistent framework of regional gross product and income accounts. Variables are included for the components of final demand, value added, employment, and wage rates by industrial sectors plus income and labor force. The demographic component disaggregates the population by race, sex, and 19 age groups from birth to age 85 and over. Births, deaths, migration, and household formation are important in this component. The energy demand component estimates the demand for various types of energy.

Scope and Coverage. The industrial portion addresses electricity, natural gas, residual and distillate oil, coal, labor, and capital and state-level total industrial energy demands but does not have any geographic or SIC disaggregation.

Structure and Techniques. The equations in the industrial demand model are shown in Fig. B-3. The basic economic theories underlying the commercial and industrial models are the same. Different factors are organized or transformed by businessmen and managers to create goods or services that are bought by people within the state and elsewhere. If one factor becomes more expensive relative to others, then it is reasonable to expect that efforts will be made to use this factor more sparingly and to replace it by other factors if possible.

A most crucial equation regarding the future viability of the state's economy is to determine how higher prices for fuels will influence employment and economic growth. Consequently, a substantial effort has been made to link employment and energy use. Expenditures by businesses and industries are allocated among different factors of production. In this analysis, the focus is on alternative fuels, employment, and capital equipment with the model predicting the proportion of total expenditures going to each of the factors identified. The statistical objective is to estimate the degree of substitutability among the different factors.

The industrial demand model is sufficiently complicated to make it virtually impossible to obtain reliable estimates from data for a single state. Consequently, data from 10 northern states (corresponding to the first three census regions with the omission of four small New England states) are combined to form a set of pooled cross-section and time-series data for the years 1967-1976.

Data Sources. The basic sources used to develop the model equations are

- Census of Manufacturers
- Annual Survey of Manufacturers
- All-electric homes
- Typical electric bills
- Gas Appliance Manufacturers Association
- Survey of current businesses
- New York Statistical Yearbook
- The Interindustry Structure of the New York State Economy.

Treatment of Conservation. The available documentation is unclear on how the econometric model treats specific conservation measures; however, conservation effects due to price changes are modeled based on historical data.

Regulatory/Policy Analysis. The model has been used to examine the impacts of time-of-day electricity pricing and the relationship between energy prices and the state's economy. The model can handle regulations or policies that directly influence prices but cannot directly address other policy options. Also, because of the lack of disaggregation by industry type, only the total industrial sector (including mining and agriculture) can be addressed. The model cannot be used for the disaggregated end-use projections required for analyzing solar energy in industry.

$$\ln\left(\frac{P_1Q_1}{P_6Q_6}\right) = a_1 - L_1 \ln\left(\frac{Q_1}{Q_6}\right)_{-1} + \frac{P_{11}}{W_1}\ln\left(\frac{P_1}{P_6}\right) + \frac{P_{12}}{W_1}\ln\left(\frac{P_2}{P_6}\right) + \frac{P_{13}}{W_1}\ln\left(\frac{P_3}{P_6}\right) + \frac{P_{14}}{W_1}\ln\left(\frac{P_4}{P_6}\right) + \frac{P_{15}}{W_1}\ln\left(\frac{P_5}{P_6}\right) + B_{11}\,CURT$$
$$+ B_{12}\,D74 + B_{13}\ln\left(\frac{ICEL}{POP}\right) + B_{33}\,D75 + B_{34}\,D76$$

$$\ln\left(\frac{P_2Q_2}{P_6Q_6}\right) = a_2 - L_1 \ln\left(\frac{Q_2}{Q_6}\right)_{-1} + \frac{P_{12}}{W_2}\ln\left(\frac{P_1}{P_6}\right) + \frac{P_{22}}{W_2}\ln\left(\frac{P_2}{P_6}\right) + \frac{P_{23}}{W_2}\ln\left(\frac{P_3}{P_6}\right) + \frac{P_{24}}{W_2}\ln\left(\frac{P_4}{P_6}\right) + \frac{P_{25}}{W_2}\ln\left(\frac{P_5}{P_6}\right) + B_{21}\,CURT$$
$$+ B_{22}\,D74 + B_{24}\ln\left(\frac{ICNG}{POP}\right) + B_{33}\,D75 + B_{34}\,D76$$

$$\ln\left(\frac{P_3Q_3}{P_6Q_6}\right) = a_3 - L_1 \ln\left(\frac{Q_3}{Q_6}\right)_{-1} + \frac{P_{13}}{W_3}\ln\left(\frac{P_1}{P_6}\right) + \frac{P_{23}}{W_3}\ln\left(\frac{P_2}{P_6}\right) + \frac{P_{33}}{W_3}\ln\left(\frac{P_3}{P_6}\right) + \frac{P_{34}}{W_3}\ln\left(\frac{P_4}{P_6}\right) + \frac{P_{35}}{W_3}\ln\left(\frac{P_5}{P_6}\right) + B_{31}\,CURT$$
$$+ B_{32}\,CURT + B_{61}\,D75 + B_{62}\,D76$$

$$\ln\left(\frac{P_4Q_4}{P_6Q_6}\right) = a_4 - L_1 \ln\left(\frac{Q_4}{Q_6}\right)_{-1} + \frac{P_{14}}{W_4}\ln\left(\frac{P_1}{P_6}\right) + \frac{P_{24}}{W_4}\ln\left(\frac{P_2}{P_6}\right) + \frac{P_{34}}{W_4}\ln\left(\frac{P_3}{P_6}\right) + \frac{P_{44}}{W_4}\ln\left(\frac{P_4}{P_6}\right) + \frac{P_{45}}{W_4}\ln\left(\frac{P_5}{P_6}\right) + B_{41}\,CURT$$
$$+ B_{42}\,D74 + B_{33}\,D75 + B_{34}\,D76$$

$$\ln\left(\frac{P_5Q_5}{P_6Q_6}\right) = a_5 - L_1 \ln\left(\frac{Q_5}{Q_6}\right)_{-1} + \frac{P_{15}}{W_5}\ln\left(\frac{P_1}{P_6}\right) + \frac{P_{25}}{W_5}\ln\left(\frac{P_2}{P_6}\right) + \frac{P_{35}}{W_5}\ln\left(\frac{P_3}{P_6}\right) + \frac{P_{45}}{W_5}\ln\left(\frac{P_4}{P_6}\right) + \frac{P_{55}}{W_5}\ln\left(\frac{P_5}{P_6}\right) + B_{51}\,CURT$$
$$+ B_{52}\,D74 + B_{33}\,D75 + B_{34}\,D76$$

where i = 1 is electricity
2 is natural gas
3 is residual oil
4 is coal
5 is labor
6 is capital
P_i is the price of the ith input
Q_i is the quantity of the ith input
D74, D75, D76 are dummy variables for 1974, 1975 and 1976, respectively.
$\frac{ICEL}{POP}$ and $\frac{ICNG}{POP}$ are the number of industrial customers per capita for electricity and natural gas, respectively.
$CURT = (1 - D)\left(\frac{Q_2}{\Sigma_{i=1}^{4} Q_i} \times \frac{1}{D}\right)_{-1}$ is a measure of expected curtailments of natural gas relative to the total amount of energy used, where D is the proportion of gas requirements delivered.
W_i are the weights used to set the symmetry conditions on price responses implied by economic theory. The choice of weights is similar to the procedure described for the commercial demand model.

Source: Greene, W. et al. 1979.

Figure B-3. Equations Describing New York State Industrial Demand Model

B.4 OREGON

Model Overview. The Oregon Department of Energy, to satisfy its legislatively-mandated requirement of making energy forecasts, developed an econometric model of energy demands in 1976 (Rocket Research Co. 1978). The model has been updated recently, but despite repeated requests, the documentation has not been received. Therefore, the review covers the 1976 version of the model (Oregon Department of Energy 1976).

The Oregon energy demand forecasting model consists of empirically derived submodels by energy sources and economic sectors. The three primary energy sources are electricity, natural gas, and petroleum products. Other energy sources are not considered because of a lack of data. The economic sectors are residential, commercial, industrial, agricultural, transportation, and others, but not all sectors are considered for each energy source. A sector's share and the total consumption of an energy source data availability are the two criteria for establishing separate submodels.

Scope and Coverage. The model covers the industrial sector as a whole (no SIC disaggregation) and addresses electricity, natural gas, and petroleum use.

Model Structure and Techniques. The model is econometric and uses two basic structures. The main difference between the two results from the relevance and usefulness of the concept of per-customer consumption of energy. In sectors where the number of customers is so large relative to the differences in size among individual customers that the average size of customers shows some consistency over time, total consumption of energy from each source is equal to the product of per customer consumption and the number of customers. Per-customer consumption of each energy source is assumed to be a function of its own real price; the prices of substitute fuels, real income, size of customer, degree days, a dummy variable representing a special supply constraint, and the adjustment in lifestyle necessitated by such events as the low water year of 1973; and the oil embargo. Whenever necessary, the dependent variable lagged one year which theoretically reflects both the existing capital stock (equipment) of energy users and the slowly changing, if ever, behavior pattern of consumers. The number of customers is assumed to be influenced by population, relative prices, and the number from the previous year. The coefficient of the lagged number of customers indicates the rate of attrition of existing customers.

Industrial electricity use is estimated as a function of value added and price of electricity. Similarly, gas use is a function of value added and gas price. Oil use is estimated using personal income, degree days, and the wholesale price index (for refined petroleum products).

Data Sources. Data from utilities were used for estimating demands. The U.S. Bureau of Mines (USBM) Mineral Industry Surveys—now Environmental Impact Assessment (EIA) Energy Data Reports—were also used.

Treatment of Conservation. Only price impacts can be treated. The econometric equations are limited in their potential for addressing other conservation measures.

Regulatory/Policy Analysis. The model structure limits the potential for regulatory/policy analysis.

B.5 TEXAS

Model Overview. A simulation model, developed for the Governor's Energy Advisory Council (GEAC) during the 1972-73 period (Holloway, Grubb, and Grossman 1975) was designed to analyze the impacts of changes in energy supply and demand on the Texas economy and to provide information on alternatives of energy policy. The model was updated and improved for use in preparing Texas Energy Outlook: The Next Quarter Century, published by the GEAC in March 1977. Because of changing economic and energy conditions, the model has been updated, refined, and improved on a regular basis (Texas Energy Advisory Council 1978). It is based on an input-output representation of the Texas economy and uses the following table:

Processing Sector	1 2...48	Final Demand						
		1 Household	2 Federal Military	3 Federal Civilian	4 State	5 Local	6 Exports	7 Capital
1 2 . . . 48	X	Y						
49 Household 50 Property Payments 51 Federal 52 State 53 Local 54 Imports								

Scope and Coverage. The input-output table, which has 54 rows and 55 columns, may be expressed as two matrices, X and Y. An energy in X, x_{ij}, denotes the flow of goods and/or services from the processing sector (rows 1 to 48) or the payment sector (rows 49 to 54) indicated by i to the j^{th} processing sector. The final demand sector Y contains 7 columns or components. Any element in Y, y_{ij}, denotes the purchase of goods and services by the j^{th} final demand component from the i^{th} processing or payment sector. A list of the processing sectors is given in Table B-2; SIC industries corresponding to the processing sectors are also presented.

Model Structure and Techniques. The final demands for the input-output (I-O) matrix are calculated using econometric equations that include energy demands. Annual values and growth rates calculated from these equations are then used in the I-O model.

Table B-2. PROCESSING SECTORS IN THE TEXAS INPUT-OUTPUT MODEL

Sector Number	Industry	SIC Groups
1	Irrigated Crops	0112-0123
2	Dryland Crops	0212-0219
3	Livestock and Poultry	0132-0235
4	Agricultural Services	0712-0741 5962,5969
5	Primary Forestry and Fisheries	0811-0989
6	Crude Petroleum	1311
7	Natural Gas Liquids	1321
8	Oil and Gas Field Services	1381, 1382, 1389
9	Other Mining	1011-1499
10	Residential Construction	1511
11	Commercial, Educational, and Instit.	1512, 1513, 1700
12	Facility Construction	1611, 1621
13	Food Processing	2011-2087
14	Textile and Apparel	2211-2399
15	Logging, Wood, and Paper	2411-2799
16	Chlorine and Alkalies	2812, 2813
17	Cyclic Crudes and Intermediate Pigments	2815
18	Organic Chemicals	2818
19	Inorganic, Plastics, Rubber	2819-2822
20	Drugs, Chemicals, Soaps, and Paint	2831-2899
21	Petroleum Refining	2911
22	Other Petroleum Products	2951, 2952 2992, 2999
23	Tires, Rubber, Plastics, Leather	3011-3199
24	Glass, Clay, Stone, Cement	3221-3273
25	Primary Metal Processing	3312-3499
26	Industrial Equipment Manufacturing	3522-3599
27	Electric Appliance Manufacturing	3611-3699
28	Aircraft, Motor Vehicle	3721-3799
29	Instruments, Photography, Games	3811-3999
30	Rail Transportation	4011, 4013 4021, 4041
31	Intercity Highway Transportation	4131, 4132, 4111 4119, 4121
32	Motor Freight Transportation	4212-4231
33	Water Transportation	4411-4469
34	Air Transportation	4511, 4521 4582, 4503
35	Pipeline Transportation	4612, 4613, 4619
36	Other Transportation	4141, 4251 4271, 4272
37	Communications	4811, 4821 4832, 4833, 4899
38	Gas Services	4922-4925
39	Electric Services	4911
40	Water and Sanitary Services	4941-4961, 9302
41	Wholesale Trade	5012-5099

Table B-2. **PROCESSING SECTORS IN THE TEXAS INPUT-OUTPUT MODEL (concluded)**

Sector Number	Industry	SIC Groups
42	Other Retail Trade	5211-5499 5611-5999
43	Auto Dealers and Repair Shops	5511-5531 5541, 7531-7549
44	F.I.R.E.	6011-6799
45	Other Services	8111, 7211- 7399, 7512 8099, 8911-8811
46	Lodging, Amusement, Recreation	7011-7041 7832-7949
47	Education	
48	Outdoor Recreation	8211-8242

In the I-O model, the row total of a processing sector is defined as the output for that sector ($X_i.$). The column total of the j^{th} processing sector (denoted as $X._j$) is defined as the total input of that sector. For any processing sector, its input should be equal to its output; i.e.,

$$X_i. = X._j \quad \text{if} \quad i = j \ .$$

Hence, the vector $\bar{X}$ is used to denote inputs or outputs by sectors.

For each resource specified in the model, there is a vector containing 54 entries. Each entry, R_{ij}, shows the amount of resource j required by sector i (across the top of the I-O table) to produce a $1 million output (1967 prices).

Resource vectors are provided in terms of the specified units per million dollars of output for

- human resource: number of jobs
- water: 1,000 acre-ft
- agricultural land: 1,000 acres
- crude oil: barrels (1,000)
- natural gas: billion cubic feet
- natural gas liquid: barrels (1,000)
- refined products: barrels (1,000)
- natural gas service: billion cubic feet
- electricity: million kWh
- self-generated electricity: million kWh
- coal: 1,000 tons
- nuclear fuel: tons.

Data Sources. The specific data sources used to develop the I-O coefficients and the econometric equations are not defined in the available documentation.

Treatment of Conservation. Conservation can be addressed by the model by changing the relevant resource coefficients; i.e., declining energy requirements per unit of output. However, the model has no internal mechanism to change these coefficients. Price elasticities of demand for energy are represented in the demand equations, but there is no documentation on how these elasticities were estimated.

Regulatory/Policy Analysis. The Texas model explicitly represents the interrelationships between energy and the economy and has a detailed representation of various economic sectors. Therefore, it is a powerful tool for analyzing various regulatory and policy issues. Examples of previous applications include

- economic projections under energy constraints,

- estimation of economic impacts of energy policies,
- the study of the increased use of coal in power generation, and
- evaluation of impacts of energy prices.

However, its potential for evaluating renewable energy resources are severely limited by the structure of the I-O coefficients and econometric equations.

B.6 WISCONSIN

Model Overview. As one of the components for a comprehensive model of state energy use, the Wisconsin Division of State Energy has developed an econometric model of its industrial demands for electricity (Lindsay 1979). Wisconsin's industrial electricity use is modeled at the 2-digit SIC level. The state's seven major electricity-consuming industries are represented separately; other manufacturing industries are combined. Thus, there are eight sectors that represent the total manufacturing industry.

Scope and Coverage. Only electricity is addressed in the model. The industrial sector is disaggregated by 2-digit SIC to seven major groups (plus all others):

- food processing
- pulp and paper
- primary metals
- fabricated metals
- machinery
- electrical equipment
- transportation equipment
- other manufacturing.

Model Structure and Techniques. The demand for electricity is determined separately for each industry, but the equation form is basically the same. In general, an industry's electricity demand depends on its level of output (value added) and capital stock and on its relative prices (average unit costs), of electricity, fuels, and labor. The relative price variables, as well as value added and capital stocks, are all specific to the individual industries. Given anticipated prices, output, and capital stock, the model determines annual electrical demands (kWh) for each industry group. The projected electrical requirements of each industry group are aggregated to produce the forecast for the total manufacturing industry.

The eight electricity-demand equations are econometric estimates derived from data for Wisconsin's industries over the past two decades. Complete energy-use statistics are generally not available annually, and more data are available for some industries than for others. The principal source of data is the U.S. Census Bureau's Annual Survey of Manufacturers.

Since the model considers only electricity, it is not applicable for studying the potential of solar energy in industry.

A Forecast of Industrial Energy Use. A study of industrial energy consumption patterns and conservation measures was performed recently by the University of Wisconsin. While no model was built, forecasts for future energy use were developed (Foell et al. 1980).

This study used data from various DOE and census reports, plus a survey by the Wisconsin Department of Natural Resources (DNR) to develop the industrial energy use profile. Energy use by 2-digit SIC for electricity, gas, oil, and coal was calculated for 1971 through 1976. Based on the DNR survey, an estimate of boiler and process use by plant size was developed. Because of the importance of the pulp and paper industry to Wisconsin's economy, a very detailed analysis of energy-use patterns for that industry was made and cogeneration and conservation were explicitly addressed.

Several issues related to industrial energy conservation were considered

- What incentives exist or should be provided to encourage conservation of the scarce fuels? Will they be adequate to help industry move away from dependence on petroleum and natural gas and ease the transition to more costly energy?
- Are the current or projected policy regulations (e.g., building codes) consistent with desired conservation targets?
- Are there conservation and economic incentives for greater decentralization of electricity generation and for industrial cogeneration? What are the technical, economic, and institutional barriers to industrial cogeneration, and how may they be eliminated?
- How do environmental quality, transportation, and costs limit use of alternatives? How much will energy conservation reduce the costs of meeting environmental standards?
- In what sectors, if any, is government action needed? What is the role of government-funded R&D? Is the necessary information available for conservation decisions? How can the regulatory process aid industry in energy conservation?

Energy intensities were calculated for fossil fuels, electricity, and total energy for each 2-digit SIC. These intensities were calculated as a ratio of energy to value added or value of shipments. Projections of employment and value added were developed and used to make energy projections. Unfortunately, the energy projections assumed a constant energy-to-value-added ratio, despite the strong declining trend in this ratio observed for the period 1971-1976.

The study provides detailed projections of fossil fuel requirements by 2-digit SIC industries, but the assumption of constant energy intensity limits the usefulness of the projections.

B.7 REFERENCES

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APPENDIX C

FEDERAL CONSERVATION ACTS AFFECTING FUTURE STATE INDUSTRIAL ENERGY DEMAND

APPENDIX C

C-1 ENERGY POLICY AND CONSERVATION ACT (EPCA)

This Act (P.L. 94-163), passed in December 1975, represented the first major piece of federal legislation that promoted energy conservation and energy emergency planning in the United States. A major provision relates to the development of industrial energy efficiency improvement targets for each of the 10 most energy-consuming industries. Part D of Title III of this Act requires that the administrator (of ERDA)

> . . . shall identify each major energy-consuming industry in the United States, and shall establish a priority ranking of such industries on the basis of their respective total annual energy consumption. Within each industry so identified, the Administrator shall identify each corporation which—
> (1) consumes at least one trillion British thermal units of energy per year, and
> (2) is among the corporations identified by the Administrator as the 50 most energy-consumptive corporations in such industry.

and

> . . . shall set an industrial energy efficiency improvement target for each of the 10 most energy-consumptive industries identified under Section 373. Each such target—
> (1) shall be based upon the best available information,
> (2) shall be established at the level which represents the maximum feasible improvement in energy efficiency which such industry can achieve by January 1, 1980. . . .

The two most significant provisions that relate to state energy planning as well as programs related to industrial energy consumption patterns are Sections 361 to 367, which create state energy conservation programs that must meet an energy conservation goal by 1980, and Part D, Sections 371 to 376, which relate to the development of individual industry energy efficiency improvement targets for the nation's 10 largest energy-consuming industries.

Most of the present state energy conservation activities are funded under EPCA. Because they receive federal funds, states are required to achieve a minimum energy conservation goal of 5% of their projected 1980 energy consumption. Each year, states must revise their state energy conservation plans and submit them to DOE for approval. As long as the mandatory provisions of their plans are addressed, the states are free to add additional measures they feel would achieve the minimum goal. As a result, many states have been developing clearinghouses and audit programs and even legislating certain measures to improve industrial energy efficiency.

C.2 ENERGY CONSERVATION AND PRODUCTION ACT (ECPA)

This Act (P.L. 94-385), passed in 1976, provided for supplemental energy conservation plans from the states. More funds were provided to the states to support additional energy conservation programs in such areas as intergovernmental relations and public education and to provide for Class A and Class C audits. Class A audits are on-site reviews of the potential for energy conservation in a building or plant. Class C audits are guidebooks or workbooks that allow a plant or building manager to conduct his own audit. The Act created a national energy information system and provided for periodic reports on the nation's sources and uses of energy. It also detailed technical documentation of all EIA forecasts that would be used to develop policies and programs. Both EPCA and ECPA have provided the basis of most state energy planning and management activities. Some states, such as California, New York, and Michigan, have provided additional state funding to expand the energy planning and management activities.

C.3 NATIONAL ENERGY CONSERVATION POLICY ACT (NECPA)

Although most of the provisions of this Act (P.L. 95-619) relate to residential, commercial, and government buildings, three requirements pertain to industrial energy conservation. Section 441 of Title IV amends Title III of EPCA by requiring the office of the Secretary of DOE to evaluate (1) pumps and motors and (2) certain other industrial plant equipment (e.g., fans, compressors, lights, ovens, boilers, and dryers) and

> (A) determine standard classification with respect to size, function, type of energy used, method of manufacture, or other factors which may be appropriate for purposes of this part; and
>
> (B) determine the practicability and effects of requiring all or part of the classes determined under subparagraph (A) to meet performance standards establishing minimum levels of energy efficiency.

Section 641 of Title IV also amends Title III of EPCA and requires that:

> . . . the Secretary shall set targets for increased utilization of energy-saving recovered materials for each of the following industries: the metals and metal products industries, the paper and allied products industries, the textile mill products industry, and the rubber industry. Such targets—
> (1) shall be based on the best available information,
> (2) shall be established at levels which represent the maximum feasible increase in utilization of energy-saving recovered materials each such industry can achieve progressively by January 1, 1987. . . .

Section 601 of Title VI of NECPA also amends Title III of EPCA expanding the information reporting requirements so all companies in each of the 10 most energy-consuming industries that consume at least one trillion Btu per year must report their energy consumption figures to DOE each year and show what actions are being taken to conserve energy. Data for each plant must be filed periodically at the corporate headquarters, where they will be kept for at least five years and be available to DOE on request.

C.4 POWER PLANT AND INDUSTRIAL FUEL USE ACT (FUA)

The major purpose of FUA (P.L. 95-620), passed in 1978, is to encourage greater use of coal and other alternative fuels instead of natural gas and petroleum as a primary energy source, especially in generating electricity and for major fuel-burning installations. A major fuel-burning installation is defined as a "stationary unit consisting of a boiler, gas turbine unit, combined cycle unit, or internal combustion engine" that either is designed to consume any fuel at a fuel heat input rate of at least 100 million Btu/hr or is combined with one or more such units located at the same site that together can consume any fuel or mixture thereof at a fuel heat input rate of at least 250 million Btu/hr. FUA explicitly prohibits the use of natural gas or petroleum as a primary energy source in any new electric power plant and, with few exceptions, in any new major fuel-burning installation with a boiler. DOE may prescribe regulations restricting the use of natural gas and petroleum in major fuel-burning installations other than boilers, with provisions for exemption. Also, the Act prohibits the use of natural gas as a primary energy source at existing power plants on or after 1 January 1990.

The Act further prohibits the use of petroleum or natural gas as a primary energy source in any existing electric power plant if the power plant previously had the technical capability to use coal or other alternative fuel or if the power plant has the technical capability to use coal or other alternative fuel without substantial plant modification or reduction in its rated capacity. It also must be financially feasible to use coal or another alternative fuel as a primary energy source. These same provisions also apply to existing major fuel-burning installations.

Again, there are provisions for permanent exemptions. Such exemptions may result from inadequate and unreliable supplies of coal or other alternative fuels, site limitations that would not permit the facility to use coal or other energy fuels, or applicable environmental requirements. Permanent exemptions are provided for cogeneration facilities if the firm has demonstrated that economic and other benefits of cogeneration are not obtainable unless petroleum and/or natural gas are used in such a facility.

C.5 NATURAL GAS POLICY ACT (NGPA)

The purpose of the 1978 NGPA (P.L. 95-621) is to increase the well-head price of natural gas and eventually decontrol certain natural gas prices to increase production. Some provisions would limit the initial increased cost of natural gas on industrial users before the cost is actually felt by residential and commercial users. Presently, much controversy surrounds the provisions related to incremental pricing. Phase I, which is now in effect and lasts until December 1980, sets the ceiling price for industrial natural gas used as boiler fuel at the price of high sulfur No. 6 fuel oil. Also, monthly natural gas ceiling prices are posted for each state. These prices represent the cost of natural gas to be used by industry. It is unknown what the escalation rate will be for the real price of natural gas, since it is based on the price of fuel oil. Given that the world price of fuel oil is significantly influenced by OPEC, there is much uncertainty about the impact of incremental pricing on future industrial energy requirements. It can be postulated that if the price of natural gas and alternative fuels used by industry increases significantly, the time when it becomes cost-effective for industry to undertake major capital investments in manufacturing processes to reduce energy cost will come much sooner. Many states are now active in evaluating the impact of incremental pricing on the supply and price of natural gas for their state's sources and uses of energy.

C.6 ENERGY TAX ACT

This 1978 Act (P.L. 95-618) provides a gas-guzzler tax, removal of excise taxes on buses and equipment, incentives for van pooling, residential energy tax credits for installing certain energy conservation measures and renewable resource technologies, and changes in the business investment credit to encourage conservation from oil and gas to new energy technologies. Businesses are allowed a 10% investment tax credit from 1975 to 1980, and a 7% tax credit beginning on 1 January 1981, for constructing certain energy technologies including a boiler modified to use an alternative fuel as its primary fuel. Other qualifiers include equipment for converting alternative fuels to synthetic liquids or equipment that uses coal, pollution control equipment, recycling equipment, shale oil equipment, or solar or wind power. In addition, states are increasingly allowing some type of financial incentive for the purchase of solar or other renewable energy devices.*

Even though the Internal Revenue Service maintains a profile of tax returns received each year including total wages and the number and types of exemptions applied for, data are not available on the number of energy tax credits applied for and the total amount applied for in each state, although nationwide aggregate data are available. Although it is relatively easy to obtain information on the types of tax incentives available in each state, it is very difficult to get information on the estimated amounts of fossil energy saved as a result of those technologies for which a request for a tax credit was received.

C.7 PUBLIC UTILITY REGULATORY POLICY ACT (PURPA)

This Act (P.L. 95-617) promotes efficient use of utility capital and supplied energy. The major provisions relate to state Public Utilities Commission (PUC) consideration and determination of certain rate-making standards. Cost-of-service studies are also being conducted to determine the cost of supplying electricity for each customer. Other measures are prohibiting declining block rates and considering time-of-day rates, seasonal rates, interruptible rates, and load management techniques. Although the state PUCs are not required to adopt any of these standards, they are required to consider the standards in a formal regulatory proceeding and disclose the results to DOE. Also, the Act provides for DOE intervention in the state's consideration of these rate-making standards. Section 210 provides for the encouragement of cogeneration and other small power production facilities. Of major concern are the standard rates electric utilities will charge for cogenerators should the cogenerators consume utility-supplied electricity.

The Federal Energy Regulatory Commission (FERC) is required under the act to prescribe

> . . . after consultation with representatives of Federal and State regulatory agencies having ratemaking authority for electric utilities, and after opportunity for interested persons to submit data, views, and arguments (such as rules) as it determines `necessary to encourage cogeneration and small power production rules which require electric utilities to offer to—
> (1) sell electric energy to qualifying cogeneration facilities and qualifying small power production facilities and
> (2) purchase electric energy from such facilities.

FERC will also issue rules and regulations to exempt certain qualifying cogeneration and small power production facilities from the Federal Power Act, the Public Utility Holding Company Act, state laws and regulations with respect to rates, or other matters that the commission deems necessary to encourage cogeneration and small power production. The

*A recent study by Common Cause (1980) showed that 40 states had financial incentives, including grants, loans, and tax credits, for solar energy and other renewable resources.

15 study states reviewed have shown a high level of interest in cogeneration. This interest is demonstrated by several states that have either issued new rules to encourage cogeneration (e.g., California), or by funding feasibility studies that record many of the technical and institutional problems affecting cogeneration. Since most states are now in the middle of evaluating the various rate-making standards and costs of services for the utilities they regulate, it is very difficult at this time to assess the impact on customer loads.

C.8 REFERENCE

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SERI

APPENDIX D

INDUSTRIAL ENERGY CONSERVATION PROGRAMS IN 15 SELECTED STATES

SERI

APPENDIX D

D.1 ALABAMA

Legislative/Regulatory: None identified.

Administrative: None identified.

Information Transfer: Class A and C audits for industrial facilities that cover a number of specific processes are provided. The audit modules, which are a series of computer programs, assess the energy conservation potential for boilers, furnaces, lighting, HVAC, waste heat recovery, dryers, evaporators, and motors. The data gathered from on-site audits are then submitted to computer analysis, and maximum energy savings information is then provided. As a result of these industrial audits, the state plans to save 4.3 trillion Btu. The state also provided six one-day seminars on boiler efficiency that resulted in an estimated 6% energy savings on boilers tested by workshop participants. In cooperation with Auburn University, Engineering Extension Service, a technical assistance program is being conducted where a series of workshops will be presented in all geographic areas of the state. Class A audits will be arranged with selected industries, and case studies and examples of industrial energy conservation programs will be discussed. The total savings projected for 1980 as a result of the increased boiler efficiency technical assistance program is 34 trillion Btu, which will help the state reach its goal of reducing industrial energy use by 12% (Alabama Energy Management Boards Undated).

Financial Incentives: None identified.

Demonstration Programs: None identified.

Concluding Comments: The state relies heavily on information transfer programs and industrial participation in state-sponsored workshops appears to be good.

D.2. CALIFORNIA

Legislative/Regulatory: Much activity is under way that is likely to affect future industrial energy requirements. On 23 May 1979, the California Energy Resources Conservation and Development Commission adopted administrative regulations pertaining to load management programs to be implemented by electric utilities. These load management programs were mandatory for residential and large and small commercial businesses. However, the regulation did provide for the utility, at its own option, to expand the commercial load management program to include industrial customers. If a utility decides to include industrial customers, it shall submit a plan for the commission's approval. For all of the sectors included in the plan, the potential energy and capacity savings as a result of specific utility actions must be provided. The Energy Commission must approve the plan if it is cost-effective and results in utility capacity savings. Annual progress reports based on surveys of facilities and detailed program evaluation measures are also to be provided by the utilities.

Another legislative/regulatory provision (California Assembly Bill No. 524) requires the California Air Resources Board to develop, in cooperation with each air pollution control district and PUC, an inventory of potential cogeneration projects in each air basin that could be constructed before 1987 (Undated). Also, the Air Resources Board, in cooperation with the Solid Waste Management Board, solid waste districts, and regional planning agencies, would have to inventory potential resource recovery projects to be constructed before 1987. The bill also requires the board to prepare revisions in the State Implementation Plan required by the Clean Air Act Amendments of 1977, to provide for the mitigation of air-quality impacts for those projects identified pursuant to the legislation. The bill also requires air pollution control districts to issue permits for the construction of cogeneration and resource-recovery facilities if certain conditions are met. Finally, this bill provides that the California PUC makes cogeneration projects the highest priority for the purchase of natural gas. Other provisions of this act pertain to Energy Commission participation in proceedings before the PUC for time of use and interruptible rates. The PUC, in a rate hearing, has required that Pacific Gas and Electric (PG&E) have 2,000 MW of new cogeneration capacity on line by 1985. Similar goals are expected to be established for other state utilities. The PUC also ruled that PG&E must pay for cogenerated power on an avoided cost basis. This is likely to serve as an incentive to industrial cogeneration. California has also adopted time-of-day rates for large commercial and industrial consumers.

Administrative: Boiler efficiency workshops for state-owned buildings have been implemented. The state now is also conducting hearings on a 5-year plan to promote increased conservation in nonresidential sectors. Clearinghouse activities, utility cost sharing, low-cost capital investment pools, and commercial and industrial conservation technical assistance programs are being considered.

Information Transfer: Case studies of industry-specific energy conservation efforts are being recorded and shared throughout the state. On-site energy audits are provided by many utilities, and workshops and technical assistance have been provided on waste heat recovery and industrial waste recycling. An end-use computer model has been developed that estimates future industrial energy requirements and controls for the effects of energy conservation programs.

Financial Incentives: The state has provided for several tax credits and other financial incentives. However, no such incentives apply to the industrial sector.

Demonstration Programs: Most demonstration activities center on utilities testing various load management programs and devices such as cycling equipment, coal gasification, or renewable energy applications.

Concluding Comments: California is one of the few states that has placed emphasis on the legislative/regulatory approach with much of its regulatory emphasis on utilities. The state has also adopted a much longer and comprehensive planning horizon and submits a biennial report reviewing the state energy situation to the legislature and the public. The state has provided a number of futuristic energy documents that review possible alternative energy scenarios. Presently, the state is conducting hearings on a 5-year energy conservation plan that would focus on all sectors except residential. A few key recommendations are the creation of an energy information clearinghouse, low-cost capital investment pools, and further utility energy conservation investments.

D.3 ILLINOIS

Legislative/Regulatory: None identified.

Administrative: None identified.

Information Transfer: Industrial energy audits and surveys examine applications of energy conservation technologies. Technology transfer programs are also provided to promote waste oil recycling as well as other solid and liquid industrial wastes. The 1980 planned energy savings as a result of industrial energy programs are 40 trillion Btu.

Financial Incentives: None identified.

Demonstration Programs: None identified.

Concluding Comments: The state's industrial energy conservation programs emphasize information transfer. No major state legislation or other programs were mentioned that would likely have an impact on future industrial energy requirements.

D.4 INDIANA

Legislative/Regulatory: None identified.

Administrative: None identified.

Information Transfer: Class A and C audits are provided to industries as well as auditor training programs. The state energy office contacts specific industries and trade associations to promote industry-specific improvements in energy-intensive processes and to encourage good housekeeping measures. An Indiana Energy Information Research Center was also established in FY 1979 that provides computer-retrievable information on various ways for industry to save energy. The state also assists DOE in promoting the Industrial Energy Efficiency Program. Total energy savings in 1979 were 71 trillion Btu. Planned 1980 energy savings are 111 trillion Btu, with planned expenditures of $151,000 (Indiana Department of Commerce 1979).

Financial Incentives: None identified.

Demonstration Programs: None identified.

Concluding Comments: The approach is primarily information transfer. No long-term state programs have been identified that will have a significant impact on Indiana industry. Indiana is cognizant of the DOE industrial reporting program and is promoting the program. The state has received an index of firms participating in the federal program and has been surveying them to determine their estimated energy savings.

D.5 LOUISIANA

Legislative/Regulatory: The state has repealed the natural gas tax credits for manufacturing firms. The estimated result of this is an energy savings of 1.09 trillion Btu.

Administrative: None identified.

Information Transfer: The state has supported a number of programs in this category, including three industrial energy management seminars for large industries (over 250 employees) in 1980; industrial energy conservation technology transfer workshops for smaller industries (e.g., food preparation and agribusiness below 250 employees); workshops for boiler efficiency improvements; funding support for applying the Second Law of

Thermodynamics to industrial energy conservation concerns; and workshops on waste-to-energy for industry. The total estimated energy savings in 1980 is 184 trillion Btu as a result of implementing these information transfer programs, which constitutes 85% of the state's total 1980 energy savings as presented in the 1979 State Energy Conservation Plan.

Financial Incentives: None identified.

Demonstration Programs: None identified.

Concluding Comments: Louisiana was one of the few states that recognized the federal voluntary industrial energy conservation program and tried to tailor its state programs in cooperation with the Industrial Energy Efficiency Program (Department of Natural Resources 1979a, b.

D.6 MICHIGAN

Legislative/Regulatory: Some initial curtailment of declining block rates.

Administrative: None identified.

Information Transfer: Workshops and literature are provided to small industries on the energy savings potential of various industrial energy conservation actions with waste heat recovery viewed as a major source of potential energy savings. Also, a State Industrial Advisory Committee has been created to guide state industrial energy conservation programs. Community college training programs as well as an industrial awards program for achieving a certain level of energy conservation are also being implemented. Class A (on-site) audits are provided for the 10 largest SIC industries. Class C audit materials (workbooks and instructions on how to perform do-it-yourself audits) are also provided to small and medium industries. A total of 0.35 trillion Btu have been saved since these programs were implemented in 1979.

Financial Incentives: None identified.

Demonstration Programs: Feasibility studies have been financed to review cogeneration and recycling opportunities in the state. Firms apply for assistance on a competitive basis. For 1979, $40,000 was set aside to fund such programs, while in 1980, $42,000 will be spent.

Concluding Comments: Michigan relies very heavily on information transfer programs. No state programs have been identified that will likely have a major impact on future energy consumption.

D.7 MISSOURI

Legislative/Regulatory: Other than the creation of an Environmental Improvement Bonding Authority that provides tax-exempt general revenue bonds for the purchase of pollution abatement equipment, the state has no regulatory programs that affect the sources and uses of industrial energy (Missouri Division of Energy 1980).

Administration: None identified.

Information Transfer: Audits, Class A or C, and workshops are provided to Missouri industries (Missouri Division of Energy 1980). Total 1979 industrial energy savings were reported to be 2.76 trillion Btu. The workshops offered for 1979 focused on energy conservation through waste heat recovery and computer controls. A fuel technology program has also been created. Guidance is provided by an Industrial Advisory Committee that reviews new energy technologies that may have potential for Missouri industry as well as considering new programs that can reduce future industrial energy requirements without jeopardizing the state's economy.

Financial Incentives: None identified.

Demonstration Programs: None identified.

Concluding Comments: Presently the state is emphasizing information transfer with respect to reducing industry's future energy requirements. However, it is now in the process of developing a long-term energy plan that looks at alternative energy conservation and production options from 1980 to 2000. Regarding the potential energy savings as a result of implementing a more rigorous energy conservation program for industry, the state projects that 22 trillion Btu/yr can be saved. The state also projects that 13.9 trillion Btu/yr can be saved as a result of cogeneration opportunities. A number of preliminary recommendations have been made as to how the state can achieve these additional energy savings in the industrial sector. The plan, which is now in draft form, is awaiting approval.

D.8 NEW JERSEY

Legislative/Regulatory: Regulations were issued on 3 August 1978 that apply to all fossil-fuel-fired large boilers, except those operated by electric and gas public utilities subject to the jurisdiction of the New Jersey Board of Public Utilities. A large boiler means any fired steam boiler, steam generator, hot water boiler, or hot oil unit whose rated capacity exceeds either 499 ft^2 of heating service of 100 boiler horsepower or 4 million Btu/hr input regardless of temperature or pressure conditions. All large boilers are required to operate at a combustion efficiency such that neither the percentage of oxygen shall be higher than 1.25 times the optimum percentage of oxygen value nor the temperature of the flue gases shall be higher than 1.15 times the optimum temperature value obtained from the performance characteristic curves for a load condition. Initial performance characteristic curves are obtained for every large boiler and for the types of fuels in use including low-fired, the upper end of the normal operating range of the boiler, and also for several intermediate points of operation. Performance characteristic curves for each boiler are redetermined every five years, when the fuel type or any component of the boiler that could change its combustion efficiency has changed, or at the request of the state. Large boilers are required to be tested for efficiency each week by the state, and records are required to be maintained by the plant where the boiler is located, for a period of at least five years. Such reports are to be made available to officials of the New Jersey Department of Energy and the Department of Labor and Industry. As a result of the state's boiler efficiency standards, it is estimated that 22.7 trillion Btu will be saved in 1980.

Administrative: None identified.

Information Transfer: The state promotes a number of programs oriented to manufacturing and process industries that include workshops, audit reference materials, and on-site audits. For 1980, a series of 12 workshops will be offered for the five most energy-intensive industries: primary metals, glass, paper, food preparation, and chemical and petrochemical. An industrial audit manual is also available for the specific industries that have been covered in a particular workshop. It is assumed that a 10% energy savings will result for each of the firms represented at the workshops. No energy savings are being estimated for the audit manual, energy efficiency sharing seminars, or walk-through audits. The 1980 New Jersey State Energy Conservation Plan (New Jersey Department of Energy 1980) also provides for municipal and industrial resource recovery programs. It is projected that 24.2 trillion Btu will be saved in 1980 as a result of recycling paper, aluminum, scrap metal, and glass.

Financial Incentives: None identified.

Demonstration Programs: None identified.

Concluding Comments: The most distinguishing characteristic of New Jersey's industrial energy conservation program is the legislative/regulatory approach. As a result of the state's boiler efficiency standards, it is estimated that 22.7 trillion Btu will be saved in 1980. The New Jersey Board of Public Utilities is also in the process of changing utility rates, which no doubt will have an impact on the sources and uses of energy. Summer energy and demand charges are higher for all utilities than winter rates. There are also interruptible rates for commercial and industrial customers served by certain utilities. In June 1978, a major utility initiated a time-of-day rate for all high-tension service customers. The Board of Public Utilities has also acted to flatten natural gas rates and to move toward price parity with fuel oil. As a result of these new rate structures, the state estimated that it will save 116.9 trillion Btu in 1980. However, how much of the energy saved will come from the industrial sector is unknown.

D.9 NEW YORK

Legislative/Regulatory: None identified.

Administrative: None identified.

Information Transfer: On-site audits are currently available for industries in 48 counties. At the end of each audit, a written report outlining no-cost and low-cost energy conservation opportunities is provided. The report describes specific suggestions for conservation, supported by a benefit/cost analysis. During 1979, 350 energy-use surveys were requested from industrial firms. A total of 175 surveys has been completed and returned to the state Energy Office. The data provided from these surveys show that an estimated average of 10 million Btu of energy has been saved by each firm. Technical seminars of general interest have been provided for a number of industries. Large companies with an awareness of energy conservation techniques work with the state Energy Office in sponsoring seminars for smaller companies within their area. These seminars use case histories of the large companies to convey the benefits of energy conservation. In 1979, seminars were conducted in six state regions and will be expanded to cover the entire state in 1980.

The state has also provided industrial boiler seminars (New York State Energy Office 1980a) for boiler operators and managers. Training workshops have also been held on testing and adjustments for various waste-heat recovery methods. To date, 12 seminars have been provided in metropolitan areas across the state with approximately 1,150 persons attending. Estimated energy savings in 1979, based on 982 participants, is 20 trillion Btu. Eight additional boiler efficiency improvement seminars are scheduled for 1980. The state will also conduct an inventory of boilers. In 1979, the state developed a wood energy information manual, performed a site-selection survey for small cogenerating wood-fired power plants, and developed a financial analysis service for wood conversions. Landfill surveys and resource recovery technologies were also reviewed. In 1979, $137,000 was spent to support these activities. In 1980, the state intends to spend $317,000 and save 16.5 trillion Btu by continuing these programs (New York State Energy Office 1980b).

Financial Incentives: None identified.

Demonstration Programs: None identified.

Concluding Comments: Like most states, emphasis is on information transfer programs. No long-term state plan has been identified that will have a significant impact on future industrial energy consumption. In the state's 1980 energy conservation plan, no indication is given of any coordination with the federal Industrial Energy Efficiency Program.

D.10 OHIO

Legislative/Regulatory: The Ohio Revised Code (ORC) 5709.45 provides for tax exemptions for energy conversion facilities, solid waste energy conversion facilities, and thermal efficiency improvement facilities. The Ohio Department of Energy will promote this exemption throughout the state.

Administrative: None identified.

Information Transfer: In 1979, the state-supported demonstration projects regarding combustion efficiency and electronic energy management systems. Combustion efficiency demonstration programs focused on oxygen enrichment and the use of furnace curtains. Boiler operator training workshops were also held. The results of workshops and demonstration programs are disseminated throughout the state. Also, the state provided technical assistance on waste heat recovery, waste oil recycling, boiler condensate recycling, and the use of wood waste for industry. The total 1980 energy savings projected from the implementation of the programs are 115 trillion Btu. Planned 1980 expenditures are $900,000.

Financial Incentives: None identified, except tax exemption discussed under Legislative/Regulatory.

Demonstration Programs: Ohio programs described under Information Transfer represented a combination of demonstration and information transfer programs. Each industrial boiler efficiency program consisted of a contract arrangement with firms to an a priori agreement to gather baseline data and disclose the results. These activities were performed in cooperation with appropriate trade and professional associations.

Concluding Comments: Ohio has one of the best nonmandatory industrial-oriented energy conservation programs of the 15 states included in this study. No indication was given, however, on what the state's future plans are in promoting industrial energy conservation, with the possible exception of boiler efficiency standards, which would have to be legislated (Ohio Department of Energy 1979; 1980).

D.11 OREGON

Legislative/Regulatory: In 1979, House Bill 2843 was introduced in the Oregon Legislative Assembly (Oregon Department of Energy 1979), and later passed. The bill encouraged conservation of electricity, petroleum, and natural gas by providing tax relief for Oregon facilities that conserve energy resources or meet future energy requirements through the use of renewable resources. The tax credit allowed in each of the first two years in which the credit is claimed shall be 10% of the certified cost of the facility, but shall not exceed the tax liability of the taxpayer. The credit allowed each of the succeeding three years shall be 5% of the certified cost, not exceeding the tax liability. If any credits are received from the Federal Government, the state tax credit is reduced by an equivalent amount with prior certification by the Director of Tax Credits. The total certified amount for rebate shall not exceed $30 million, but not less than $5 million of the $30 million may be allocated to facilities having a certified cost of $100,000 or less. No estimates were made of the impact of this program in altering industrial energy use requirements. The state has also implemented time-of-day rates for large industrial and commercial customers, and marginal cost pricing is also being considered.

Administrative: None identified.

Information Transfer: Industrial research and workshops have been implemented. In 1980 the total industrial and commercial budget was $167,000, and the planned energy savings for this period was 16.4 trillion Btu (Oregon Laws 1979). No separate energy-saving and budget information was provided for the industrial sector. The state also has an Industrial Energy Advisory Committee that assists the state in developing and implementing industrial energy conservation programs as well as an energy information clearinghouse that provides information on how certain industries can reduce energy consumption. In March 1980, an Energy Management Conference was held for business and industry. The state Energy Office presented forecasts of future energy supplies, demand, and prices. Presentations were made of industrial energy conservation experiences and state energy emergency plans. A series of regional workshops will be held on boiler efficiency, lighting, and energy management for the food industry.

Financial Incentives: No additional incentives were identified other than what was discussed in Legislative/Regulatory.

Demonstration Programs: The state has supported an industrial waste-recovery program. The potential impact on other Oregon industries is unknown at this time.

Concluding Comments: Again, emphasis is placed on information transfer-type programs; however, Oregon appears to be moving toward more programs of a regulatory nature. No clear indication was given of possible additional programs that would likely have a significant impact on future industrial energy consumption.

D.12 PENNSYLVANIA

Legislative/Regulatory: New legislation was recently introduced that would create a Pennsylvania Energy Development Authority, a cabinet-level energy department, and channel $2 million in state funds to promote demonstration projects including conservation and new energy production technologies.

Administrative: None identified.

Information Transfer: A technical assistance program, energy conservation manual, and awards program were established in 1979 (Governor's Energy Council 1979). A recycling program for paper, glass, aluminum, and motor oil was to be established in all 67 counties in 1979. A review of the institutional barriers affecting industrial cogeneration was also made. The total planned 1980 energy savings as a result of these programs is 158 trillion Btu.

Financial Incentives: None identified.

Demonstration Programs: Outside of the recycling programs identified in Information Transfer, no other demonstration programs were identified by state energy staff.

Concluding Comments: Pennsylvania's industrial sector is the major energy consumer because of such large energy-consuming industries as primary metals and chemical and allied products. Although many Pennsylvania industries are likely to be participating in the DOE Industrial Energy Efficiency Program, very little recognition or coordination was evident. Also, although coal interests have requested an increase in the use of coal in the state, no state programs are now in existence to significantly impact existing industrial energy-use patterns.

D.13 TEXAS

Legislative/Regulatory: None identified.

Administrative: None identified.

Information Transfer: Through EPCA/ECPA funds, an Industrial Energy Conservation Resources Center has been supported and on-site audits are provided. The state has six engineers aiding small industry in reducing energy consumption with waste heat recovery as a major means. Workshops have been held to promote waste heat recovery for specific industries. The state reported energy savings of 78 trillion Btu in 1979, and plans to save 282 trillion Btu in 1980. The Texas Energy and Natural Resources Advisory Council has funded a cogeneration study in cooperation with the Texas PUC that will result in a manual for specific industries considering cogeneration alternatives.

Financial Incentives: No industrial energy-conservation financial incentives were identified.

Demonstration Projects: No state-supported projects were identified that would likely have an impact on the state's future industrial energy requirements.

Concluding Comments: As of 1979, the state reportedly has spent $1.5 million for industrial-related energy conservation programs. For 1980, expenditures are expected to total $596,000. Emphasis still seems to be on information transfer. No information was obtained on post-1980 policies and programs that will likely affect industrial energy consumption.

D.14 WEST VIRGINIA

Legislative/Regulatory: None identified.

Administrative: None identified.

Information Transfer: Workshops for training industrial energy auditors will be provided in 1980 as well as a workbook on energy conservation for industrial establishments. It is anticipated that those attending the workshops will share their information with others in the state, resulting in additional energy savings. It is estimated that 1.8 trillion Btu will be saved as a result (West Virginia State Energy Office 1979).

Financial Incentives: None identified.

Demonstration Programs: None identified.

Concluding Comments: Typical of most states reviewed, emphasis is on information programs. No major future policy proposals were identified that would likely have a significant impact on the future industrial energy requirements.

D.15 WISCONSIN

Legislative/Regulatory: The Wisconsin Public Service Commission has been investigating alternative rate designs for electric utilities by requiring time-of-day rates for large commercial and industrial customers. Beginning January 1978, utilities were prohibited from issuing declining block rates. The state Public Service Commission also has approved utility-financed audits for residential, commercial, and industrial sectors.

Administrative: None identified.

Information Transfer: An intensive energy-management course for small industries is offered by the University of Wisconsin extension. The 3-day workshops cover the general to the specific in terms of the energy-saving actions that can be taken in a given industry. Previously, the state has offered over 30 two-day workshops on improving boiler efficiency. Future boiler efficiency workshops are not planned. The total energy savings estimated to result from implementing 1980 industrial energy conservation programs are 13 trillion Btu. The total funding for 1980 commercial and industrial programs is $76,127. No separate expenditures were listed for 1980 conservation programs. Several courses on industrial auditor training are offered throughout the year. Many major gas and electric utilities offer Class A audits and other energy management services. The state is also looking at cogeneration and district heating opportunities. The Wisconsin Public Service Commission has undertaken a study to evaluate cogeneration opportunities in terms of (1) the system-wide effects of cogeneration (2) a computer model for evaluating the impact of cogeneration of electrical demands (3) a computer model for evaluating the impact of cogeneration on total fuel savings and (4) an implementation plan to facilitate the use of industrial and utility cogeneration facilities in Wisconsin. The district heating study will focus on market analysis, technical review and assessment, institutional assessment, and an economic analysis of district heating in a Wisconsin community (Division of State Energy 1980).

Financial Incentives: None identified.

Demonstration Programs: None identified.

Concluding Comments: Again, reliance is placed on information transfer programs and housekeeping measures to aid industry in reducing its future energy requirements.

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SERI

APPENDIX E

RESULTS OF ANALYSIS OF ENERGY INTENSITIES

SERI

Table E-1. PROJECTION OF STATE INDUSTRIAL ENERGY CONSUMPTION BY 2-DIGIT SIC: ALABAMA

SIC	Ratio of Purchased Fuels to Value Added[a] 1971	Ratio of Purchased Fuels to Value Added[a] 1976	Ratio of Purchased Fuels to Value Added[a] 1990	Value Added (Million $)[b] 1976	Value Added (Million $)[b] 1990	Value Added (Million $)[b] Annual Avg. Growth Rate	Purchased Fuels (Trillion Btu) 1976	Purchased Fuels (Trillion Btu) 1990
20 Food & Kindred Products	18.34	13.93	10.49	445.0	575.2	1.85%	6.2	4.8
22 Textile Mill Products	29.23	20.35	14.46	486.5	747.0	3.11%	9.9	10.8
24 Lumber & Wood Products	N/A	23.82	12.06	298.7	552.5	4.72%	6.9	6.7
26 Paper & Allied Products	163.05	108.71	78.18	665.1	1414.9	5.54%	72.3	110.6
28 Chemicals, Allied Products	97.84	102.36	77.38	467.0	997.4	5.57%	47.8	77.2
30 Rubber, Miscellaneous Plastics Products	17.57	11.96	7.89	362.7	628.9	4.01%	5.8	5.0
32 Stone, Clay, Glass Products	193.63	185.91	143.45	153.3	265.8	4.01%	28.5	38.1
33 Primary Metal Industries	105.68	66.14	48.76	982.7	1396.1	2.54%	65.0	68.1
34 Fabricated Metal Products	19.51	9.42	6.85	414.0	560.7	2.19%	3.9	3.8

[a]Thousand Btu per dollar of value added (in 1972 dollars).
[b]In 1972 dollars.

Table E-2. **PROJECTION OF STATE INDUSTRIAL ENERGY CONSUMPTION BY 2-DIGIT SIC: CALIFORNIA**

	Ratio of Purchased Fuels to Value Added[a]			Value Added (Million $)[b]			Purchased Fuels (Trillion Btu)	
SIC	1971	1976	1990	1976	1990	Annual Avg. Growth Rate	1976	1990
20 Food & Kindred Products	23.61	18.71	13.56	4606.4	5203.3	1.01%	86.2	71.9
24 Lumber & Wood Products	21.10	12.90	6.52	1139.2	1579.2	2.36%	14.7	10.3
26 Paper & Allied Products	42.58	33.19	24.93	927.9	1543.1	3.70%	30.8	38.5
28 Chemical, Allied Products	40.11	24.70	18.05	2012.0	3085.0	3.10%	49.7	55.7
29 Petroleum & Coal Products	86.05	90.36	35.60	1301.5	1568.1	1.34%	117.6	55.8
32 Stone, Clay, Glass Products	103.63	88.11	65.21	1111.1	1585.0	2.57%	97.9	103.4
33 Primary Metal Industries	50.56	47.23	34.26	893.5	1448.3	3.51%	42.2	49.6
34 Fabricated Metal Products	11.21	7.75	5.24	2401.3	2779.4	1.05%	18.6	14.6
37 Transportation Equipment	3.41	2.31	1.97	6233.0	7284.8	1.12%	14.4	14.4

[a]Thousand Btu per dollar of value added (in 1972 dollars).
[b]In 1972 dollars.

Table E-3. PROJECTION OF STATE INDUSTRIAL ENERGY CONSUMPTION BY 2-DIGIT SIC: ILLINOIS

SIC	Ratio of Purchased Fuels to Value Added[a] 1971	Ratio of Purchased Fuels to Value Added[a] 1976	Ratio of Purchased Fuels to Value Added[a] 1990	Value Added (Million $)[b] 1976	Value Added (Million $)[b] 1990	Value Added (Million $)[b] Annual Avg. Growth Rate	Purchased Fuels (Trillion Btu) 1976	Purchased Fuels (Trillion Btu) 1990
20 Food & Kindred Products	29.41	26.32	16.16	3535.9	3818.1	0.55%	76.2	61.7
26 Paper & Allied Products	45.12	31.77	22.69	705.0	1005.7	2.57%	22.4	22.8
28 Chemicals, Allied Products	35.24	34.78	25.44	2360.6	3541.6	2.94%	82.1	90.1
32 Stone, Clay, Glass Products	85.67	63.96	48.24	783.3	1062.3	2.20%	50.1	51.2
33 Primary Metal Industries	103.63	74.76	59.08	2062.6	2962.5	2.62%	154.2	175.0
34 Fabricated Metal Products	13.50	11.71	8.68	2902.8	3904.4	2.14%	34.0	33.9
35 Machinery, Except Electrical	10.75	7.01	3.81	4494.6	6473.3	2.64%	31.5	24.7

[a] Thousand Btu per dollar of value added (in 1972 dollars).
[b] In 1972 dollars.

Table E-4. **PROJECTION OF STATE INDUSTRIAL ENERGY CONSUMPTION BY 2-DIGIT SIC: INDIANA**

SIC	Ratio of Purchased Fuels to Value Added[a]			Value Added (Million $)[b]			Purchased Fuels (Trillion Btu)	
	1971	1976	1990	1976	1990	Annual Avg. Growth Rate	1976	1990
20 Food & Kindred Products	29.41	26.32	19.94	1003.1	1013.0	0.07%	26.4	20.2
28 Chemicals, Allied Products	30.04	18.03	14.19	1359.1	2103.3	3.17%	24.5	29.9
32 Stone, Clay, Glass Products	117.73	104.64	81.23	458.7	641.1	2.42%	48.0	52.1
33 Primary Metal Industries	96.30	112.63	88.88	2225.0	3042.4	2.26%	250.6	270.4
34 Fabricated Metal Products	14.91	13.89	10.30	1195.1	1540.5	1.83%	16.6	15.9
35 Machinery, Except Electrical	11.49	6.54	3.87	1545.5	2268.8	2.78%	10.1	8.8

[a]Thousand Btu per dollar of value added (in 1972 dollars).
[b]In 1972 dollars.

Table E-5. **PROJECTION OF STATE INDUSTRIAL ENERGY CONSUMPTION BY 2-DIGIT SIC: LOUISIANA**

SIC	Ratio of Purchased Fuels to Value Added[a] 1971	1976	1990	Value Added (Million $)[b] 1976	1990	Annual Avg. Growth Rate	Purchased Fuels (Trillion Btu) 1976	1990
20 Food & Kindred Products	44.53	38.11	34.35	582.5	694.1	1.26%	22.2	23.8
26 Paper & Allied Products	190.89	136.94	118.33	504.6	750.9	2.88%	69.1	88.9
28 Chemicals, Allied Products	235.23	203.31	153.31	2329.9	2458.3	5.51%	473.7	756.9
29 Petroleum & Coal Products	516.12	131.49	86.21	1028.2	1048.0	1.93%	135.2	115.8
32 Stone, Clay, Glass Products	156.54	108.41	96.53	152.2	276.6	4.36%	16.5	26.7
33 Primary Metal Industries	N/A	228.46	124.22	197.0	488.4	6.70%	60.2	60.7

[a]Thousand Btu per dollar of value added (in 1972 dollars).
[b]In 1972 dollars.

Table E-6. PROJECTION OF STATE INDUSTRIAL ENERGY CONSUMPTION BY 2-DIGIT SIC: MICHIGAN

SIC	Ratio of Purchased Fuels to Value Added[a]			Value Added (Million $)[b]			Purchased Fuels (Trillion Btu)	
	1971	1976	1990	1976	1990	Annual Avg. Growth Rate	1976	1990
20 Food & Kindred Products	22.64	15.77	12.52	1382.1	1590.9	1.01%	21.8	19.9
26 Paper & Allied Products	135.34	98.43	72.52	512.0	549.8	0.51%	50.4	39.9
28 Chemicals, Allied Products	72.73	45.12	35.09	1389.5	1863.8	2.12%	62.7	65.4
32 Stone, Clay, Glass Products	113.05	115.91	88.32	453.8	616.3	2.21%	52.6	54.4
33 Primary Metal Industries	61.64	60.35	50.40	1882.3	2641.5	2.45%	113.6	133.1
34 Fabricated Metal Products	9.96	10.65	8.14	2958.6	4090.0	2.34%	31.5	33.3
35 Machinery, Except Electrical	9.62	6.05	3.77	3109.0	3237.6	0.29%	18.8	12.2
37 Transportation Equipment	15.52	14.82	13.27	6349.7	9182.5	2.67%	94.1	121.9

[a]Thousand Btu per dollar of value added (in 1972 dollars).
[b]In 1972 dollars.

Table E-7. PROJECTION OF STATE INDUSTRIAL ENERGY CONSUMPTION BY 2-DIGIT SIC: MISSOURI

SIC	Ratio of Purchased Fuels to Value Added[a]			Value Added (Million $)[b]			Purchased Fuels (Trillion Btu)	
	1971	1976	1990	1976	1990	Annual Avg. Growth Rate	1976	1990
20 Food & Kindred Products	25.05	20.25	14.82	1012.3	1084.0	0.49%	20.5	16.1
28 Chemicals, Allied Products	36.80	24.65	18.45	973.8	1348.0	2.35%	24.0	24.9
32 Stone, Clay, Glass Products	234.82	205.73	153.31	262.0	353.9	2.17%	53.9	54.3
33 Primary Metal Industries	58.71	44.16	34.79	369.1	624.7	3.83%	16.3	21.7
34 Fabricated Metal Products	11.17	14.83	9.77	532.8	544.1	0.15%	7.9	5.3
37 Transportation Equipment	5.70	3.44	2.97	2763.2	3899.0	2.49%	9.5	11.6

[a]Thousand Btu per dollar of value added (in 1972 dollars.)
[b]In 1972 dollars.

Table E-8. PROJECTION OF STATE INDUSTRIAL ENERGY CONSUMPTION BY 2-DIGIT SIC: NEW JERSEY

SIC	Ratio of Purchased Fuels to Value Added[a]			Value Added (Million $)[b]			Purchased Fuels (Trillion Btu)	
	1971	1976	1990	1976	1990	Annual Avg. Growth Rate	1976	1990
20 Food & Kindred Products	18.35	14.28	10.64	1583.3	1777.5	0.83%	20.5	18.9
22 Textile Mill Products	28.39	24.61	19.75	276.3	350.8	1.72%	6.8	7.0
26 Paper & Allied Products	61.28	41.58	33.40	584.4	942.1	3.47%	24.3	31.5
28 Chemicals, Allied Products	29.41	18.64	15.65	4206.0	7108.9	3.82%	78.4	111.3
30 Rubber, Miscellaneous Plastics Products	16.01	10.80	8.29	574.0	756.3	1.99%	6.2	6.3
32 Stone, Clay, Glass Products	N/A	63.48	75.94	636.4	649.1	1.99%	40.4	63.7
33 Primary Metal Industries	54.06	27.31	23.15	571.3	521.5	0.65%	15.6	12.1
34 Fabricated Metal Products	13.70	8.66	7.04	1454.6	2117.9	2.72%	9.0	10.7
35 Machinery, Except Electrical	8.13	6.47	4.49	1110.1	1430.9	1.83%	7.2	6.4

[a]Thousand Btu per dollar of value added (in 1972 dollars).
[b]In 1972 dollars.

Table E-9. PROJECTION OF STATE INDUSTRIAL ENERGY CONSUMPTION BY 2-DIGIT SIC: NEW YORK

	Ratio of Purchased Fuels to Value Added[a]			Value Added (Million $)[b]			Purchased Fuels (Trillion Btu)	
SIC	1971	1976	1990	1976	1990	Annual Avg. Growth Rate	1976	1990
20 Food & Kindred Products	18.35	14.28	12.40	2086.8	1696.1	-1.47%	29.8	21.0
26 Paper & Allied Products	59.56	47.93	39.43	1102.4	917.5	-0.63%	39.5	29.7
28 Chemicals, Allied Products	27.95	25.23	20.86	2247.2	2450.3	0.62%	56.7	51.1
32 Stone, Clay, Glass Products	58.99	53.24	42.92	711.9	765.5	0.52%	37.9	32.9
33 Primary Metal Industries	59.98	44.85	38.41	1192.8	1399.9	1.15%	53.5	53.7
34 Fabricated Metal Products	13.60	8.18	6.86	1454.6	1454.6	0.00%	11.9	10.0
35 Machinery, Except Electrical	8.33	5.37	3.81	3390.8	3990.5	1.17%	18.2	15.2
37 Transportation Equipment	7.76	10.24	9.80	1338.0	1343.6	0.03%	13.7	13.2
38 Instruments, Related Products	8.61	7.49	6.38	3804.4	4090.9	0.52%	28.5	26.1

[a]Thousand Btu per dollar of value added (in 1972 dollars).
[b]In 1972 dollars.

Table E-10. PROJECTION OF STATE INDUSTRIAL ENERGY CONSUMPTION BY 2-DIGIT SIC: OHIO

SIC	Ratio of Purchased Fuels to Value Added[a] 1971	Ratio 1976	Ratio 1990	Value Added (Million $)[b] 1976	Value Added 1990	Value Added Annual Avg. Growth Rate	Purchased Fuels (Trillion Btu) 1976	Purchased Fuels 1990
20 Food & Kindred Products	20.18	14.64	11.38	2000.9	2296.8	0.99%	29.3	26.1
26 Paper & Allied Products	85.52	69.85	48.22	665.7	831.4	1.60%	46.5	40.1
28 Chemicals, Allied Products	54.73	35.16	26.38	2090.6	3293.6	3.30%	73.5	86.9
29 Petroleum & Coal Products	116.56	46.27	22.13	438.7	621.6	2.52%	20.3	19.5
32 Stone, Clay, Glass Products	108.42	79.67	62.28	1206.2	1667.5	2.34%	96.1	103.9
33 Primary Metal Industries	116.55	86.94	69.91	3514.1	4877.9	2.37%	305.5	341.0
35 Machinery, Except Electrical	12.52	7.57	7.96	3883.7	5376.2	2.35%	29.4	38.8
37 Transportation Equipment	9.05	7.29	3.84	3989.7	6209.3	3.21%	29.1	20.6

[a]Thousand Btu per dollar of value added (in 1972 dollars).
[b]In 1972 dollars.

Table E-11. PROJECTION OF STATE INDUSTRIAL ENERGY CONSUMPTION BY 2-DIGIT SIC: OREGON

SIC	Ratio of Purchased Fuels to Value Added[a] 1971	1976	1990	Value Added (Million $)[b] 1976	1990	Annual Avg. Growth Rate	Purchased Fuels (Trillion Btu) 1976	1990
20 Food & Kindred Products	27.57	16.00	11.74	487.5	606.3	1.57%	7.8	7.1
24 Lumber & Wood Products	24.37	14.83	7.57	1557.2	2085.9	2.11%	23.1	15.8
26 Paper & Allied Products	108.66	68.54	49.66	366.2	669.2	4.40%	25.1	33.2
28 Chemicals, Allied Products	68.45	51.38	39.79	79.8	137.4	3.96%	4.1	5.5
32 Stone, Clay, Glass Products	N/A	90.80	65.48	85.9	150.9	4.08%	7.8	9.9

[a]Thousand Btu per dollar of value added (in 1972 dollars).
[b]In 1972 dollars.

Table E-12. **PROJECTION OF STATE INDUSTRIAL ENERGY CONSUMPTION BY 2-DIGIT SIC: PENNSYLVANIA**

SIC	Ratio of Purchased Fuels to Value Added[a] 1971	1976	1990	Value Added (Million $)[b] 1976	1990	Annual Avg. Growth Rate	Purchased Fuels (Trillion Btu) 1976	1990
20 Food & Kindred Products	20.71	14.28	12.28	2144.7	2287.0	0.46%	31.9	28.1
26 Paper & Allied Products	85.96	52.14	37.78	935.9	1245.1	2.06%	48.8	47.0
28 Chemicals, Allied Products	40.61	29.31	22.66	1814.8	2358.7	1.89%	53.2	53.5
29 Petroleum & Coal Products	101.60	67.12	28.85	520.0	520.0	0.63%	34.9	16.4
32 Stone, Clay, Glass Products	115.16	94.04	72.10	1023.0	1281.1	1.62%	96.2	92.4
33 Primary Metal Industries	105.97	85.09	67.14	4399.9	5781.7	1.97%	374.4	388.2
34 Fabricated Metal Products	14.52	12.19	9.78	2001.3	2793.2	2.41%	24.4	27.3

[a]Thousand Btu per dollar of value added (in 1972 dollars).
[b]In 1972 dollars.

Table E-13. PROJECTION OF STATE INDUSTRIAL ENERGY CONSUMPTION BY 2-DIGIT SIC: TEXAS

SIC	Ratio of Purchased Fuels to Value Added[a] 1971	1976	1990	Value Added (Million $)[b] 1976	1990	Annual Avg. Growth Rate	Purchased Fuels (Trillion Btu) 1976	1990
20 Food & Kindred Products	20.08	17.45	14.06	1977.4	2748.6	2.38%	34.5	38.6
26 Paper & Allied Products	109.23	93.78	72.10	446.8	820.8	4.44%	41.9	59.2
28 Chemicals, Allied Products	195.26	166.56	128.67	4625.4	7733.9	3.74%	770.4	995.1
29 Petroleum & Coal Products	470.68	208.26	107.37	2926.7	3670.2	1.63%	609.5	394.1
32 Stone, Clay, Glass Products	167.14	131.82	105.46	688.8	1284.2	4.55%	90.8	135.4
33 Primary Metal Industries	181.96	100.42	74.20	735.9	1445.9	4.94%	73.9	107.3

[a]Thousand Btu per dollar of value added (in 1972 dollars).
[b]In 1972 dollars.

Table E-14. PROJECTION OF STATE INDUSTRIAL ENERGY CONSUMPTION BY 2-DIGIT SIC: WEST VIRGINIA

SIC	Ratio of Purchased Fuels to Value Added[a] 1971	1976	1990	Value Added (Million $)[b] 1976	1990	Annual Avg. Growth Rate	Purchased Fuels (Trillion Btu) 1976	1990
28 Chemicals, Allied Products	122.33	94.07	71.66	905.7	1000.0	0.71%	85.2	71.7
29 Petroleum & Coal Products	180.85	174.85	95.23	32.6	83.5	6.95%	5.7	8.0
32 Stone, Clay, Glass Products	100.91	76.09	59.59	304.9	404.0	2.03%	23.2	24.1
33 Primary Metal Industries	87.99	85.37	64.46	561.1	809.2	2.65%	47.9	52.2

[a]Thousand Btu per dollar of value added (in 1972 dollars).
[b]In 1972 dollars.

Table E-15. PROJECTION OF STATE INDUSTRIAL ENERGY CONSUMPTION BY 2-DIGIT SIC: WISCONSIN

	Ratio of Purchased Fuels to Value Added[a]			Value Added (Million $)[b]			Purchased Fuels (Trillion Btu)	
SIC	1971	1976	1990	1976	1990	Annual Avg. Growth Rate	1976	1990
20 Food & Kindred Products	30.06	22.78	17.38	1545.2	1908.6	1.52%	35.2	33.2
26 Paper & Allied Products	111.92	78.72	55.67	1109.0	1632.4	2.80%	87.3	90.9
28 Chemicals, Allied Products	23.10	13.58	10.87	360.9	592.1	3.60%	4.9	6.4
32 Stone, Clay, Glass Products	60.37	26.55	20.80	199.6	293.4	2.79%	5.3	6.1
33 Primary Metal Industries	49.17	26.41	21.50	549.1	974.2	4.18%	14.5	20.9
34 Fabricated Metal Products	12.71	13.72	10.00	1107.9	2038.1	4.45%	15.2	20.4
35 Machinery, Except Electrical	10.12	6.21	3.55	2495.6	3569.8	2.59%	15.5	12.5
37 Transportation Equipment	7.85	7.78	6.76	1079.5	1521.1	2.48%	8.4	10.3

[a]Thousand Btu per dollar of value added (in 1972 dollars).
[b]In 1972 dollars.

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15. Supplementary Notes

16. Abstract (Limit: 200 words) This three-volume report examines current and future energy demands, end uses, and cost used to characterize typical applications and resultant services in the industrial sector of the United States and 15 selected states. A review and evaluation of existing industrial energy data bases was undertaken to assess their potential for supporting SERI research on: (1) market suitability analysis, (2) market development, (3) end-use matching, (3) industrial applications case studies, and (4) identification of cost and performance goals for solar systems and typical information requirements for industrial energy end use. In reviewing existing industrial energy data bases, the level of detail, disaggregation, and primary sources of information were examined. The focus was on fuels and electric energy used for heat and power purchased by the manufacturing subsector and listed by 2-, 3-, and 4-digit SIC, primary fuel, and end use. Projections of state level energy prices to 1990 are developed and presented using the energy intensity approach. The effects of federal and state industrial energy conservation programs on future industrial sector demands were assessed. Future end-use energy requirements were developed for each 4-digit SIC industry and were grouped as follows: (1) hot water, (2) steam (212°-300°F, each 100°F interval from 300°-1000°F, and greater than 1000°F), and (3) hot air (100°F intervals). Volume I details the activities performed in this effort; Volume II presents data on the U.S. Manufacturing subsector energy consumption, efficiency, growth rates, and cost for 1971, 1974, and 1976; and Volume III contains the same data but for the 15 selected states in 1974 and 1976.

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