Statement by Dr. Edward E. David, Jr.
Director, Office of Science and Technology
before the
House Committee on Science and Astronautics
May 25, 1972

Mr. Chairman, members of the Committee:

I appreciate the opportunity to appear before you today at the close of your extensive series of hearings on energy research and development. This is an area vital to the nation's future well-being and an area in which the Office of Science and Technology has played a significant role over the past several years.

Energy research and development is but part of the larger issue involving the nation's future energy supplies and the impact of their production and consumption on the environment. In my view, new energy technologies are essential and offer perhaps the only real opportunity for meeting our energy needs in the decades ahead.

Just about one year ago in his June 4, 1971 message to Congress the President recognized the need for a sufficient supply of clean energy to sustain economic growth and improve the quality of our national life. In announcing a broad action program to assure adequate supplies of clean energy for the years ahead and to make better use of our existing supplies, the President recognized the importance of new technology. Three technological options were given high priority in the message -- the liquid metal fast breeder reactor, high Btu. coal gasification and sulfur oxide control processes. Development of these technologies will permit greater reliance on the energy resources which this country possesses in greatest abundance - coal and uranium. In conjunction with the accelerated leasing program for off-shore oil and gas, oil shale and geothermal resources, also announced in the message, these actions will assure that the nation's domestic resource base is adequately developed to avoid excessive dependence on foreign energy supplies and the uncertainties inherent therein.

Whereas the liquid metal fast breeder and coal gasification programs are intended to meet needs beyond 1980, the sulfur oxide control technology is essential if the Clean Air Act Amendments of 1970 are to be implemented by 1975. Most domestic coal has an unacceptably high sulfur content to be used without prior cleanup or suitable stack gas cleanup systems. Both are costly options and at this time neither approach has been adequately demonstrated. The accelerated program to develop stack gas cleaning systems should yield results later this year from jointly funded industry - government efforts. If these approaches are successful, industry will still face a significant challenge in manufacturing and installing the equipment in time to meet the 1975 standards.

Natural gas, our cleanest fuel, is currently in short supply and unavailable for new consumers in many parts of the country where the need is the greatest. For years we have made growing use of this fuel, but the low cost supplies of the past are being rapidly depleted. There are several alternative sources -- imports of liquified natural gas and liquid feedstocks for synthetic natural gas, deeper domestic drilling on shore, off-shore exploration, nuclear stimulation and gasification of coal. Unfortunately all of these will produce more expensive gas with several of the options costing on the order of $1 per thousand cubic feet as compared with current wellhead prices of about 25¢ per thousand cubic feet.

The President's acceleration of the coal gasification program offers the promise of meeting these needs beyond 1980, but if the needs of this decade are to be met, it is imperative that domestic exploration and production be markedly increased. The Administration has supported legislation which would permit wellhead price increases which appropriately reflect the value of natural gas as a premium fuel and the increased cost of finding and producing it from more remote formations.

Nuclear energy offers the most promising solution to meeting our future electrical power requirements. The current generation of light water reactors, while among our cleanest source of electrical energy, utilize only 2% of the energy potential in the uranium they consume.

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While not as dramatic as the breeder, a variety of options are available for improving energy utilization. We do not believe an arbitrary curtailment of demand for energy is either necessary nor desirable at present. It appears, however, that we can have homes and offices as warm in winter and as cool in summer as we do at present with significantly less energy through the use of better designs, more insulation, heat pumps, total energy systems and recuperators. Not only does such improved utilization reduce the resources consumed and the environmental impact at the point of use, but it reduces waste and pollution throughout the entire cycle.

The Office of Science and Technology played a special role in two of the actions noted in the message. The effort leading to the power plant siting legislation proposed by the Administration was chaired by OST. This legislation which would establish comprehensive procedures for long range planning, early site review and preconstruction certification of all large power plants and transmission lines was sent to Congress more than a year ago. The need for action on this legislation has become increasingly evident in recent months.

In the Message the President also asked me to review promising technologies not already highlighted to establish additional priority programs. With the cooperation of the other agencies involved in energy R&D, we have undertaken a broad study of promising technological areas. This effort, under the auspices of the Federal Council for Science and Technology and chaired by Mr. Weinhold, involves three specific steps. (1) The Associated Universities, Inc., which operates Brookhaven National Laboratory, has prepared a study plan and reference projections to be used in the assessment of the various technologies. (2) The agencies are sponsoring 11 technical panels which are studying the specific technological options in detail. These panels will assess the potential impact of each of the technologies using the reference system developed by AUI, and will develop detailed R&D plans for the most promising of the options. (3) Finally, an OST overview panel of consultants will review the work of the technical panels, to assure a degree of uniformity and objectivity. The technological areas to be considered range from clean fuels from coal and nuclear fusion to solar energy and utilization technology. This effort which is scheduled to be completed this fall is intended to provide options for consideration during the preparation of the FY 74 budget.

We have not waited until the completion of the study for some new initiatives to be taken in energy R&D. I have attached to my statement a paper on Federal energy R&D funding which describes briefly the ongoing efforts of the different Federal agencies involved in civilian energy R&D and includes a tabulation of their funding levels during the past five fiscal years. I am pleased to note that there have been significant increases over this period, particularly between FY 71 and FY 72 reflecting the energy message and the FY 72-FY 73 change reflecting new priorities. The overall Federal energy R&D funding has gone from approximately $360 million to $620 million per year over this period. Not only does this represent a significant increase but also a shift in priorities. Although the absolute magnitude for the funding for fusion and the breeder increased during this period, their relative share of the total decreased due to the large expansion of coal and environmentally related energy R&D.

As we look to the future we see a wide variety of promising new sources such as solar energy, geothermal energy, and nuclear fusion. During the past year Representative McCormack's Task Force and more recently your Subcommittee, have heard many individuals discuss these options which I will not take time to reiterate.

Some appear to offer the perfect solution -- abundant low cost energy with no adverse environmental impact. As one looks closely at the entire energy system from resources in the ground through the transmission, conversion, utilization and waste disposal processes, he finds that the attractiveness of the option varies and no one stands head and shoulders above all the rest. Our energy economy is too complex and nature not so gracious as to allow the simple quick fix.

After considering the many technological options, I feel quite optimistic about the role technology can play in resolving the nation's energy problems. The big question, however, is whether we can bring the necessary funds and management to bear on the subject. Developing an improved energy system for the domestic economy is a far different exercise than building a new weapons system or even sending men to the moon. Many more organizations and individuals, each with different motivations and interests, are involved, particularly when the groups which will actually use the technology are considered. This fragmentation makes it much harder to establish R&D priorities, accumulate the necessary funds and determine management responsibility.

The fragmentation within the government is well known to you. In the Executive Branch, the Atomic Energy Commission and Department of Interior have been the predominant energy R&D agencies. Today although they continue to fund the major fraction of civilian energy R&D, they have been joined recently by the Environmental Protection Agency, the National Science Foundation, the Department of Commerce's

National Bureau of Standards, the Tennessee Valley Authority and The Department of Housing and Urban Development. It was for just this reason that the President proposed to establish an Energy Administration within the Department of Natural Resources. As it is now envisioned the Energy Administration would set energy programs and priorities for virtually all of the Federal energy R& D efforts. Such an agency would be able to establish a broadly constituted program staff to assure that all of the most promising efforts were being pursued either by government or the private sector.

Turning now to the private sector we find just as much fragmentation and diversity of interest. Several distinctly different and independent groups play major roles in energy R&D. Traditionally, large equipment manufacturers were the primary source of R&D programs and funding. Large turbine, boiler and electrical equipment manufacturers developed the fossil fuel electric power generation equipment as it has evolved. For these firms energy R&D is really a form of product development paid for through the price of the equipment they sell. Recently the emergence of foreign suppliers competing in the U. S. market coupled with tariff and non-tariff barriers to U. S. companies marketing in Western Europe and Japan have reduced the ability of the domestic firms to recover the cost of their R&D. These factors coupled with the increasing cost of energy R&D has caused manufacturers to reassess the levels of their efforts.

The consumers of this technology, specifically the electric and gas utilities, are even more fragmented with about 3400 electric firms alone. They have recently begun to recognize the need for much greater direct participation in the funding and management of energy R&D. The electric utilities through their trade associations and more recently through the Electric Research Council, which encompasses all segments of the industry, are planning a much more vigorous role. They have recently incorporated as an Electric Power Research Institute which will conduct its own R&D to be funded through an industry wide assessment. In our testimony of last March when the Senate Commerce Committee was considering a mandatory energy R&D fee, we indicated our preference for the voluntary approach but recognized several serious problems which must be overcome. In view of the vital need for additional funding in this area we suggested that following a trial period, the voluntary approach be evaluated and if it were not working satisfactorily a mandatory approach should be reconsidered. In the meantime we would hope that the gas utilities could establish a similar mechanism for R&D support to achieve the benefits of a pluralistic system.

Coal companies have traditionally been smaller businesses with little or no research and development capability. They depended upon their equipment manufacturers and the Bureau of Mines for technological innovation and development. More recently petroleum companies have begun to acquire an increasing interest in the coal industry. While this trend toward integration in the energy field has concerned some, one positive aspect which deserves recognition is the potential value of coupling the R&D oriented petroleum companies with our most abundant, but least researched energy source - coal. It is our hope that the technology needed to convert coal to a clean more useable fuel will receive higher priority within the private sector, where much of the know how resides.

One of the major strengths of the United States research and development establishment has been its pluralistic nature. This concept is sound providing that there are groups or organizations capable of bringing together a critical mass of talent and funding to develop the ideas through commercialization. Unfortunately, in many areas the fragmentation has been so great that adequate funding and management have not emerged. The need, therefore, is to ensure an energy R&D system which maintains as much flexibility and pluralism as is possible, but still retains the ability to pursue promising technologies through ultimate implementation.

As we look to the future, there is need for better institutional structures and for clear policy guidance for them. The Energy Administration in the proposed Department of Natural Resources should provide a mechanism for developing more unified energy policies and for guiding all Federal energy R&D. With a well defined energy policy, industry can better chart its own course and undertake a bigger share of the load on its own.

We envision three basic types of projects. Projects which industry sees as profitable will be supported by industry. Projects which offer high benefits to the nation, but where these benefits can not be captured by the industries, should be supported primarily by the Federal Government. A limited number of large high cost, high priority programs will warrant a government-industry partnership effort.

The three programs highlighted in the President's Energy Message are all partnership efforts with the Federal Government and industry jointly providing the funds and management direction. A joint management team has already been set up by the Interior Department and the American Gas Association to manage the high Btu. coal gasification effort. A new corporation has been set up to handle the LMFBR demonstration program. The sulfur oxide control technology demonstration efforts likewise involve joint funding by the Federal Government and utilities. It is difficult to predict at this point which of the management techniques and approaches will prove most successful or what further modifications may be required in the future. Many fundamental questions of risk sharing and management decision making are involved which can be solved only through practice.

Looking ahead I see the technological opportunities to solve many of our energy problems available and waiting for exploitation. The mechanisms for converting this promise to reality have been identified but they have not yet been implemented. I would hope to see several strong independent private and government entities each pursuing vigorous R&D programs in constructive competition. Strong industry R&D groups should be able to develop much of the new technology required in the years ahead, but the Federal Government must continue to exhibit a strong leadership role. The ideas and potentialities are there but they will require the energies of all concerned to bring them to fruition.

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Organization of the

Federal Council for Science and Technology

ENERGY R&D GOALS STUDY

The Office of Science and Technology in response to the request in the President's June 4, 1971 message to Congress on energy, designed and organized a study to assess other promising technologies in order that additional ones might be identified for priority treatment. The basic study plan was developed and technologies selected for study by Associated Universities, Inc., which operates Brookhaven National Laboratory, on the basis of consultations with OST, other government agencies and knowledgeable experts from outside the government. Modifications have been made to the original plan to reflect changing circumstances.

The plan involves three distinct phases which are administratively coordinated through the Federal Council for Science and Technology Energy R&D Goals Committee. This Committee, chaired by Mr. J. Frederick Weinhold from the Office of Science and Technology, is the vehicle by which all government agencies with operational as well as advisory interests in energy R&D can participate in the effort.

The first phase of the study, preparation of a common framework in which to evaluate energy technologies, has recently been completed by Associated Universities, Inc., under contract with OST. A brief description of the Reference Energy System approach is included in this report.

The second and largest phase involves eleven different federal agency sponsored technical panels, which are conducting detailed technical assessment of each of the promising technologies. These panels are responsible for assessing the technologies and for preparing R&D plans for developing the priority technologies. As described below each of the panels is organized to deal with the specific questions involved and the current state of knowledge. These panels have been working actively during the past several months and most are expected to complete their preliminary reports this month.

The third phase of the study involves the use of an Office of Science and Technology panel of consultants to review and integrate the reports of the eleven technical panels. This overview panel, using the other panel reports as well as independent inputs is intended to assure a degree of uniformity and objectivity. This panel is just beginning its work and the membership list is not yet final. It will include a broad spectrum of individuals from the energy industries and the universities experienced in moving technology from the laboratory to commercial use.

The report of the overview panel together with the eleven technical panel reports and backup information are intended to identify technically sound elements for a national energy R&D program. Specific operational and budgetary decisions for Fiscal Year 1974 based on this report will be made by the existing agency and budgetary machinery. Although no decision concerning the reports has been made, it is hoped that much of the material will be released in early 1973.

Part I - Reference Energy System - Associated Universities, Inc.

From the beginning of the OST assessment it was clear that an important requirement was a common framework in which to evaluate the great variety of possible new energy technologies. A key concept that was created for this purpose is the Reference Energy System.

A Reference Energy System is a representation of the set of technical activities that are required to convert various energy resources into useful forms of energy for specific end uses. A network flow diagram is used to describe the resource consumption, fuel transportation, conversion processes and end uses that characterize the system at a given time. The systems are quantified and supplemented with a standardized data base that includes estimates of energy demands, resource availability, economic factors, and environmental impacts.

Reference Energy Systems, to be used by both technical panels and the overview committee, have been prepared for the base year 1969 and four future years: 1977, 1985, 2000, and 2020. These time periods were selected to provide for the evaluation of both near and longer term energy technologies within the same overall framework. The systems provide "snapshots" of the future energy systems that are essentially "surprise-free" from a technological viewpoint. They are formulated essentially around existing technologies; however, coal gasification to pipeline quality gas and the liquid metal fast breeder reactor (LMFBR) have been introduced into future systems reflecting the fact that these have been identified for priority R&D support and active development work is in progress.

Projections of energy demand, by specific end use, and the fuel mix used to satisfy those demands have been made for the four future reference years. Related to each Reference Energy System is a compilation of the major environmental impacts: pollutant emissions, radioactivity release, land use, etc. Estimates of resource availability and costs of various elements of the energy system have been assembled from various sources.

In the context of this assessment the Reference Energy Systems and associated data serve two basic purposes. First, they assure that all of the technical panels use common assumptions regarding future energy demand, resources, environmental impact and economics. In fact this uniformity of assumptions is considered to be more important than the accuracy of the projections per se. Second, they provide a means of evaluating the impact of the development of a new energy technology. By substituting a new technology for a portion of the Reference Energy System at some appropriate time in the future one can determine the effect of that technology on the total environmental impact of the system, resource consumption and overall cost.

Of course, the Reference Energy System framework includes explicitly only the major quantifiable parameters that describe the energy system of the country. Energy is such a pervasive and basic element in our society that it is impossible to quantify many important aspects of it. In some areas technical knowledge is lacking (e.g. the links between emissions of air pollutants and health effects). In other areas essentially non-technical factors are involved (e.g. the question of national self-sufficiency in energy resources). Nevertheless, the technical panels are requested to consider a variety of factors, such as reliability and national security implications, that are not explicitly included in the Reference Energy Systems. The technical panels are also requested to outline appropriate R&D programs to bring their technologies to fruition in the most efficient manner.

Although the Reference Energy Systems, the associated data on resources, etc., and the common instructions to the panels are intended to provide the basic structure of the assessment, they by no means provide the final answers. These must be determined by the technical panels and the overview committee through a process of iteration.

Part II - Technology Panels

A - Clean Fuels from Coal - Office of Coal Research, Department of the Interior

As indicated in the President's Clean Energy Message of June 4, 1971, coal can be transformed into a clean liquid fuel, a clean gaseous fuel, and a clean solid fuel. For purposes of discussion, we regularly refer to these primary clean coal products as low-sulfur fuel oil, low-B.t.u. gas, and solvent refined coal. If any of these products are to meet EPA air quality standards, the coal must be chemically manipulated to produce hydrogen sulfide which can then be removed and converted to elemental sulfur using commercially available processes.

A contract has been executed between the Office of Coal Research and the National Academy of Engineering to study the production of clean fuels from coal. Membership of the panel is the same as the panel which studied the production of high-B.t.u. pipeline gas and is shown on Attachment No. A. This committee has met for about one day each month and has considered fixed, moving, and fluid bed gasification systems as well as the appropriate gas cleanup. In developing their report, the committee will consider each of the presentations made to them and factor in the detailed knowledge they have as a result of their prior study for the Department of the Interior on the production of high-B.t.u. pipeline gas from coal.

Low sulfur fuel oil can be produced from coal by a number of alternate routes:

1. Direct hydrogenation.

2. Solvent extraction followed by hydrogenation.

3. Carbonization followed by hydrogenation.

The direct hydrogenation of coal must include a detailed evaluation of hydrogenation in a fixed-bed catalyst system and an ebullated-bed catalyst system. Some work, in each area, is being conducted with private funding, but all the announced efforts have been at a small-scale stage of experimentation.

Coal may be dissolved in a process derived solvent with subsequent separation of the undissolved mineral matter. The resulting liquid can then be hydrogenated to yield a fuel oil and the solvent needed. Hydrogen required for the hydrogenation can be produced from the undissolved mineral fraction. To insure practicality, the system must be operated at a low total pressure with minimum hydrogen use.

Carbonization of coal is effective in producing a tar-like liquid oil, a gas, and a residual char. Such systems can be operated at relatively modest pressures ranging from a few pounds to as much as 30 atmospheres. Most systems of interest, however, cannot be applied to high rank caking coals typical of Appalachia. The oil and gas, resulting from the carbonization, can be converted to clean burning fuels by removing hydrogen sulfide from the gas and by hydrogenating the oil followed by removal of the hydrogen sulfide resulting from the hydrogenation. The residual char, with a sulfur content dependent on process conditions, can be used to produce the hydrogen needed and additional low-B.t.u. gas. Carbonization systems have a significant advantage since they are relatively simple and therefore cheaper than more sophisticated systems.

Low-B.t.u. fuel gas may be obtained by gasifying coal in any of a number of ways. The primary feature of all processes, however, is the use of air in a simple gasification system which is followed by removal of hydrogen sulfide from the resulting low-B.t.u. gas. Principal efforts will be devoted to the study of the best mechanical system for gasification of the widest range of coals. Additionally, improved gas cleanup systems, that can be integrated with the gasifier, will be evaluated on a research basis for subsequent inclusion in a final development plant. The effect of pressure on the gasification system chosen must be evaluated with particular reference to incorporating the production of gas with its final end use. It may be appropriate to use one system for an advanced combined cycle powerplant, with another system used for an existing powerplant. Quite obviously, either or both systems may find application in the production of low-B.t.u. gas for other industrial purposes.

The production of low-B.t.u. gas from coal can be substantially improved if a gas cleanup system, operating at gasifier temperature, can be developed. A number of candidates appear worthy of tests and will be included in the ultimate developmental plan.

Substantially, any coal can be completely dissolved by slurrying it in a process derived oil with subsequent dissolution occurring in the presence of either hydrogen or synthesis gas produced from the undissolved mineral matter in the coal. The process differs from that used in the production of low-sulfur fuel oil by combining the hydrogenation and dissolution in a single step. After separation of the mineral matter, the coal can be reformed yielding the solvent needed and a solid low-sulfur, low-ash coal.

To convert coal to a clean-burning fuel may require a combination process that produces some gas and some liquid or some liquid and some solid. It is important, therefore, to continue detailed engineering assessments of the technology in each area as the research and development work proceeds to insure that the best process is obtained in the shortest possible time.

Attachment A

CLEAN FUELS FROM COAL PANEL

Thomas H. Chilton, Retired, E. I. du Pont de Nemours and Company, Inc., Chairman

Howard R. Batchelder, Battelle Memorial Institute

Martin A. Elliott, Texas Eastern Transmission Corporation

Harold L. Falkenberry, Tennessee Valley Authority

Edward J. Gornowski, ESSO Research & Engineering Company

William B. Harrison, Southern Services, Inc.

Hoyt C. Hottell, Massachusetts Institute of Technology

Stephen Lawroski, Argonne National Laboratory

B. M. Louks, Stanford Research Institute

Brunn W. Roysden, Commonwealth Edison Company, Inc.

STAFF

R. W. Crozier, Executive Secretary, Committees on Pollution Abatement and Control, National Research Council

Wilburn C. Schroeder, Staff Engineer, Committees on Pollution Abatement and Control, National Research Council

LIAISON REPRESENTATIVE - Office of Coal Research - Interior Department

Leroy Furlong, Research Advisor to the Assistant Secretary of Mineral Resources, U.S. Department of the Interior

B - Advanced Fossil Fuel Fired Central Station Power Plants - Office of Coal Research, Department of the Interior

A contract has been executed with the National Academy to study this area in depth. That work is just now getting under way and a report could not be available in time for the FCST timetable. An additional study panel has been assembled to meet the timetable, however. Membership is shown on Attachment B. This group has held one meeting and assignments were given to each member of the committee. A second meeting will be held shortly.

Advanced cycles to be studied include:

1. Magnetohydrodynamics -- MHD
   a. Open cycle
   b. Closed cycle
   c. Liquid metal
2. Combined cycles
   a. Gas turbines
   b. Alkali metal turbines
   c. Thermionic convertors
   d. Ammonia and other low temperature working fluids
3. Nonconventional combustion
   a. Fluid bed
   b. Surface
   c. Advanced system (high intensity units similar to rocket nozzles)
   d. Submerged
4. Fuel cells
   a. Solid electrolyte
   b. Molten carbonate
   c. Aqueous
5. Unconventional cycles
   a. Feher cycle
   b. Electrogas dynamics -- EGD
   c. Closed Brayton
   d. Ferro-fluid cycle
   e. Open cycle Rankin
   f. Otto engine

6. Energy storage

   a. Electrolysis
   b. Batteries
   c. Inductive
   d. Salt
   e. Compressed gas

7. Combinations

The work of this panel will include a detailed assessment of the current situation in each of these major areas in an effort to determine what problems must be solved if the systems are to be used commercially and what period of time will be required to achieve a solution. This is extremely important since a number of the systems appear technically sound but are not expected to be commercially attractive. If solutions can be seen for all problem areas, the panel recommendations will include every candidate system that appears to have any reasonable chance of success.

Attachment B

ADVANCED CYCLE FOSSIL FUEL FIRED
CENTRAL STATION POWERPLANT PANEL

Dr. Bernie Baker
Energy Research Corporation

Dr. S. Baron
Burns and Roe, Inc.

Dr. Daniel Berg
Westinghouse Electric Corporation

Martin U. Gutstein
NASA Lewis Research Center

Malcom Jones
Consultant

R. M. Lundberg
Commonwealth Edison Company

Dr. Richard Rosa
Avco Everett Research Laboratory

Dr. Z. J. J. Stekly
Magnetic Corporation of America

Neal P. Cochran
Department of the Interior

C - Controlled Nuclear Fusion Research - Atomic Energy Commission

Background: The long-term goal of the Controlled Thermonuclear Research (CTR) program is the development of a major new source of energy employing nuclear fusion reactions. Current research is devoted mainly to the study of production, heating, and confinement of the ultrahigh temperature (100 million degrees) reacting mixture (plasma) and to the development of the associated technology necessary to conduct experiments in this field.

Objectives: To assess the potential contribution of nuclear fusion to future U.S. energy needs, to assess the probable environmental impact of fusion power, and to identify the research and technological development which is needed. The steps, probable time-scales and costs involved in the development of fusion reactors are also being considered.

Organization: The controlled fusion power evaluations are being conducted under the cognizance of the Atomic Energy Commission's Division of Controlled Thermonuclear Research. The panel consists of CTR laboratory representatives, the Chairman of two specially appointed committees, and an AEC coordinator who also represents the AEC laser fusion program. The membership of the panel and subpanels, as well as the Controlled Thermonuclear Research Standing Committee (which will review the final report) is shown in the attachment C.

Technological Considerations: An evaluation of the potential operating characteristics of central station fusion power systems is one focal point for the study. Aspects being considered include the size, construction materials, efficiency, operating and environmental characteristics. Configurations under study include a number of magnetic confinement systems as well as inertially confined laser fusion systems.

Reference Documents: Background documents are being prepared to provide details of the program's research and development requirements.

ATTACHMENT C

CONTROLLED NUCLEAR FUSION RESEARCH

Panel Membership

R. L. Hirsch	U.S. Atomic Energy Commission	(Panel Coordinator and Laser-Fusion Representative)
A. P. Fraas	Oak Ridge National Laboratory	(Chairman, CTR Technology Subpanel)
A. Trivelpiece	University of Maryland	(Chairman, Offsite Program Subpanel)
M. B. Gottlieb	Princeton University	
H. Motz	Los Alamos Scientific Laboratory	
T. K. Fowler	Lawrence Livermore Laboratory	
H. Postma	Oak Ridge National Laboratory	

Subpanels

1. Technology Committee

A. P. Fraas, Oak Ridge National Laboratory (Chairman)
S. Burnett, Los Alamos Scientific Laboratory
T. Coultas, Argonne National Laboratory
D. Dudziak, Los Alamos Scientific Laboratory
G. Hopkins, Gulf General Atomic
G. Kulcinski, University of Wisconsin
B. Meyers, Lawrence Livermore Laboratory
F. Ribe, Los Alamos Scientific Laboratory
F. Tenney, Princeton Plasma Physics Laboratory

2. Offsite Committee

A. Trivelpiece, University of Maryland (Chairman)
W. Drummond, University of Texas
B. Fried, University of California, Los Angeles
A. Haught, United Aircraft Corporation
T. Kammash, University of Michigan
W. Kunkel, Lawrence Berkeley Laboratory
D. Meade, University of Wisconsin
D. Rose, Massachusetts Institute of Technology
N. Rostoker, Cornell University

3. AEC Laser-Fusion Coordinating Committee

L. E. Killion, AEC, (Chairman)
K. Boyer, Los Alamos Scientific Laboratory
A. Clogston, Sandia Laboratories
C. Haussmann, Lawrence Livermore Laboratory
R. L. Hirsch, AEC, CTR
D. I. Gale, AEC, DMA

Controlled Thermonuclear Research Standing Committee

R. W. Gould, AEC (Chairman)
S. J. Buchsbaum, Bell Laboratories
H. R. Crane, University of Michigan
E. Creutz, National Science Foundation
T. K. Fowler, Lawrence Livermore Laboratory
M. B. Gottlieb, Princeton University
H. Motz, Los Alamos Scientific Laboratory
H. Postma, Oak Ridge National Laboratory
J. R. Whinnery, University of California, Berkeley

D - Nuclear Breeder Strategy - Atomic Energy Commission

Objective: To assess the recent developments that have taken place in the gas cooled fast breeder reactor (GCFR) and the molten salt breeder reactor (MSBR) technologies, and to determine the influence of these developments upon the results of the Atomic Energy Commission's (AEC) previous breeder reactor assessment.

Organization: In 1967 the AEC undertook a broad overall assessment of the civilian nuclear power program. This assessment included consideration of the technical status and economic potential of advanced converters and breeders, the role of thorium, various reactor fuel cycles, and a systems analysis of the future nuclear electrical power complex. The assessment involved a number of task forces with broad technical representation from the nuclear industry, the electric power utilities, the national laboratories and the AEC. These task force efforts provided the basis for arriving at a number of decisions regarding the potential of various nuclear power concepts, including the selection of the Liquid Metal Fast Breeder Reactor (LMFBR) as a national requirement warranting the highest priority in the civilian reactor development program. In light of the extensive assessments previously conducted, it was not deemed necessary to again undertake a comprehensive examination of alternate breeder concepts but rather to conduct an internal assessment which would examine the technical developments that have taken place in the continuing research and development and design efforts on the GCFR and the MSBR systems, and relate the influence of these developments to the results of the earlier overall assessment. This assessment is being conducted by the AEC's Division of Reactor Development and Technology with contributions from representatives of the Oak Ridge National Laboratory (ORNL) and the Gulf General Atomic Company (GGA).

Technologies Being Considered: The concepts being considered as candidate technologies for parallel breeder development are the GCFR and the MSBR. The majority of the GCFR work is being conducted by GGA, while the MSBR is being investigated principally by ORNL.

The GCFR concept uses helium as the coolant gas, which leads to several potentially favorable attributes of the GCFR concept. Helium is both optically and neutronically transparent and does not become radioactive. The GCFR has a potentially high breeding ratio resulting largely from the coolant properties.

The MSBR concept is based on use of a circulating fluid fuel with on-line continuous fuel processing. As presently envisioned, it would operate as a thermal spectrum reactor system utilizing a thorium-uranium fuel cycle. The concept could offer the potential for broadened utilization of the Nation's natural resources through operation of a breeder system employing yet another fertile material (thorium instead of uranium).

Reference Documents: The references pertinent to the effort by this panel are listed in Attachment D.

Attachment D

NUCLEAR BREEDER STRATEGY

References

, "The 1967 Supplement to the 1962 Report to the President on ian Nuclear Power," February 1967.

, "Potential Nuclear Power Growth Patterns," WASH-1098, ber 1970.

, "Cost-Benefit Analysis of the U.S. Breeder Reactor Program," 1126, April 1969.

, "Cost Benefit Analysis of the U.S. Breeder Reactor Program," ed (1970), WASH-1184, January 1972.

lt Breeder Reactor

C, "The Use of Thorium in Nuclear Power Reactors," WASH-1097,

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l Hearings on Reactor Development Program, USAEC Authorizing slation, Hearings before the Joint Committee on Atomic Energy, 972, p. 820-830, March 4, 1971, U.S. Government Printing Office.

ear Applications & Technology, Volume 8, February 1970.

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thal, M. W., et al., "Advances in the Development of Molten Breeder Reactor," A/CONF. 49/P-048, Fourth United Nations rnational Conference on the Peaceful Uses of Atomic Energy, va, September 6-16, 1971.

o, J. R. (ed.), "Molten Salt Reactor Technology," Technical rt of the Molten Salt Group, Part I, December 1971.

o, J. R. (ed.), "Evaluation of a 1000 MWe Molten Salt Breeder tor," Technical Report of the Molten Salt Group, Part 4.

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tors,"

E - Electrical Transmission and Systems - Department of the Interior

This Group was fortunate in that some very intensive, comprehensive studies of its technological area have been completed within the past year. The most significant of these were (1) the ERC R&D Goals Task Force report "Electric Utilities Industry Research and Development Goals Through the Year 2000" and (2) the Arthur D. Little, Inc. report "Underground Power Transmission." In order to reap maximum benefit from these year-long efforts, several key members of the committees responsible for the reports were invited to participate on the Technical Group (i.e. ERC R&D Goals TF--Bell, Gillette, Parry, Zook; ERC Underground Transmission R&D Program Steering Committee--Corry, Fink, Parry).

The Technical Group is examining areas of technology which are of major importance to the electric power industry in meeting its share of the Nation's energy requirements. The areas initially selected for examination are as follows:

- UHV AC overhead transmission
- Underground transmission by superconducting cable, AC and DC
- Underground transmission by resistive cryogenic cables
- Reduction of AC/DC conversion terminal cost and size
- Reduction of underground transmission line installation costs
- Microwave and charged particle transmission
- Bulk power transmission system configurations
- Bulk power systems operation

For convenience, the Technical Group arranged these topics under six convenient subject headings,

- UHV AC Transmission
- DC Components and Systems
- Underground Power Transmission

- Microwave and Charged Particle Transmission
- High Power Transmission Systems
- Controls and Control Systems

To avoid neglecting important technical areas not explicitly mentioned in the initial list of recommended topics, the Technical Group broadened the scope of its investigation. The most significant additions to the original list were electrical system controls and control systems, and non-cryogenic underground transmission.

The Technical Group reviewed each of the six technical areas just mentioned to determine where the investment of R&D funds would be of greatest benefit to the electrical transmission aspects of the nation's future energy problems. The Group examined the candidate programs to determine potential contribution to lessening any undesirable impact of the energy system on the environment, to the conservation of natural resources, and to improved economics.

Each of the detailed anayses will contain a review of the status of the technology under discussion, an assessment of the technical evolution to be expected in the future, and an identification of the areas in which R&D can make significant improvements. Each will be concluded with a survey of the R&D programs that appear most worthy of support. Those summaries will be brought together and the Technical Group's recommendations regarding the most deserving areas of R&D support, time frames and suggested funding identified.

Membership of this panel is listed in attachment E.

Attachment E

FCST ENERGY TECHNOLOGY PANEL

ELECTRICAL TRANSMISSION AND SYSTEMS

Membership:

F.F. Parry	Department of the Interior, Chairman
W.J. Balet	Federal Power Commission
R.A. Bell	Consolidated Edison Company of New York
A.F. Corry	Boston Edison Company
C.C. Diemond	Bonneville Power Administration
L.H. Fink	Philadelphia Electric Company
R.W. Gillette	Grant County PUD
S. Linke	National Science Foundation
C.E. Winn	Tennessee Valley Authority
R. Zook	Cooperative Power Association

F - Synthetic Fuel Systems - Atomic Energy Commission

Objective: To assess the potential of energy systems based on non-fossil synthetic fuels and to evaluate the capabilities of synthetic fuels to contribute to the solution of the U.S. energy problems. All segments of the energy systems are being examined; fuel production, storage, transport, final use and an overall systems analysis, including economic, environmental and safety considerations. Areas of technological and economic uncertainties will be identified and needed research and development efforts defined.

Organization: The synthetic fuel systems evaluation is being conducted under the cognizance of the Atomic Energy Commission (AEC) as part of the AEC's Division of Reactor Development and Technology program. The panel is under the leadership of John W. Michel, Oak Ridge National Laboratory (ORNL), and includes technical staff representatives from industry and the AEC's laboratories. The composition of the panel and the contributing organizations are identified in Attachment F-1.

Technologies Being Considered: Under the panel effort, technologies for the following fuels are being considered; hydrogen, ammonia, methanol, hydrazine, and fuels derived from agricultural and waste products. Production methods being considered include electrolysis, as well as thermochemical and radiolytic means. Biological and chemical approaches will also be assessed. Current technologies will be identified and advanced technologies will be discussed relative to their potential, and research and development needs will be defined.

In addition to the production technologies, the technologies for storage, transport, and use will be identified for the more promising fuels. Particular attention will be given to hydrogen because of its environmental characteristics when used as a combustion fuel and its adaptability to the many societal needs.

Reference Documents: The published references which are being used by the panel as basic working documents are listed in Attachment F-2. In addition, the panel is obtaining additional information from unpublished documents and proprietary reports of industry, as well as that obtained through direct contact by panel members with specialists in fuels and related technologies.

ATTACHMENT F-1

SYNTHETIC FUEL SYSTEMS

Panel Organization

J. W. Michel	Oak Ridge National Laboratory	(Panel Leader)
F. J. Salzano	Brookhaven National Laboratory	(Systems Analysis)
E. Hammel	Los Alamos Scientific Laboratory	(Urban Uses of Hydrogen)
A. L. Austin	Lawrence Livermore Laboratory	(Transportation)
D. P. Gregory	Institute of Gas Technology	(Uses of Synthetic Fuels)
J. E. Johnson	Union Carbide Corporation, Linde Division	(Storage and Transportation)
C. F. Williams	Teledyne Isotopes	(Electrolysis)
J. Braunstein	Oak Ridge National Laboratory	(Thermo-chemical Production)
W. J. D. Escher	Escher Technology Associates	(Transportation and Electric Generator)

Technical contributors to the panel include W. Hautz and G. G. Leath, General Electric-TEMPO; W. J. Lueckel, Pratt & Whitney Aircraft; G. M. Blouin, Tennessee Valley Authority; C. Marchetti, URATOM; and many staff members of the Atomic Energy Commission's laboratories.

Attachment F-2

SYNTHETIC FUEL SYSTEMS

References

1. National Petroleum Council's Committee on U.S. Energy Outlook, U.S. Energy Outlook: An Initial Appraisal 1971-1985, Vol. 1, July 15, 1971.

2. N. C. Hallett, Study, Cost, and System Analysis of Liquid Hydrogen Production, Final Report, NASA CR 73,226, June 1968.

3. Abundant Nuclear Energy, Proceedings of a Symposium at Gatlinburg, Tennessee, August 26-29, 1968, AEC Symposium Series 14, sponsored by Oak Ridge Associated Universities and U.S. Atomic Energy Commission.

4. Army Energy Depot Study Report, Series ERD Numbers: 3687, 3714, 4200, 4447, 4610, 4496, GM-Allison Division (1965-1966).

5. A. I. Project Study Team, Nuclear Energy Centers--Industrial and Agro-Industrial Complexes, USAEC Report ORNL-4290, November 1968.

6. R. B. Scott, et al (ed.), Technology and Uses of Liquid Hydrogen, Pergamon Press, 1964.

7. R. H. Wiswall, Jr., and J. J. Reilly, Metal Hydrides for Energy Storage, Brookhaven National Laboratory proposed paper for the 7th Intersociety Energy Conversion Engineering Conference to be held in San Diego on September 25-29, 1972.

8. Panel on Electrically powered vehicles, The Automobile and Air Pollution--A Program for Program for Progress, Part 1, U.S. Department of Commerce, October 1967, Vol. 118, No. 5, 1971.

9. Federal Power Commission, The 1970 National Power Survey, Part III.

10. W. J. Lueckel, L. G. Eklund, and S. H. Law, Fuel Cells for Dispersed Power Generation, IEEE Paper T72-235-5, February 1972.

11. Hydrogen Systems in Electric Energy, G.E.-TEMPO 72 TMP-15, 1972.

12. Chemical Economics Handbook, Stanford Research Institute, Menlo Park, California.

G - Solar Energy - National Aeronautics and Space Administration and National Science Foundation

The Solar Energy Panel is cochaired by Mr. William H. Woodward of NASA and Dr. Paul Donovan of NSF and is structured as shown in the attached organization chart (G). A NSF grant, equally funded by NASA and NSF, was let to the University of Maryland to defray the meeting expenses of the Panel, to pay for the publishing of reports, and to acquire technical assistance in preparing the report.

Four working meetings of the Panel have taken place. The first was an organization meeting to assign specific tasks to the subpanel chairmen and to select the rest of the panel members, now numbering about 40 from industry, government and university as shown in the attached list. The second meeting was used to establish the working procedures for evaluating the various methods of using solar energy. Numerous systems were identified and the Panel was organized into five subpanels as follows:

- Energy for Buildings
- Bioconversion Systems
- Central Station Electric Power
- Photovoltaic Systems
- Unique Systems including Wind and Ocean Thermal Gradients

The third and fourth were used to integrate the subpanel input into a draft report.

At this time there appear to be several areas where solar energy can have a significant impact upon the nation's future energy needs:

- Heating and Cooling of Buildings and Hot Water Supply
- Manufacture of Fuels such as Hydrogen, Methane and Oil
- Production of Protein for Animals from Solar Activated Algae
- Generation of Electrical Power using Thermal and possibly Photovoltaic Processes
- Generation of Electrical Power from Wind and Ocean Thermal Gradients

ATTACHMENT G

FEDERAL COUNCIL ON SCIENCE & TECHNOLOGY

COMMITTEE ON ENERGY R&D GOALS

SOLAR ENERGY PANEL

CO-CHAIRMEN: Paul Donovan - NSF
William Woodward - NASA

EXECUTIVE COMMITTEE

Univ Md. Grant
Technical Support --- William R. Cherry - NASA (Executive Secretary)
F. H. Morse — Lloyd O. Herwig - NSF

SUBPANELS

Bio-Conversion Systems	Direct Thermal System For Space Conditioning	Photovoltaic System
Prof. M. Kamen Univ. of Calif.	Dr. J. Weingart Cal. Tech.	Prof. M. Wolf Univ. of Penn.
Dr. B. Kok RIAS Inc.	Lt. R. Reines (Government)	Dr. S. Isakoff DuPont Co.
Prof. W. Oswald Univ. of Calif.	Dr. G. Lof Colorada State Univ.	Dr. P. Glaser Arthur D. Little, Inc.
Prof. L. Krampitz Case Western Reserve Univ.	Prof. J. Duffie Univ. of Wisconsin	Mr. P. Iles Globe Union Inc.
Dr. G. Christopher United Aircraft Res. Lab.	Mr. R. Rittelmann 610 Mellon Bank Butler, PA (Reg. Architect)	Prof. J. Loferski Brown Univ.
		Dr. N. Yannoni Air Force Cambridge Res. Lab.

Unique Systems	Thermal to Electric Central Power Systems
Prof. R. Bailey Univ. of Fla.	Mr. F. Smits Bell Laboratories
Mr. J. Anderson 1615 Hillock La. York, PA (Consulting Engineer)	Mr. R. VanVliet (Government)
Prof. E. Faber Univ. of Fla.	Dr. L. Maissel IBM Corporation
Prof. W. Heronemus Univ. of Mass.	Prof. E. Sparrow Univ. of Minnesota
Prof. W. Sears Cornell Univ.	Dr. A. Meinel Univ.of Arizona
Dr. G. Szego Intertechnology Corp.	Prof. O. Edwards UCLA
	Prof. W. Gouse Carnegie Mellon Univ.

SPECIAL CONSULTANTS

Economist:	M. Searl - RFF
Environmentalist:	J. McKenzie - MIT
Psychologist:	R. Bauer - Harvard
Sociologist:	S. Klausner - U. Penn.
Industrialist:	P. Rappaport - RCA

H - Geothermal Energy - U.S. Geological Survey, Department of the Interior

Geothermal Energy R&D Goals are being assessed by two panels of experts who will submit separate reports to the FCST Overview Panel. The first R&D assessment will be submitted this month and will be drafted by an informal interagency geothermal committee, a panel of federal geothermal experts who have been meeting monthly since September 1971 to promote communication between federal agencies involved in the geothermal resources field. The second geothermal R&D assessment will be drafted by the Conference of Geothermal Resources Research which was established in May 1972, when the National Science Foundation, under the RANN program, approved a research proposal submitted by Walter J. Hickel, Adjunct Professor of the University of Alaska, to hold a conference "To develop an assessment of the state-of-the-art and to recommend a research program to provide the requisite knowledge for establishing the proper role of geothermal resources in providing additional energy to alleviate the nation's impending shortage, water to supplement present supplies, and mineral resources."

The Conference is planned for September 1972 and will include about 60 knowledgeable scientists, engineers, and other experts from industry, universities, and state and federal agencies. Because of this time schedule, the final report of this conference will not be available to the FCST until the first week in October; however, the National Science Foundation invited Dr. Dallas Peck, chairman of the FCST Geothermal R&D Assessment Panel, to attend their preliminary meeting held in May, where cochairmen of each panel submitted written recommendations on R&D goals and expenditures to be included in the July report. The final report from the September conference will provide an expanded and detailed list of recommended research topics that will provide a useful supplement to the shorter initial report.

The specific technologies being considered in the July report include the following:

1. Standard electrical production and economics from dry steam and hot water geothermal systems.

2. Binary fluid conversion systems (isobutane, freon, etc.) for utilization of low enthalpy geothermal fluids.

3. Heat recovery from hot rock masses of low porosity and permeability by creation or stimulation of reservoirs with chemical, hydraulic, thermal, and explosive fracturing techniques.

4. Multiple use systems. Desalination and mineral by-product recovery.

5. Geothermal exploration, heat flow measurement, drilling and borehole logging technology.

6. Geothermal system modeling, physical and economic.

7. Space heating, manufacturing, refrigeration, and alternate uses technology.

8. Environmental effects technology including air pollution control, noise suppressents and waste brine reinjection.

Agencies and members of the panel who are contributing to, drafting, and reviewing the assessment of geothermal energy R&D goals to be submitted this month are listed in Attachment H-1. The industry, university and stage agency persons cochairing sessions for the September conference and also contributing to the initial report are listed in Attachment H-2. The areas to be covered in the initial report are as follows:

I. Conclusions and recommendations

II. Nature and sources of geothermal energy

III. Current utilization worldwide and U.S.
  Impact of Geothermal Steam Act

IV. Current research and development
  International
  National
    Federal research and development
    Research by State organizations
    Research and development by private industry
    Relevant research directed at other energy resources

V. Ultimate potential, U.S.
   Estimated reserves and resources
   Economics
   Impact on Nation's energy needs
   Impact of new technologies
      Binary cycle heat exchangers
      Nuclear, chemical, and hydrofracturing techniques
      Water and mineral recovery
   Time frame for significant impact on Nation's energy needs
   Environmental Effects

VI. Research and development needs
   Resource evaluation
   Exploration methods
   Reservoir development and production
   Utilization technology and economics
   Environmental effects
   Legal and institutional aspects

VII. References

Attachment H-1

Contributors to Initial Geothermal Energy Report

U.S. Geological Survey
- Dr. Dallas Peck, Chairman of panel
- Dr. Richard S. Fiske
- Mr. Peter Popenoe

U.S. Bureau of Reclamation
- Mr. James J. O'Brien
- Mr. William C. Klostermeyer
- Dr. Chung-ming Wong
- Mr. Stanley S. Larsen

Office of Saline Water
- Dr. Glen Coury
- Mr. Paul B. Pruett

U.S. Bureau of Mines
- Mr. Larry Miller

U.S. Department of Interior
- Mr. Reid Stone
- Mr. George H. Davis

Advanced Research Projects Agency
- Dr. Valentine Zadnick (ARO)
- Major Donald Klick (AFOSR)

U.S. Atomic Energy Commission
- Mr. Anthony H. Ewing
- Mr. M. Marcey Williamson

National Aeronautics and Space Administration
- Dr. Martin W. Malloy
- Dr. Luke Liccini

Environmental Protection Agency
- Ms. Lillian K. Stone

Attachment H-2

Cochairmen of Panels for Conference on Geothermal Resources Research Contributing to Initial Report

Mr. Walter J. Hickel Principal Investigator	Adjunct Professor University of Alaska
Mr. Donald D. Dunlop Executive Secretary	Fairfax, Virginia
Prof. L. T. Grose Co-chairman, Resources Evaluation Sub-panel	Colorado School of Mines
Prof. Robert W. Rex Co-chairman, Resources Evaluation Sub-panel	University of California, Riverside
Prof. Gunnar Bodvarsson Co-chairman, Resources Exploration Sub-panel	Oregon State University
Mr. Donald H. Stewart Co-chairman, Reservoir Development and Production Sub-panel	Battelle Northwest
Mr. Herbert Rogers, Jr. Co-chairman, Utilization Technology and Economics Sub-panel	Rogers Engineering Company, Inc.
Mr. John P. Finney Co-chairman, Utilization Technology and Economics Sub-panel	Pacific Gas and Electric Company
Prof. Hamilton Hess Co-chairman, Environmental Effects Sub-panel	University of San Francisco
Mr. Richard Bowen Co-chairman, Environmental Effects Sub-panel	Oregon Department of Geology and Mineral Industries
Mr. Joseph W. Aidlin Co-chairman, Institutional Problems Sub-panel	General Council, Magma Power Company
Mr. Stewart French Co-chairman, Institutional Problems Sub-panel	Private Law Practice (Washington, D.C. former Chief Council, Senate Interic Committee

I - Extraction of Energy Fuels - Bureau of Mines, Department of the Interior

The scope of this panel has been gradually expanded at the request of the Office of Science and Technology. Six sub-panels now constitute the total, and the panel has been renamed from "Oil and Gas Production" to "Extraction of Energy Fuels" to more nearly reflect the scope of these studies.

The organization and members of the panel are detailed in Attachment I. Because of relatively short time-frames, the Bureau of Mines has drawn heavily on its in-house expertise to expedite the completion of the reports. While it is not yet possible to detail priorities, recommended programs, or funding levels, the scope of each subpanel report can be described as follows:

1. Stimulation of Petroleum and Natural Gas Production - Known oil and gas fields contain some 60 billion barrels of oil and 300 trillion cubic feet of gas that do lend themselves to economical recovery at current prices with existing technology. In addition, the location is known of some 100 billion barrels of heavy oil that is not now being recovered. This subpanel is assessing those promising stimulation methods that may be rapidly developed for this field application. A pertinent reference for this study is the National Petroleum Council, Impact of New Technology on the U.S. Petroleum Industry 1946-1965, Part 1 (1967).

2. Production of Oil from Tar Sands - Tar sands represent one domestic resource that has not been developed in the U.S. One large-scale operation is now in progress, producing oil from the Athabasca tar sands of Alberta, Canada. Little effort has been made to delineate the extent or develop technology suitable for extraction from deposits typcial of those found in this country. Known resources contain in excess of 25 billion barrels, but this could be considerably higher.

3. Development of Oil Shale - The oil shale deposits of Colorado, Utah, and Wyoming represent the largest concentrated hydrocarbon deposit known to exist in the world. The Department of the Interior is moving toward implementation of its' prototype leasing program to stimulate the development of commercial technology by private industry. This subpanel is assessing technologic needs in relation to the development expected from that program. Pertinent references include two reports by the Department of the Interior, Prospects for Oil Shale Development (1968), and Program Statement for the Proposed Prototype Oil Shale Leasing Program (1971).

4. In-situ Gasification - Worldwide interest in underground gasification of coal was abandoned in the 1960's following over a half-century of trying to establish a viable technology. A recent report prepared by A. D. Little, Inc. on behalf of the Bureau of Mines (A Current Appraisal of Underground Coal Gasification, 1971) recommends that this technology be reexamined in light of today's needs and progress in related technologies.

5. Oil and Gas Production from Organic Wastes - The conversion of organic wastes that are collected each year in the United States would yield nearly 170 million barrels of oil. Unlike conventional resources, this resource is continuously replenishable in ever-increasing quantities. A high degree of environmental enhancement is possible, but considerable effort will be required to move from laboratory to commercial units.

6. Primary Extraction of Coal - Coal, the largest known domestic resource, is being viewed as the basis for our future fossil fuel needs. However, if the continued full use of coal in solid, gaseous, or liquid form is to be realized, better methods of extraction are required. This subpanel is examining methods that may be used to increase capacity, reduce extravagant and wasteful past practices, improve environmental relationships, and decrease the health and safety hazards associated with the production of coal.

Attachment I

Organization of Extraction of Energy Fuels Panels

1. Stimulation of Petroleum and Natural Gas Production

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Marcie Williamson, Division of Applied Technology, Atomic Energy Commission, Washington, D. C.

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W. C. Elliott, Division of Fossil Fuels, Washington, D. C.

Daniel Edwards, Office of Economic Analysis, Washington, D. C.

Bill Maple, U. S. Geological Survey, Denver, Colorado

R. T. Johansen, Research Supervisor, Bartlesville Energy Research Center, Bartlesville, Oklahoma

2. Production of Oil from Tar Sands

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3. Development of Oil Shale

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P. L. Russell, Research Director, Denver Mining Research Center, Denver, Colorado

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M. J. Spendlove, Research Director, College Park Metallurgy Research Center, College Park, Maryland

4. In situ Gasification

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John Capp, Bureau of Mines, Washington, D. C.

Dr. Ulrich Merten, Gulf Research and Development Co.

Dr. Charles Bliss, A. D. Little, Inc.

Dr. William Watson, A. D. Little, Inc.

5. Organic Wastes

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John S. Tosh, Staff Research Coordinator, Division of Coal, Bureau of Mines, Washington, D. C.

Charles B. Kenahan, Division of Metallurgy, Bureau of Mines, Washington, D. C.

Dr. Robert Yeck, Department of Agriculture, Beltsville, Maryland

Dr. Boyd Riley, Environmental Protection Agency, Rockville, Maryland

6. Primary Extraction of Coal

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J - Transportation Energy - Department of Transportation

I. INTRODUCTION

The Department of Transportation is leading a panel on Transportation Energy R&D Goals.

A. Purpose

1. To support the FCST Energy R&D Goals Study.

2. To provide inputs, regarding the problem of Energy for Future Transportation, to:

   The Office of Science and Technology
   The Department of Transportation
   The Transportation Community at large

B. Major Concerns

1. Maintain or improve transportation services at reduced energy consumption. (Technologically oriented approaches in perspective with regulatory approaches).

2. Diversify the very intensive dependence of transportation on petroleum.

C. Expected Output

1. Projected transportation demand and transportation energy consumption, (to the year 2020).

2. Identification and outline of propulsion options for future transportation.

3. Evaluation of the potential impact of these options on:

   Resources
   Environment
   Socio-Economic Complex

4. Identification and outline of R&D goals leading to the most promising options.

5. Anticipated costs schedules and benefits.

II. ORGANIZATION OF THE PANEL REPORT

A. Support and Participation

The Transportation Energy Panel is supported by representatives from both DOT and other Federal Agencies.

1. Contributions from within DOT are made by the following organizations: (alphabetically by code)

FAA	(Aviation Admin.)
FHWA	(Highway Admin.)
FRA	(Railroad Admin.)
NHTSA	(Highway Traffic Safety Admin.)
TEU	(Assist. Secretary for Environment and Urban Systems)
TPI	(Assist. Secretary Policy and International Affairs)
TST	(Assist. Secretary Systems Development and Technology)
USCG	(Coast Guard)
UMTA	(Urban Mass Transportation Administration)

2. Substantial contributions are made by the following non-DOT organizations:

DOD
EPA
NASA
OST (ex officio)

3. Important Participation, (especially in specific workshops), is provided by individuals of specific expertise, affiliated with:

Government Laboratories
Academic Institutions
Industry
Consulting Firms

4. Liaison is maintained with other panels and sub-panels, (under AEC and DOI), as well as with the overview panel.

Organization

Inputs to the total effort are made by the following groups:

1. Transportation Energy Demand

   DOT is leading this group with the participation of DOT (TPI, FHWA, FAA, FRA, USCG, and TST). The Department of Defense is also providing inputs regarding military transportation demand.

2. Propulsion Alternatives at Lower Powers

   DOT is leading this group with the participation of DOT (TST, FHWA, FRA, and TEU). Very important contributions are also provided by DOD/USATACOM; EPA and NASA.

3. Propulsion Alternatives at Higher Powers

   NASA is leading this group with the participation of NASA-LeRC and other NASA Centers; DOT/(FAA, FRA, USCG, and TST); DOD/USATACOM; and EPA.

   The aforementioned three groups review rather integrated transportation concepts, while the following four groups are concerned with the evaluation of specific sub-technologies and components.

4. Technology for Fuel Economy in Automotive Propulsion

   DOD/USATACOM is leading this group with the participation of, (alphabetically): Chrysler; DOT/(FHWA, TST); Eng. Manufacturing Association; EPA; Ford; General Motors; GSA; Southwest Research Institute; University of Wisconsin.

5. Thermochemical and Thermechemical R&D for Conventional and Novel Fueled Propulsion

   DOT is leading this group with the participation of, (alphabetically): Battelle; DOD/USATACOM; DOI/Petroleum Res. Center; DOT/(TST, FRA); EPA; JPL; MIT; NASA/LeRC; and Tufts University.

EXECUTIVE OFFICE OF THE PRESIDENT
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May 25, 1972

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FEDERAL ENERGY R&D FUNDING

The Federal Government each year spends significant sums on research and development aimed at improving the methods for locating, producing, converting and transporting both the primary energy sources--petroleum, gas, coal, uranium and water power--and the secondary energy source--electricity. Research is also underway to develop new advanced sources such as oil shale, fusion energy, geothermal steam, and solar energy. The government also supports research on energy in high demand fields such as transportation, housing, etc.

During the past several years, there has been major new emphasis and significant funding increases in energy R&D. A major source of this emphasis has been concern over how the nation is to meet its growing demands for energy without degrading the environment.

Five-Year Survey of Federal Energy R&D

Federal energy R&D funding for the past five years has been assessed by staff members of the Office of Science and Technology, and their results are presented by major categories in Tables I and II. In summary, however, energy R&D funding increased over 72%, or $261 million, from FY 1969 to FY 1973. This represents a compounded growth rate of more than 11%. The increase is due in part to expansion of several key efforts including the fast breeder nuclear reactor, coal gasification, sulfur oxide removal from fossil fuel stack gases and controlled thermonuclear fusion.

Although the funding increase is probably the survey's most striking feature, another is an obvious trend toward a Federal R&D program which balances the energy resources of the nation and the engineering R&D required to utilize those resources most effectively. For example, coal resource R&D funding has been growing at a much faster rate than nuclear power funding, 305% compared to 29% over the five-year period. Significant increases in funding for stack gas cleanup technology and coal gasification are aimed at making the nation's abundant coal resources available for both electric generation and industry. Where nuclear fission accounted for 77% of the FY 1969 energy R&D budget, it now accounts for only 58 %. In the meantime, funding for the liquid metal fast breeder reactor has grown by 97% thus reflecting its changing status as a national priority program. Controlled thermonuclear fusion, geothermal steam, and solar energy have also received considerably more attention as funding patterns evolved.

The FY 1973 Federal Energy R&D Budget

In his Energy Message to Congress on June 4, 1971, the President announced a broad range of actions including a forward-looking agenda for research to ensure adequate future supplies of clean energy. To meet the challenge spelled out in the Energy Message, Federal agencies have vigorously expanded their efforts in critical areas and the overall energy R&D budget for fiscal 1973 was increased by $96. 9 million or about 18. 4%.

The major increases were aimed primarily at developing adequate supplies of clean electrical energy while simultaneously enhancing the quality of national life through long and short term R&D. Coal gasification and liquefaction, magnetohydrodynamics, the liquid metal fast breeder, controlled thermonuclear fusion, cryogenic generation and transmission, geothermal steam and solar energy account for 74%, or $72. 0 million, of the increase.

R&D programs are underway to provide new technological options for resolving conflicts between energy needs and environmental protection. For instance, to help meet stricter air and water quality standards related to energy use, FY 1973 funding will be expanded $21. 5 million or 22. 5%.

The FY 1973 funding pattern clearly reflects the objective of achieving a more strategic approach to our national R&D investment. A stronger R&D partnership between government and industry is a crucial component of this approach. The Atomic Energy Commission and the electric utilities are building a demonstration fast breeder reactor and the Department of Interior and the American Gas Association are working on coal gasification, both efforts excellent examples of such partnerships.

The utilization of the outstanding capabilities of the high technology agencies to deal with domestic problems such as energy needs is another key component. Examples include the Atomic Energy Commission's work on high energy density storage batteries, dry cooling towers, and underground transmission lines and the National Bureau of Standards' research on cryogenic generation.

Industrial Energy R&D

In addition to the electric utility industry's major cooperative commitments to the demonstration breeder reactor, it is also planning a vast expansion of the Electric Research Council's voluntary, private sector R&D activities as described in a recent report entitled "Electric Utilities Industry R&D Goals Through the Year 2000." Private research and development efforts in the petroleum industry are less well documented due to the tradition of proprietary research and development. Historically, however, the petroleum industry has spent considerably more on research and development than the other sectors of the energy industry combined.

Highlights of Major Energy R&D for FY 1973

Nuclear Fission R&D

The largest single high priority item in the energy R&D budget is for the development of the liquid metal fast breeder reactor (LMFBR) by the Atomic Energy Commission and industry. The anticipated Federal funding for FY 1973 is approximately $260 million. The LMFBR will expand, by a factor of 30 to 40, the energy obtainable from natural uranium thus assuring abundant supply of low-cost electrical energy for centuries. A demonstration of LMFBR plant by 1980 is a mid-term goal. The long-term objective is to develop a broad technological and engineering base with extensive utility and industrial involvement. This will lead to an economic breeder design and the establishment of a strong commercial breeder industry in the mid-1980's.

The first demonstration plant, a joint Government/industry undertaking, is expected to be built by the TVA and Commonwealth Edison of Chicago using funds from all segments of the electric utility industry and the Government. The Fast Flux Test Facility in Hanford, Washington, and other engineering test and development facilities are included in the AEC budget. The AEC fission power program is not limited to the LMFBR.

Other efforts are aimed at other breeders--the fast, gas-cooled reactor, the molten-salt breeder and the light water breeder. The first two are technology development efforts with modest funding. The light water breeder effort is aimed at an early demonstration of a prototype core for the Shippingport plant in Pennsylvania.

The AEC budget also includes a R&D program on the safety of current light water reactors. This program has been significantly expanded during the past two years to assure continuance of the excellent safety record of civilian nuclear power.

Coal Research and Development

Although the Federal Government's energy R&D efforts began with coal well over a half century ago, this resource has until recently been supported as a poor stepchild. The Office of Coal Research (OCR), Department of the Interior, and the American Gas Association have jointly undertaken, subject to the approval of Congress, a $30 million accelerated pilot plant program for deriving high Btu gas from coal. The division of costs is two-thirds government and one-third industry. The program life of four years will lead to either a demonstration plant or, if feasible, direct commercial application. Three pilot plants associated with this program are in various stages of development. The first has already produced a small amount of gas. The second, is in its shakedown period. Groundbreaking for the third is scheduled for early summer of 1972.

OCR is also accelerating its R&D effort aimed at converting coal to clean fuel gases using combined cycles, clean liquid hydrocarbons, solvent refined coal, and the magnetohydrodynamic (MHD) generation of electric power.

The Bureau of Mines is conducting smaller scale R&D to extract high Btu gas from coal and to develop other clean fuels and MHD. The Bureau, as a result of the Coal Mine Health and Safety Act of 1969, increased its efforts on coal mine health and safety research by an order of magnitude in five years, approximately $30 million per year in FY 1972-73.

Closely related to Interior's work on coal mining and utilization are efforts by EPA and TVA to control air pollutants from coal and other fossil fuel combustion in stationary power plants. Nearly all of this effort has been applied to sulfur oxide controls, particularly by means of stack gas cleaning systems. The FY 73 budget includes a large increase to allow TVA to install a stack gas cleaning system on one of its large power plants and increases for EPA efforts on advanced, more efficient means for controlling sulfur oxides and other pollutants.

Nuclear Fusion Research

The AEC conducts the major portion of Federal research on controlled thermonuclear fusion. Its ultimate goal is to provide mankind with a new and different kind of energy source as the long term approach to the energy problem. Some of the reasons for pursuing fusion are:

(1) The possibility of unlimited low cost fuel--deuterium from sea water;
(2) Inherent safety against runaway reactions;
(3) Manageable radioactivity problems;
(4) High thermal efficiencies.

The fusion effort has been aimed at understanding the physics of plasmas and demonstrating the scientific feasibility of confining plasma long enough to produce useful amounts of energy. Most of this work involves magnetic systems for confining the plasma. Funding for this research has increased nearly 36%, or $10.6 million, in the five-year period.

In recent years, the use of high powered lasers to initiate the thermonuclear fusion reaction has been under study. It offers a possible additional approach to a fusion reactor, one which would supplement the three major magnetic confinement techniques now being studied. The multipurpose laser-fuel pellet effort has grown significantly in the last three years to over $25 million in FY 1973. Neither approach will see commercial use before the 1990's.

Petroleum and Natural Gas R&D

As mentioned previously, Federal efforts in petroleum and natural gas have been relatively modest in comparison with those of industry. The Bureau of Mines has long worked on oil shale and secondary petroleum extraction. The AEC's Plowshare Program has recently been directed almost exclusively at gas stimulation by nuclear devices. This technology offers a good deal of promise provided the related environmental questions are answered and objections to nuclear explosions are met satisfactorily.

Other Energy R&D Efforts

The National Science Foundation has for a number of years sponsored basic R&D on energy-related issues as part of its Engineering Energetics effort. With the establishment of the RANN (Research Applied to National Needs) Program, NSF's involvement has now moved from basic laboratory studies to advanced energy conversion systems such as solar power and policy studies related to energy and transmission systems research. The NSF's budget for energy studies has increased 31.2%, or $4.3 million, in FY 1973.

The Department of the Interior jointly sponsors, with the utility industry and through the Electric Research Council, an expanding program on underground transmission. It also has increased its efforts in the field of geothermal energy by 260%, or $1.8 million, in the FY 1973 budget.

The National Bureau of Standards and HUD also have expanded efforts involving civilian energy production and utilization.

Summary

The development of the technology to provide an adequate supply of electrical energy with minimal environmental impact is a critical factor in the nation's economic future. To attain that goal while simultaneously balancing energy needs and environmental concerns is a fundamental factor in the evolution of energy R&D programs. As presently constituted, that program has the following two salient components:

(1) A Federal energy R&D budget which has been growing at the compounded rate of 11% during the last five years;

(2) A pattern of funding which is continually being adjusted to reflect a realistic balance between domestic energy resources and the R&D required to utilize those resources most effectively.

TABLE I

FEDERAL ENERGY R&D FUNDING[a]

FY 1969 through FY 1973
(in millions of dollars)

	FY 69	FY 70	FY 71	FY 72	FY 73	1-yr. Increases, %	5-yr. Increases, %
Coal Resources Development	$ 23.3 M	$ 30.4 M	$ 49.0 M	$ 76.8 M	$ 94.4 M	22.9	305
Petroleum and Natural Gas	13.5	14.8	17.5	23.8	26.1	9.7	93.3
Nuclear Fission							
LMFBR[b]	132.5	144.3	167.9	237.4	261.5	10.2	97.4
Other Civilian Nuclear Power[b]	144.6	109.1	97.7	90.7	94.8	4.5	- 34.4
Nuclear Fusion							
Magnetic Confinement[b]	29.7	34.3	32.3	33.2	40.3	21.3	35.6
Laser-Pellet[b, c]	2.1	3.2	9.3	14.0	25.1	79.2	1095.2
Energy Conversion with Less Environmental Impact	12.3	22.9	22.8	33.4	55.3	66	350
General Energy R&D	3.0	4.2	8.7	15.4	24.1	66.2	753.3
	$361.0 M	$363.2 M	$405.2 M	$524.7 M	$621.6 M	18.4 ave	72.2 ave.

TABLE II

FEDERAL ENERGY R&D FUNDING[a]

FY 1969 through FY 1973
(in millions of dollars)

	Agency	FY 69	FY 70	FY 71	FY 72	FY 73
Coal Resources Development						
Production and Utilization R&D, incl. gasification, liquifaction and MHD	DOI - BOM	$12.3 M	$13.2 M	$15.4 M	$14.7 M	$19.0 M
	DOI - OCR	8.7	13.5	18.8	31.1	45.3
Mining Health and Safety Research	DOI - BOM	2.3	3.7	14.8	31.0	30.1
Petroleum and Natural Gas						
Petroleum Extraction Technology	DOI- BOM	2.6	2.7	2.7	3.2	3.1
Nuclear Gas Stimulation[b]	AEC	2.4	3.7	6.1	7.0	7.5
Oil Shale	DOI- BOM	2.5	2.4	2.7	2.6	2.5
Continental Shelf Mapping	DOI- GS	-	-	-	5.0	7.0
	DOC	6.0	6.0	6.0	6.0	6.0
Nuclear Fission						
LMFBR[b]	AEC	132.5	144.3	167.9	236.6	259.9
	TVA	-	-	-	0.8	1.6
Other Civilian Nuclear Power[b]	AEC	144.6	109.1	97.7	90.7	94.8
Nuclear Fusion						
Magnetic Confinement[b]	AEC	29.7	34.3	32.3	33.2	40.3
Laser-Pellet[b, c]	AEC	2.1	3.2	9.3	14.0	25.1
Energy Conversion with Less Environmental Impact						
Cleaner Fuels R&D-Stationary Sources	EPA	10.7	19.8	17.4	24.5	29.5
SO_x Removal	TVA	-	-	-	2.6	15.2
Improved Energy Systems	HUD	0.3	0.8	3.0	2.4	2.8
Thermal Effects R&D	EPA	0.5	0.8	0.6	0.7	1.0
	AEC	0.8	1.5	1.8	3.2	6.8[d]
General Energy R&D						
Energy Resources Research[e]	NSF	-	1.1	5.0	9.8	13.4
Geothermal Resources	DOI	0.1	0.2	0.2	0.7	2.5
Engineering Energetics Research	NSF	2.9	2.9	2.7	4.0	4.7
Underground Transmission	DOI	-	-	0.8	0.9	1.0
Cryogenic Generation	NBS	-	-	-	-	1.0
Non-Nuclear Energy R&D	AEC	-	-	-	-	1.5
		$ 361.0M	$ 363.2 M	$ 405.2 M	$ 524.7M	$ 621.6 M

Footnotes - Tables I and II

[a]The funding listed in these tables cover the Federal R&D programs in development-exploration and production, conversion, and transmission of our energy resources. This funding includes energy conversion R&D for stationary applications only; R&D funding for improved mobile applications (e.g., automotive, rail, seagoing) are not included. Fundamental research on environmental health effects of combustion products and low-dose radiation exposure) is not included.

[b]This funding includes operating, equipment, and construction costs.

[c]The primary applications of the multipurpose laser-pellet effort are for other than energy production (see text).

[d]This entry includes $1.5 million for dry cooling tower R&D under the AEC's new Non-Nuclear Energy R&D category. Other related work is carried out under Other Civilian Nuclear Power.

[e]The NSF RANN Program includes research on solar energy as well as fundamental energy policy studies.

Note: The totals in Tables I and II differ from the earlier total reported at the time the FY 1973 budget was released (p. 57, The Budget of The United States Government for FY 1973). The data presented in Tables I and II includes additional budget components, viz., Coal Mine Health and Safety Research is included in the Bureau of Mines budget and capital and equipment as well as operations are included in the Atomic Energy Commission budget.

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For immediate release

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"Patterns of Energy Consumption in the United States"

While there are more than 100 separate uses for energy, only four -- transportation, space heating, industrial process steam and direct industrial heat -- account for more than 70% of our total energy usage.

"Patterns of Energy Consumption in the United States", a report prepared for the Office of Science and Technology by Stanford Research Institute of Menlo Park, California, and released today, contains this new data on the detailed uses of energy.

Based on statistics from the decade of the 1960's, the report provides far greater insight into the uses of energy than the previous conventional end use categories -- residential, commercial and industrial.

Industrial consumption was also analyzed by specific industries or products. Sixteen activities accounted for half the industrial consumption, or more than 20% of total energy consumption.

In releasing the report, Dr. Edward E. David, Director of the Office of Science and Technology, noted the growing concern for adequate supplies of clean energy evidenced by the President's June 4, 1971 Energy Message and said:

> "As individuals begin to ask what they and their government might do to conserve energy, it is vitally important to improve our understanding of just how we use our energy today.
>
> "The report is intended as a basic reference for policy makers, scholars and concerned citizens in their efforts to assure that energy demands will match energy supplies in the future. We view it not as the last word about energy use, but rather as a stimulus to further study and dialogue."

The report indicates that the overall annual growth rate in energy use was 4.3% from 1960 to 1968. Air conditioning and clothes drying were the most rapidly growing end uses while the direct use of heat by industry was significantly below the average.

The report also emphasizes that the generation of electricity is not an end use of energy itself. The oil, gas, coal, nuclear and hydropower used to generate electricity are therefore allocated in terms of the ultimate use of the electric power produced.

The following are the leading, primary end uses:

	Percent of total
Transportation (fuel; excludes lubes and greases)	24.9%
Space heating (residential, commercial)	17.9
Process steam (industrial)	16.7
Direct heat (industrial)	11.5
Electric drive (industrial)	7.9
Feedstocks, raw materials (commercial, industrial, transportation)	5.5
Water heating (residential, commercial)	4.0
Air conditioning (residential, commercial)	2.5
Refrigeration (residential, commercial)	2.2
Lighting (residential, commercial)	1.5
Cooking (residential, commercial)	1.3
Electrolytic processes (industrial)	1.2
Total	97.1%

The report's data on the technical efficiency of energy conversion can, when combined with the utilization data, suggest several potentially significant areas for conservation improvements. These include applications such as space heating, water heating and air conditioning.

###

Copies of the report "Patterns of Energy Consumption in the United States" are available from the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price is $2.25. Check or money order must accompany request.

PATTERNS OF ENERGY CONSUMPTION IN THE UNITED STATES

Office of Science and Technology
Executive Office of the President
Washington, D.C. 20506

January 1972

PATTERNS OF ENERGY CONSUMPTION IN THE UNITED STATES

BY: STANFORD RESEARCH INSTITUTE
of Menlo Park, California

Office of Science and Technology
Executive Office of the President
Washington, D.C. 20506

January 1972

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I INTRODUCTION

The availability of energy, and the impact of the utilization of energy upon the environment, are urgent issues in the United States. However, much of the information required to deal effectively with these issues is not available. An obvious gap has been the absence of statistics on how energy is used in the United States, broken down into meaningful end uses and compiled on an overall energy basis.

The Energy Policy Staff of the President's Office of Science and Technology has retained Stanford Research Institute to delineate the trends in energy consumption that have prevailed since 1960, in the important specific end uses in the residential, commercial, and industrial sectors of the U.S. economy. The objectives of the study are to determine:

(1) What significant purposes (end uses) have fuels been used for in the United States?

(2) What portion of the nation's energy requirements for the various end uses have been met by each fuel?

(3) What has been the rate of growth of consumption in the major end uses of each fuel?

(4) What technical efficiency can be expected when each fuel is used for those end uses for which it is suitable?

While the emphasis of the study has been on the residential, commercial, and industrial sectors, the use of electric power has also been incorporated, along with the transportation sector, in order to arrive at a total energy balance.

It should be emphasized that the study deals only with energy consumption in the recent past; there are no projections of energy demand, nor are there observations as to the significance of the results to the future or to policy considerations. This report is strictly a factual document; its purpose is to provide the most detailed information practicable on how the nation uses its energy.

In accomplishing this purpose, it has been necessary to go beyond the statistics commonly available, and to estimate or calculate the consumption in a specific application within a broad sector.

The specific applications for which energy consumption has been estimated are as follows:

Residential	Commercial
Space heating	Space heating
Water heating	Water heating
Cooking	Cooking
Clothes drying	Refrigeration
Refrigeration	Air conditioning
Air conditioning	Feedstock
Other:	Other:
Television	Lighting
Food freezing	Miscellaneous uses
Dishwashers	
Washing machines	
Lighting	
Small appliances	

Industrial

- Process steam
- Electric drive
- Electrolytic processes
- Direct heat
- Feedstock
- Other

Transportation

- Transportation fuel
- Raw material

Electricity is not separately indicated above because its use has been allocated to each of the ultimate end uses listed. The end uses are self-explanatory except for the following:

- Commercial--Feedstock: asphalt and road oil
- Industrial--Feedstock: primarily for conversion to chemicals
- Transportation--Raw Material: lubes and greases

The primary source of information used is the year-by-year energy consumption data developed by the U.S. Bureau of Mines. Other important basic data were developed through contacts with personnel of the major energy consuming industries. Trade associations, governmental agencies, and technical literature were also important sources of information. However, much of the end use information has been estimated or inferred in the absence of adequate recorded data. The lack of data is understandable because there is no metering or other regular means of measuring fuel and energy use in highly discrete applications. Electricity and gas use in the home are metered on a total basis, not for each appliance. Industrial establishments know how much fuel and energy they consume, but generally keep no record of the amount used for each application; reporting of such data is not required by the government or requested by trade associations or similar groups.

The method used by SRI in making the detailed estimates varies considerably from application to application; both the methods and sources of data used are given in the appropriate places of the report.

Other characteristics of the report include the following:

- Fuel quantities have been converted to a common thermal unit, the Btu.
- The years 1960 and 1968 have been selected for the detailed analysis of fuel consumption. The breakdown by application is provided for each fuel and for all fuels combined, plus hydroelectric and nuclear power. Data are provided on the Btu consumption in each discrete application, the percent of total consumption accounted for by each application, and the growth rate between 1960 and 1968.

Both 1960 and 1968 are considered to be reasonably representative years and the trends in energy consumption were smooth in the 1960-68 period. Therefore, the growth rates between 1960 and 1968, calculated solely on the basis of 1960 and 1968 consumption, are considered to be reasonably representative of growth rates for the entire period. Moreover, based upon data for 1969 and 1970, there is every indication that the same basic trends have persisted through 1970, and probably are continuing in 1971.

The use of electric power in each application was converted to a Btu equivalent on the basis of the average heat rate for thermal power plants that prevailed in each year. While this procedure is considered to yield the most realistic measure of electricity consumption in Btu equivalent, because it accounts for all the primary fuel input to electric generating plants, separate tables have also been prepared on the output basis of electricity conversion at 3,413 Btu per kwh (Appendix A).

The project manager for this study was Sherman H. Clark, Director of SRI's Energy and Resources Economics Group. The Project Leader was Richard E. MacDonald, Senior Industrial Economist in that group; other participants included Louise Levison, William V. Morris, Klaus P. Rose, Frank E. Walker, and John M. Warner.

II SUMMARY

Total and Sectoral Energy Consumption

The total energy consumption in the United States increased from 43.1 quadrillion Btu in 1960 to 60.5 quadrillion Btu in 1968; the 1960-68 growth rate (compounded) was 4.3% per year.

The breakdown by broad sector was:

	Consumption (quadrillion Btu)		Growth Rate	Percent of Total	
	1960	1968	(percent)	1960	1968
Residential	8.0	11.6	4.8%	18.6%	19.2%
Commercial	5.7	8.8	5.4	13.2	14.4
Industrial	18.3	25.0	3.9	42.7	41.2
Transportation	11.0	15.2	4.1	25.5	25.2
Total	43.1*	60.5*	4.3%	100.0%	100.0%

The growth rates vary from a low of 3.9% per year for the largest sector--industrial--to a high of 5.4% per year for the smallest sector--commercial. But industrial use still remained the dominant use of energy, at over 40% of the nation's total consumption.

Transportation is growing almost as rapidly as the total, and continues to account for about one-quarter of total energy consumption. Residential consumption has been increasing at 4.8% per year, above the overall average, and accounts for almost 20% of the total.

Data for the broad sectors are summarized in Table 1, which also shows the consumption by 22 end use categories.

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* May not add because of rounding.

Table 1

ENERGY CONSUMPTION IN THE UNITED STATES BY END USE
1960-1968
(Trillions of Btu and Percent per Year)

Sector and End Use	Consumption 1960	Consumption 1968	Annual Rate of Growth	Percent of National Total 1960	Percent of National Total 1968
Residential					
Space heating	4,848	6,675	4.1%	11.3%	11.0%
Water heating	1,159	1,736	5.2	2.7	2.9
Cooking	556	637	1.7	1.3	1.1
Clothes drying	93	208	10.6	0.2	0.3
Refrigeration	369	692	8.2	0.9	1.1
Air conditioning	134	427	15.6	0.3	0.7
Other	809	1,241	5.5	1.9	2.1
Total	7,968	11,616	4.8	18.6	19.2
Commercial					
Space heating	3,111	4,182	3.8	7.2	6.9
Water heating	544	653	2.3	1.3	1.1
Cooking	98	139	4.5	0.2	0.2
Refrigeration	534	670	2.9	1.2	1.1
Air conditioning	576	1,113	8.6	1.3	1.8
Feedstock	734	984	3.7	1.7	1.6
Other	145	1,025	28.0	0.3	1.7
Total	5,742	8,766	5.4	13.2	14.4
Industrial					
Process steam	7,646	10,132	3.6	17.8	16.7
Electric drive	3,170	4,794	5.3	7.4	7.9
Electrolytic processes	486	705	4.8	1.1	1.2
Direct heat	5,550	6,929	2.8	12.9	11.5
Feed stock	1,370	2,202	6.1	3.2	3.6
Other	118	198	6.7	0.3	0.3
Total	18,340	24,960	3.9	42.7	41.2
Transportation					
Fuel	10,873	15,038	4.1	25.2	24.9
Raw materials	141	146	0.4	0.3	0.3
Total	11,014	15,184	4.1	25.5	25.2
National total	43,064	60,526	4.3	100.0%	100.0%

Note: Electric utility consumption has been allocated to each end use.

Source: Stanford Research Institute, using Bureau of Mines and other sources.

Significant End Uses

There are probably over 100 separate uses for energy. However, only a few of the applications are a signicant proportion of the total energy consumption, i.e., over 1%, as indicated by the summary tabulation below (for 1968):

	Percent of Total
Transportation (fuel; excludes lubes and greases)	24.9%
Space heating (residential, commercial)	17.9
Process steam* (industrial)	16.7
Direct heat* (industrial)	11.5
Electric drive (industrial)	7.9
Feedstocks, raw materials (commercial, industrial, transportation)	5.5
Water heating (residential, commercial)	4.0
Air conditioning (residential, commercial)	2.5
Refrigeration (residential, commercial)	2.2
Lighting (residential, commercial)	1.5
Cooking (residential, commercial)	1.3
Electrolytic processes (industrial)	1.2
Total	97.1%

The 12 applications above account for all but about 3% of the nation's total energy consumption, and this remaining 3% is spread over a host of large and small appliances, elevators and other commercial installations, and many other uses.

In general, market shares are changing very gradually. None of the end uses have exhibited any decline between 1960 and 1968, and the largest uses are growing almost as rapidly as the national total. Applications with extremely rapid growth are still small in relation to the total. As a result, the shifts are gradual and the basic applications that have been predominant for a long time--transportation, space heating, and various industrial processes--continue to account for most of the energy consumption: the top four applications account for 71% of the total, and the top six for 84%.

* Includes some use for space heating, probably enough to bring total space heating to about 20%.

Energy Consumption by End Use*

Each of the major end use categories is discussed below, in order of relative importance.

Space Heating--Residential, Commercial, and Industrial

Space heating for residential and commercial establishments (and industrial establishments†) is the largest single end use of energy. The total is close to 20%, and the growth rate approximating 4% per year is close to that for all energy.

Residential space heating is much larger than commercial space heating, which in turn is probably much larger than industrial space heating.

Process Steam--Industrial

The use of process steam by industry accounts for some 17% of total U.S. energy consumption (40% of total industrial fuel and energy consumption), and the 1960-68 growth rate was 3.6% per year. Process steam has myriad applications in industry and is the largest of the various industrial applications of fuel and energy.

Direct Heat--Industrial

In many industrial processes, fuel is burned directly in the process (e.g., in the manufacture of cement or steel). Although the fuel so consumed is over 11% of total U.S. energy consumption, the 1960-68 growth rate was 2.8% per year, well below the average growth rate for total energy.

Electric Drive--Industrial

The industrial use of electricity for the direct drive of machinery and equipment accounts for close to 8% of total energy. The growth rate of 5.3% per year is well above the average for all energy.

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* Other than transportation.

† The use of fuel and energy for industrial space heating has not been separately identified but is included in "process steam" and "direct heat" and is a relatively small share of these uses. Industrial space heating is probably about 1% to 2% of total U.S. energy consumption.

Feedstock and Other Nonenergy Uses--Commercial and Industrial

The various nonenergy uses of fuel, e.g., lubes and greases, asphalt and road oil, and feedstocks for the manufacture of chemicals (both coal and petroleum based), amount to between 5% and 6% of the total use of fuel and energy, and the 1960-68 growth rate was 5.3% per year. Within this category, growth rates varied over a wide range, with petrochemical feedstocks growing much more rapidly than the average, and lubes and greases barely increasing at all.

Water Heating--Residential and Commercial

Water heating amounts to 4% of total energy consumption. Water heating grew at 5.2% per year in the residential sector but at only 2.3% per year in the commercial sector.

Air Conditioning--Residential and Commercial

Air conditioning amounts to only 2.5% of total energy demand, but the growth rate was 10.2% per year. Space heating accounts for about eight times more energy than air conditioning but the latter has been growing two and a half times more rapidly.

Refrigeration--Residential and Commercial

There is almost as great a use of energy in refrigeration (2.2% of total demand) as in air conditioning (2.5% of the total). The growth rate was 5.3% per year but was 8.2% for residential refrigeration alone.

Cooking--Residential and Commercial

Despite the widespread need for cooking, its consumption of energy in domestic and commercial applications combined amounts to only 1.3% of total energy consumption, and its share is declining; the growth was only about 2% per year. Commercial cooking is growing a little more rapidly than cooking in the home, but in 1968 was still only about one-fifth of the residential use of energy for cooking.

Electrolytic Processes--Industrial

The use of energy in electrolytic processes (e.g., conversion of alumina to aluminum) is only 1.2% of the total energy use, and requires far less energy than such other industrial uses as process steam, direct heat, and electric drive. The growth rate was 4.8% per year.

Clothes Drying--Residential

The residential use of energy for clothes drying is only 0.3% of total energy use, and less than 2% of the total use of energy in the home. However, the growth rate--10.6% per year--is high, more than twice the rate for total energy use or for total use in the home.

All Other End Uses

There are many end uses not specified above (e.g., all the small appliances in the home) but for all sectors combined they amount to only 4.1% of total consumption:

Residential	2.1%
Commercial	1.7
Industrial	0.3
Total	4.1%

In the residential sector, the other uses--27 different applications have been identified--can be classified as follows for 1968:

	Trillion Btu
Small appliances	180
Lighting	412
Washing machines	41
Dishwashers	36
Television	352
Food freezers	220
Total	1,241

Table 2

ELECTRICAL CONSUMPTION--
SELECTED SMALL APPLIANCES
1969

	Annual kwh per Item*	Number of Items (millions)†‡	Total Annual Consumption (billion kwh)	Total Annual Consumption (trillion Btu)
Bed coverings	147	27.0	3.97	42.6
Blenders	15	16.0	0.24	2.6
Broilers	100	14.0	1.40	15.0
Clocks	17	55.0	0.94	10.1
Coffee makers, automatic	106	50.0	5.30	56.7
Dehumidifiers	377	3.8	1.43	15.3
Fans (circulating)	43	75.0	3.23	34.5
Food disposers	30	13.5	0.41	4.4
Hair dryers	14	22.5	0.32	3.4
Humidifiers	163	4.0	0.65	7.0
Frypan skillets	186	33.0	6.14	65.7
Heaters (portable)	176	17.0	2.99	32.0
Hot plates	90	15.0	1.35	14.4
Irons	144	57.0	8.21	87.8
Knives (carving)	8	13.0	0.10	1.1
Mixers	13	49.0	0.64	6.8
Radios	86	57.0	4.90	52.4
Shavers	18	24.0	0.43	4.6
Toasters	39	54.0	2.11	22.6
Toothbrushes	5	15.0	0.08	0.9
Vacuum cleaners	46	53.0	2.44	26.1
Total			47.28	506.0

* Source is Edison Electric Institute.
† Estimated number in households in mid-1969.
‡ Source is Merchandising Week, February 23, 1970; SRI estimates.

Residential lighting amounts to only 0.7% of total national energy use; all lighting applications would probably bring the total use in this application to between 1.0% and 1.5% of total energy consumption.

None of the individual appliances, large or small, accounts for over 1% of the total U.S. energy consumption; for example, television accounts for 0.6%. A breakdown for small appliances is given in Table 2 for the year 1969 (data for 1968 are not available).

The Table 2 total of 506 trillion Btu is not in agreement with the estimate of small appliance energy consumption shown on Page 9 (180 trillion Btu) which is an estimate devised in another manner (essentially, it is the remainder after deducting from total electric energy use the consumption for all other known uses). The difference in the two estimates is quite large, but the absolute magnitude is small in either case. Table 2 is considered to overstate the consumption because the annual kwh per individual appliance is based upon a limited sample and the number of appliances represents the total estimated to be in existence, yet some of them are not used at all, or rarely. Actual energy consumption of small appliances in 1968 was probably about 300 trillion Btu.

A breakdown of other uses in the commercial sector was not attempted. In addition to lighting, this category consists primarily of mechanical drive for computers, office machinery, elevators, and escalators.

Industrial Energy Consumption

Sixteen industries or products accounted for an estimated 50% of the total industrial energy* consumption in 1968. Their share--in percent of total industrial energy consumption--has been estimated as follows:

Iron and steel	13.6%
Petroleum refining	11.3
Paper and paper board	5.2
Petrochemical feedstock	4.9
Aluminum	2.8
Cement	2.1
Ammonia	2.0
Ferrous foundries	2.0

* Including use of energy materials for feedstocks; electricity consumption converted to heat input at 9375 Btu/kWh.

Carbon black	0.9
Grain mills	0.8
Copper	0.8
Glass	0.8
Concrete	0.7
Meat products	0.7
Soda ash	0.7
Sugar	0.7

Fuel and Electrical Energy

Figures 1 and 2 portray (for 1960 and 1968, respectively) the energy consumption by sector and major end use, including the allocation of electricity; Table 3 shows these uses on a percentage basis. In Table 4, electricity has been converted to a Btu equivalent on the basis of 100% efficiency, or 3,413 Btu per kwh, and the waste heat in generating electricity is not allocated to end uses. Overall, the results are less than 10% different from the full allocation basis presented earlier (Table 1) but the difference is greater for some individual applications.

Technical Efficiency

The technical efficiency in the use of fuel (coal, oil, and gas) and electricity has been estimated for a number of applications--see Table 5. The efficiency calculated is solely for the energy consuming equipment and not for the total system. For example, the space heating efficiencies calculated are the percent of the total heat content of the fuel (or total energy content of electricity) that is made available to an establishment. The efficiency calculations do not take into account losses from the structure, nor do they include the effectiveness of heat distribution--temperature gradients and degree of air movement. These latter factors vary enormously, depending upon building design, insulation, and design of the heating system. The same limitations apply even to important end uses such as process steam. In this case, the calculation refers to the generation of the steam but does not allow for losses between the point of production and the various points at which the steam is used. In general, the technical efficiencies that have been calculated are reasonably high and are essentially static. In contrast, the total system efficiencies are often relatively low and can be greatly improved through better design and insulation, more sophisticated energy systems, and other efforts.

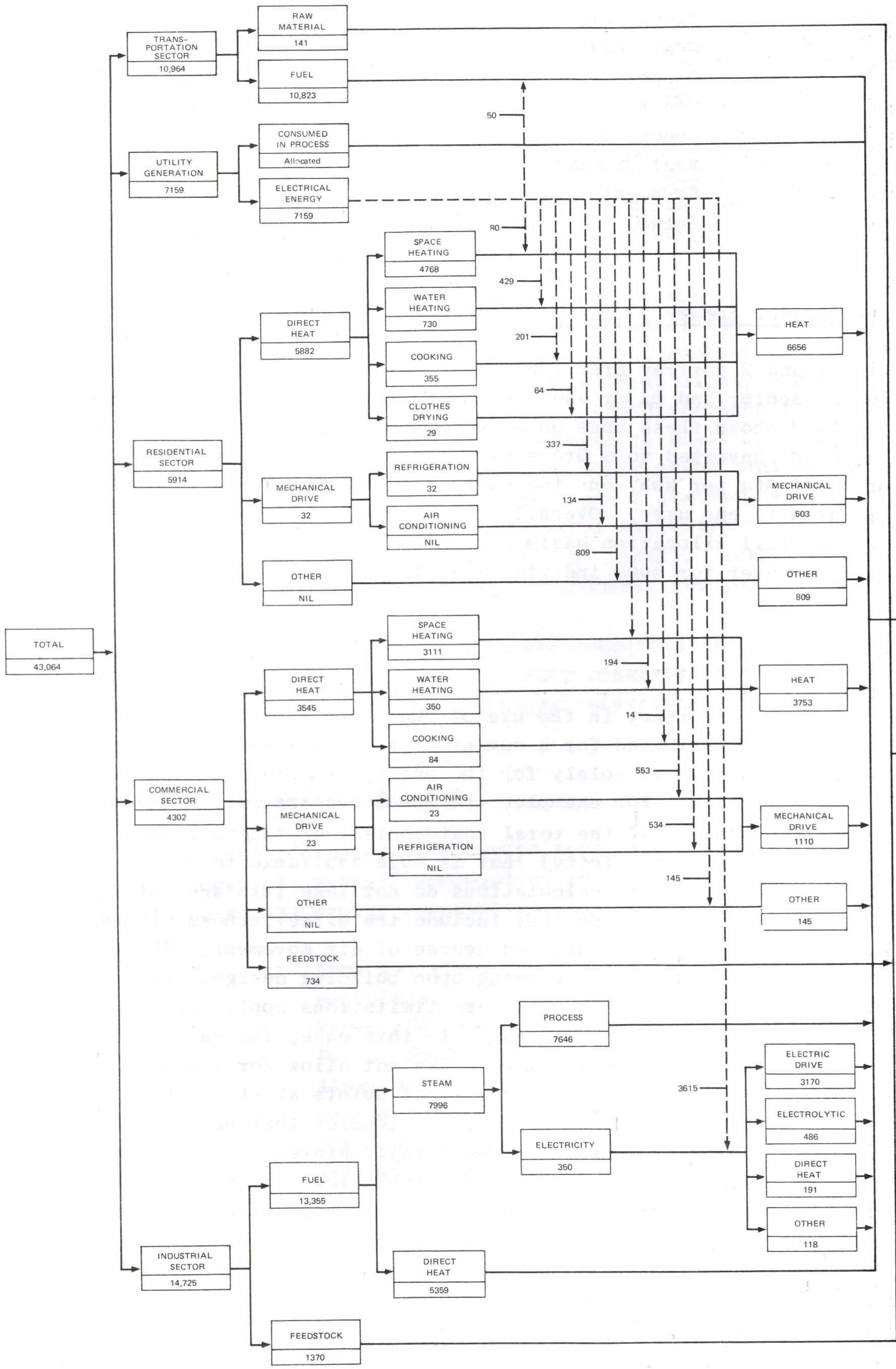

FIGURE 1 1960 ENERGY CONSUMPTION—ALL FUELS (Trillions of Btu)

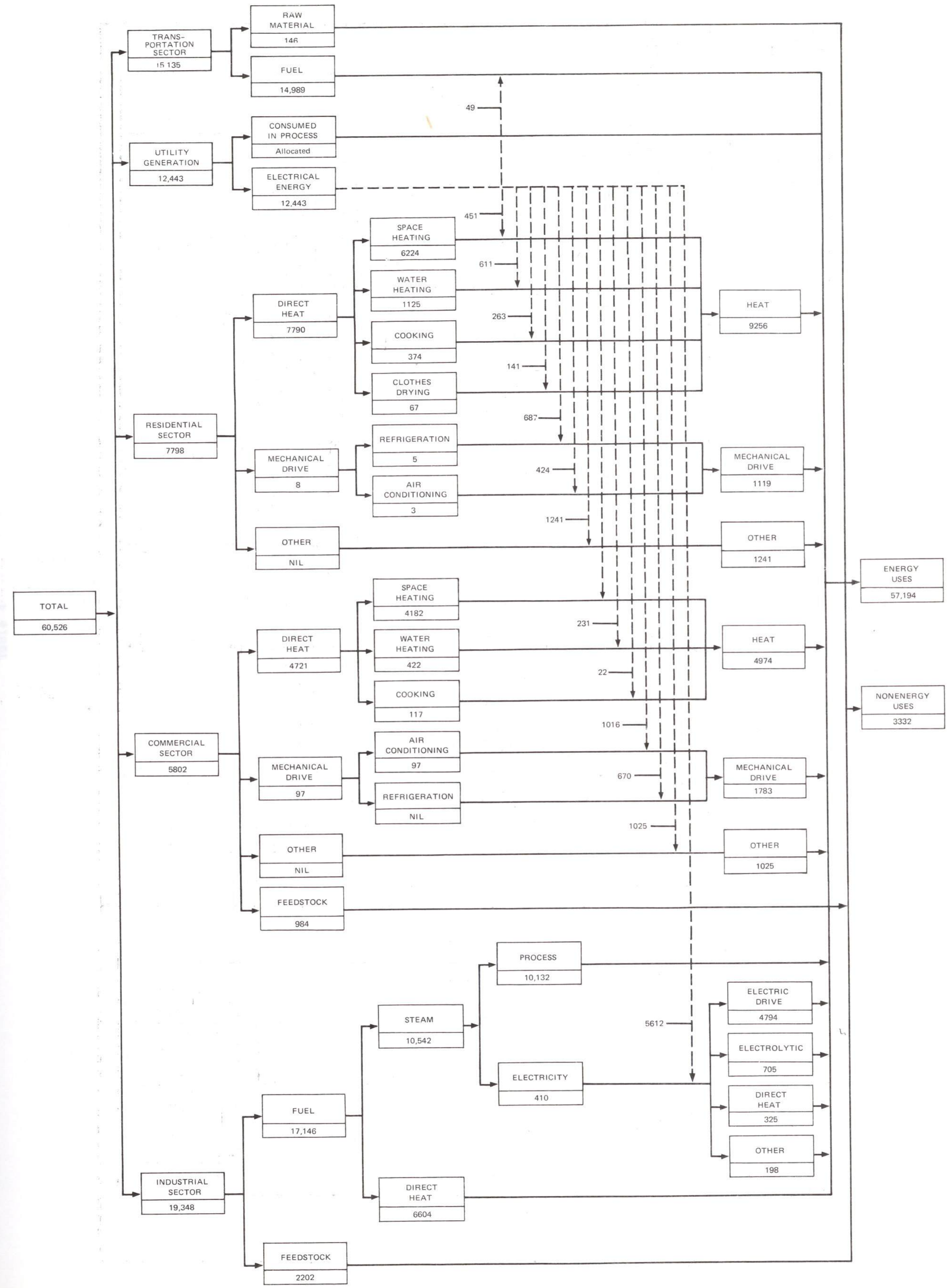

FIGURE 2 1968 ENERGY CONSUMPTION—ALL FUELS (Trillions of Btu)

Table 3

ENERGY CONSUMED, BY SECTOR AND END USE
AS A PERCENTAGE OF NATIONAL TOTAL*
1960 and 1968

	1960			1968		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential						
Space heating	11.1%	0.2%	11.3%	10.2%	0.7%	10.9%
Water heating	1.7	1.0	2.7	1.9	1.0	2.9
Cooking	0.8	0.5	1.3	0.7	0.4	1.1
Clothes drying	0.1	0.1	0.2	0.1	0.2	0.3
Refrigeration	nil	1.7	1.7	nil	1.6	1.6
Air conditioning	nil	0.2	0.2	nil	0.3	0.3
Other	nil	1.1	1.1	nil	2.1	2.1
Total	13.7%	4.8%	18.5%	12.9%	6.3%	19.2%
Commercial						
Space heating	7.6	nil	7.6	7.0	nil	7.0
Water heating	0.5	nil	0.5	0.6	nil	0.6
Cooking	0.1	0.1	0.2	0.1	0.3	0.4
Air conditioning	0.1	1.5	1.6	0.3	1.5	1.8
Feedstock	1.7	--	1.7	1.6	--	1.6
Other	nil	1.7	1.7	nil	3.1	3.1
Total	10.0%	3.3%	13.3%	9.6%	4.9%	14.5%
Industrial†						
Process steam	25.1			20.7		
Electricity generation	0.8			0.7		
Direct heat	5.1			7.0		
Feedstock	3.5			3.6		
Total	34.5%	8.4%	42.9%	32.0%	9.2%	41.2%
Transportation	25.1	0.2	25.3	25.0	0.1	25.1
Total	83.3%	16.7%	100.0%	79.5%	20.5%	100.0%

* Including heat wasted in production of electricity.
† Purchased electricity not allocated separately.

Sources: Bureau of Mines. Stanford Research Institute.

Table 4

GROWTH IN ENERGY CONSUMED, BY SECTOR AND END USE*
1960 and 1968
(Trillions of Btu)

	1960			1968			Average Annual Rate of Growth 1960-68 (percent)		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential									
Space heating	4,795	29	4,824	6,194	164	6,358	3.3%	24.0%	3.5%
Water heating	730	155	885	1,125	223	1,348	5.6	4.7	5.4
Cooking	360	71	431	412	78	490	1.7	1.2	1.6
Clothes drying	29	23	52	67	51	118	11.0	10.5	10.8
Refrigeration	nil	261	261	nil	354	354	n.a.	3.9	3.9
Air conditioning	nil	26	26	nil	66	66	n.a.	12.3	12.3
Other	nil	177	177	nil	454	454	n.a.	12.5	12.5
Total	5,914	742	6,656	7,798	1,390	9,188	3.5	8.2	4.1
Commercial									
Space heating	3,272	nil	3,272	4,214	nil	4,214	3.2		3.2
Water heating	226	nil	226	371	nil	371	6.4		6.4
Cooking	27	23	50	61	79	140	10.7	16.7	13.7
Air conditioning	43	226	269	172	323	495	18.9	4.6	7.9
Feedstock	734	--	734	984	--	984	3.7		3.7
Other	nil	271	271	nil	677	677		12.1	12.1
Total	4,302	520	4,822	5,802	1,079	6,881	3.8	9.6	4.5
Industrial†									
Process steam	10,795			12,524			1.9		
Electricity generation	350			410			2.0		
Direct heat	2,210			4,212			8.4		
Feedstock	1,370			2,202			6.1		
Total	14,725	1,306	16,031	19,348	2,043	21,391	3.5	5.8	3.7
Electric utility	7,159	(2,586)	4,573	12,443	(4,530)	7,913	7.2	7.3	7.1
Transportation	10,964	18	10,982	15,136	18	15,154	4.1	--	4.1
Total	43,064	--	43,064	60,527		60,527	4.3		4.3

* Not including heat wasted in production of electricity.
† Purchased electricity not allocated separately.

Sources: Bureau of Mines. Stanford Research Institute.

Table 5

TECHNICAL EFFICIENCY OF ENERGY CONVERSION, BY END USE
(Percent)

	Coal	Natural Gas	Petroleum Products	Electricity
Residential				
Space heating	55%	75%	63%	95%
Water heating	15 *	64	50	92
Cooking	*	37	37 †	75
Clothes drying	*	47	47 †	57
Refrigeration	*	*	*	50
Air conditioning	*	30	*	50
Other	*	*	*	**
Commercial				
Space heating	70 ‡	77	76	95
Water heating	70 ‡	64	50	92
Cooking	*	37	37 †	75
Refrigeration	*	*	*	50
Air conditioning	*	30	*	50
Other	*	††	*	††
Industrial				
Process steam production	70	64	68	*
Generation of electrical energy	88 §	88 §	88 §	*
Electric drive	*	*	*	90
Electrolytic process	*	*	*	**
Direct heat				
Other	*	††	††	††
Utility	37 ‡‡	34 ‡‡	36 ‡‡	*

* Fuel shown is not commonly used for end use shown.
† LPG is the petroleum product assumed to be used for this purpose. Consequently the efficiency shown is the same as that for natural gas.
‡ It has been assumed that water heating and space heating are co-functions when coal is fired (per SRI).
§ The efficiency shown is based upon the assumption that electrical energy is a by-product of process steam production. Consequently, condenser losses, stack losses, etc., are assigned to process steam production.
** Indeterminate.
†† Since a multitude of uses are included, it is infeasible to produce an efficiency figure.
‡‡ A wide range of steam station efficiency prevails due to varying economic factors. The values shown are representative and show the difference between fuel on a relative basis.

As Table 5 shows, efficiencies in the industrial sector vary from a low of 64% for process steam production using natural gas to a high of 90% for electric drive. In the residential and commercial sectors, the lowest efficiencies are in air conditioning and refrigeration--30% for gas and 50% for electricity--and the highest efficiency is in electric space heating, at 95%.

Individual Fuels

Total U.S. energy consumption, by year and type of fuel, is given in Figure 3. The growth rate of total consumption is depicted year-by-year in Figure 4; since 1962, the growth rate has varied within a rather narrow range--between 3.7% and 6.2% per year--for an annual average of 4.3% over the eight-year period 1961-68.

The energy consumption by source (type of fuel) is given in Table 6 for the years 1960 to 1968, and the share of the total market supplied by each source is shown in Figure 5 for the years 1960 and 1968. The share of the total market met by each source of energy shows only a gradual shift, with gas gaining almost 3 percentage points and oil and coal each dropping between 1 and 2 percentage points, although both were still increasing in absolute terms.

The consumption of each fuel by major sector (Table 7) includes data on the fuel input to electric power plants. Without allocating to each sector the waste heat in producing electricity, the growth rates of the major sectors are somewhat higher than when all electricity is allocated, as in some of the earlier tables. The difference is concentrated in the residential and commercial sectors:

	Annual Increase in Fuel Consumption (percent per year)	
	Electricity Including Waste Heat	Electricity at 3,413 Btu/kwh
Residential	4.8%	4.1%
Commercial	5.4	4.5

The industrial sector is not much changed in growth rate, and the transportation sector is not affected at all because there is so little electricity used in transportation.

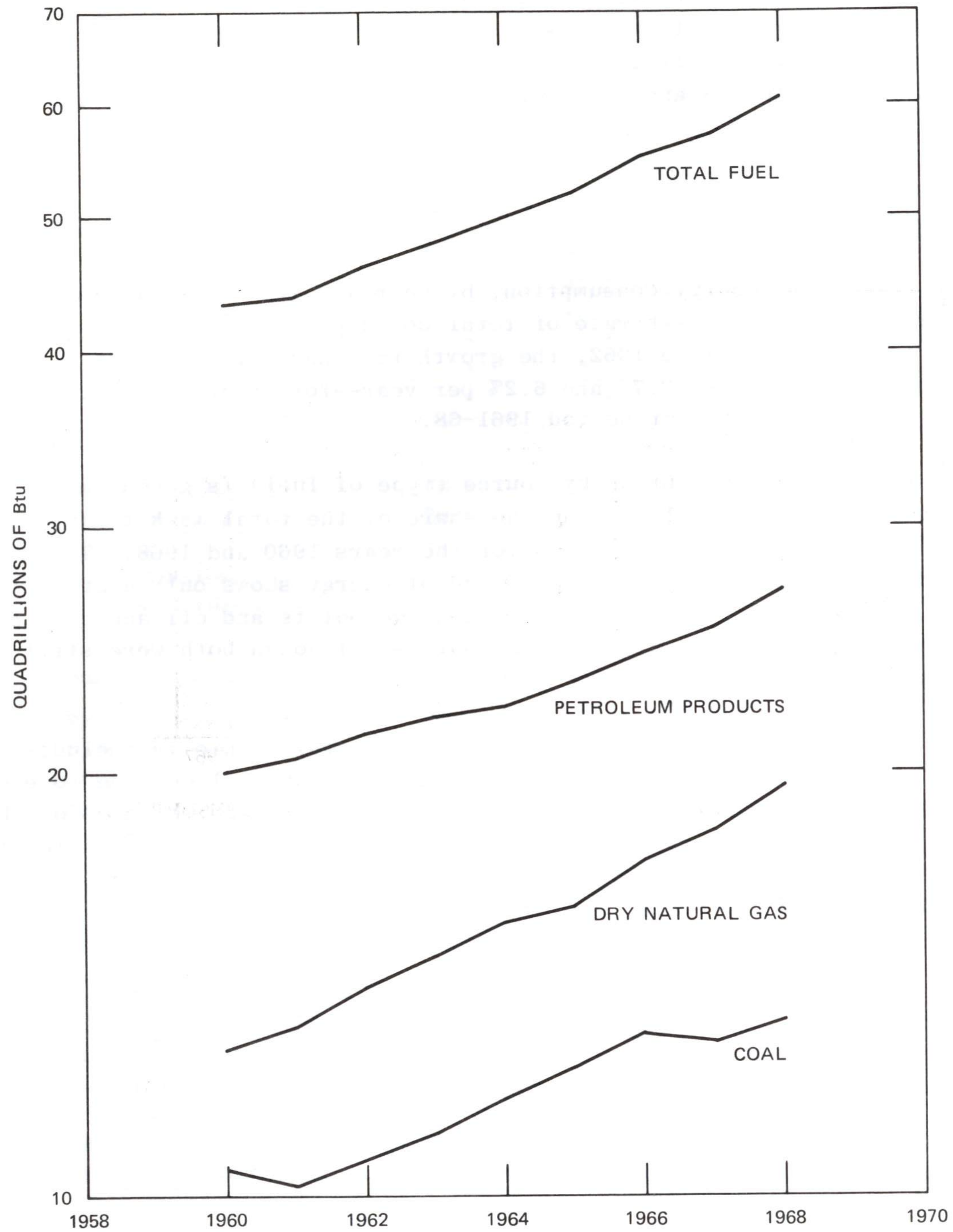

FIGURE 3 ENERGY CONSUMPTION, BY MAJOR FUEL

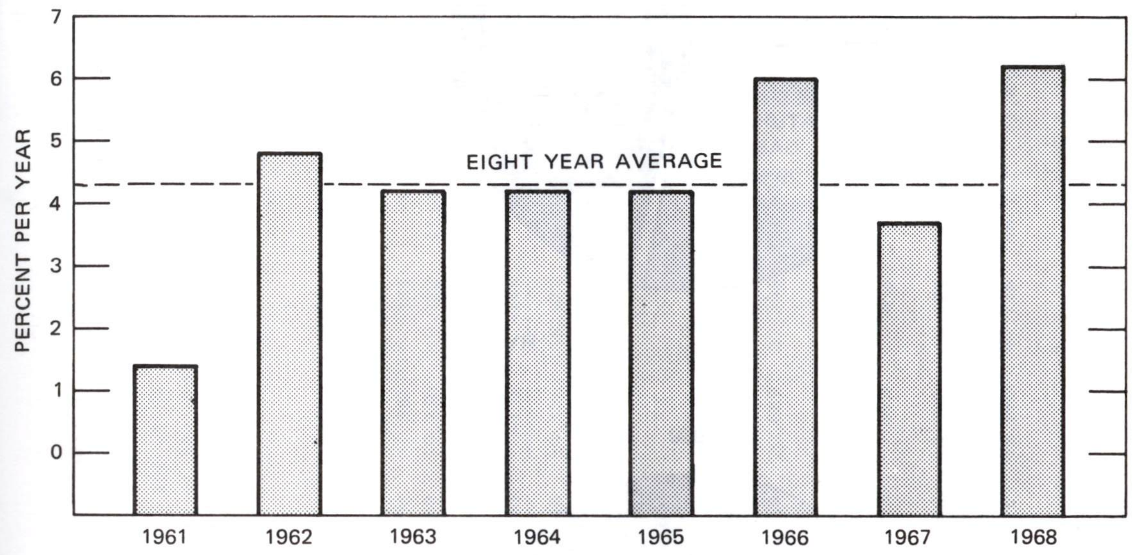

FIGURE 4 ANNUAL GROWTH OF ENERGY CONSUMPTION

FIGURE 5 DISTRIBUTION OF ENERGY CONSUMPTION, BY FUEL

Table 6

CONSUMPTION OF ENERGY BY FUEL
1960-1968
(Trillions of Btu and Percent)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	Rate of Growth
Coal										
Anthracite	447	404	381	361	365	328	290	274	258	-6.7%
Bituminous and lignite	9,967	9,809	10,160	10,722	11,295	12,030	12,740	12,587	13,069	3.4
Total consumption	10,414	10,213	10,541	11,083	11,660	12,358	13,030	12,861	13,327	3.1
Misc. and unaccounted for consumption	-145	-165	-153	-146	-2	-4	-3	-1	-1	-50.5
Accounted for consumption	10,269	10,048	10,388	10,937	11,658	12,354	13,027	12,860	13,326	3.3
Dry natural gas	12,699	13,228	14,120	14,844	15,648	16,098	17,392	18,250	19,564	5.6
Petroleum products										
Gross consumption	20,069	20,488	21,269	21,951	22,389	23,243	24,396	25,335	27,045	3.8
Misc. and unaccounted for consumption	-526	-625	-580	-592	-585	-545	-594	-276	-295	-7.0
Accounted for consumption	19,543	19,863	20,689	21,359	21,804	22,698	23,802	25,059	26,750	4.0
Nuclear fuel	6	17	23	33	34	38	58	81	130	47.0
Hydroelectric energy	547	520	572	563	609	664	668	755	757	4.2
Total gross consumption	43,735	44,466	46,525	48,474	50,340	52,401	55,544	57,282	60,823	4.3
Total misc. and unaccounted for consumption	-671	-790	-733	-738	-587	-549	-597	-277	-296	-9.8
Total accounted for consumption	43,064	43,676	45,792	47,736	49,753	51,852	54,947	57,005	60,527	4.5

Table 7

SECTORAL CONSUMPTION OF ENERGY, BY SOURCE

1960-1968

(Trillions of Btu)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	Average Annual Rate of Growth (percent)
Residential sector										
Coal	--	--	--	--	--	--	--	--	--	--%
Dry natural gas	3,212	3,362	3,756	3,713	3,917	4,038	4,283	4,464	4,606	4.6
Petroleum products	2,702	2,721	2,807	2,801	2,719	2,944	2,966	3,022	3,192	2.1
Electricity	742	785	847	910	988	1,062	1,155	1,274	1,390	8.2
Total	6,656	6,868	7,410	7,424	7,624	8,044	8,404	8,760	9,188	4.1
Commercial sector										
Coal	1,023	912	920	774	751	714	718	625	568	-7.1
Dry natural gas	1,056	1,115	1,093	1,314	1,426	1,480	1,662	1,759	1,845	7.2
Petroleum products	2,223	2,308	2,422	2,458	2,474	2,692	2,801	3,184	3,389	5.4
Electricity	520	600	643	735	807	886	946	983	1,079	9.6
Total	4,822	4,935	5,078	5,281	5,458	5,772	6,127	6,551	6,881	4.5
Industrial sector										
Coal	4,897	4,739	4,810	5,072	5,477	5,740	5,894	5,643	5,616	1.7
Dry natural gas	6,287	6,471	6,841	7,160	7,451	7,671	8,202	8,599	9,258	4.9
Petroleum products	3,541	3,544	3,734	3,852	4,035	3,985	4,194	4,298	4,474	3.0
Electricity	1,306	1,306	1,402	1,464	1,544	1,634	1,788	1,868	2,043	5.8
Total	16,031	16,061	16,787	17,548	18,507	19,030	20,078	20,408	21,391	3.7
Transportation sector										
Coal	92	22	20	19	20	19	18	14	12	-22.0
Dry natural gas	359	391	396	439	451	517	553	594	610	6.9
Petroleum products	10,513	10,713	11,147	11,648	11,940	12,333	12,936	13,542	14,514	4.1
Electricity	18	19	18	19	17	18	16	17	18	--
Total	10,982	11,145	11,581	12,125	12,428	12,887	13,523	14,167	15,154	4.1
Electric utility sector										
Coal	4,257	4,375	4,638	5,072	5,410	5,880	6,396	6,578	7,130	6.7
Dry natural gas	1,785	1,889	2,034	2,218	2,403	2,392	2,692	2,834	3,245	7.8
Petroleum products	564	577	579	600	636	744	905	1,013	1,181	9.7
Nuclear energy	6	17	23	33	34	38	58	81	130	47.0
Hydroelectric energy	547	520	572	563	609	664	668	755	757	4.1
Energy to other sectors (deduct)	2,586	2,710	2,910	3,129	3,356	3,600	3,905	4,142	4,530	7.3
Total	4,573	4,668	4,936	5,357	5,736	6,118	6,814	7,119	7,913	7.1
National total	43,064	43,676	45,792	47,735	49,753	51,851	54,946	57,005	60,527	4.3

The relative importance of each fuel varies from sector to sector, as shown in the tabulation below:

	Percentage of Sector Requirements - 1968				
	Coal	Gas	Petroleum	Electricity	Total
Residential	- %	50.1%	34.8%	15.1%	100.0%
Commercial	8.3	26.8	49.2	15.7	100.0
Industrial	26.2	43.3	20.9	9.6	100.0
Transportation	0.1	4.0	95.8	0.1	100.0

The contribution of each fuel to the requirements of the utility sector in 1968 were:

Coal	57.3%
Gas	26.1
Petroleum	9.5
Hydro and nuclear	7.1
	100.0%

The use of coal is concentrated mostly in the industrial and utility sectors, yet in the former, coal is only 26% of the total. Oil serves almost the entire transportation market (electricity is only 0.1% of the total, and gas is used in this sector to power the transmission of the fuel itself) and is a significant factor in every sector. Gas has also become a significant factor in every sector except transportation and is the major source of energy in the residential and industrial sectors.

The breakdown of the consumption of the individual fuels into end uses is given in Tables 8 through 12. Additional data are given in Appendix B.

Coal

The growth in coal use, excluding its use as a power plant fuel, was negligible--0.3% per year--between 1960 and 1968. Coal used as such was also negligible in the residential sector and its use in the commercial sector (for space heating only) declined at a rate of 7% per year.

Table 8

GROWTH IN CONSUMPTION OF ALL TYPES OF COAL*
1960 and 1968
(Trillions of Btu)

	1960			1968			Average Annual Rate of Growth 1960-68 (percent)		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential									
Space heating	nil	48	48	nil	258	258	n.a.%	23.5%	23.5%
Water heating	nil	255	255	nil	350	350	n.a.	4.1	4.1
Cooking	nil	119	119	nil	151	151	n.a.	3.0	3.0
Clothes drying	nil	38	38	nil	81	81	n.a.	9.9	9.9
Refrigeration	nil	200	200	nil	394	394	n.a.	8.9	8.9
Air conditioning	nil	80	80	nil	243	243	n.a.	14.9	14.9
Other	nil	481	481	nil	711	711	n.a.	5.0	5.0
Total	nil	1,221	1,221	nil	2,188	2,188	n.a.	7.6	7.6
Commercial									
Space heating	1,023	nil	1,023	568	nil	568	-7.1	n.a.	-7.1
Water heating	nil	115	115	nil	132	132	n.a.	1.7	1.7
Cooking	nil	8	8	nil	13	13	n.a.	6.2	6.2
Air conditioning	nil	329	329	nil	582	582	n.a.	7.3	7.3
Refrigeration	nil	318	318	nil	384	384	n.a.	2.4	2.4
Other	nil	86	86	nil	587	587	n.a.	27.2	27.2
Total	1,023	856	1,879	568	1,698	2,266	-7.1	8.9	2.4
Industrial									
Process steam	2,007	--	2,007	2,349	--	2,349	2.0	n.a.	2.0
Electricity generation	92	-92	--	95	-95	--	nil	nil	n.a.
Electric drive	--	1,793	1,793	--	2,634	2,634	n.a.	4.9	4.9
Electrolytic process	--	274	274	--	388	388	n.a.	4.4	4.4
Direct heat	2,667	108	2,775	3,025	179	3,204	1.6	6.5	1.8
Feedstock	131	--	131	147	--	147	1.4	n.a.	1.4
Other	--	67	67	--	109	109	nil	6.2	6.2
Total	4,897	2,150	7,047	5,616	3,215	8,831	1.7	5.2	2.9
Electric utility	Allocated			Allocated					
Transportation	92	29	121	12	29	41	-22.0	--	-12.7
Total, all sectors	6,012	4,257	10,269	6,196	7,130	13,326	0.3	6.6	3.3

Note: n.a. = not applicable.

* Including heat wasted in production of electricity.

Sources: Bureau of Mines. Stanford Research Institute.

Table 9

GROWTH IN CONSUMPTION OF DRY NATURAL GAS*
1960 and 1968
(Trillions of Btu)

	1960			1968			Average Annual Rate of Growth 1960-1968 (percent)		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential									
Space heating	2,188	20	2,208	3,236	118	3,354	5.0%	24.0%	5.3%
Water heating	650	107	757	979	159	1,138	5.2	5.1	5.2
Cooking	316	50	366	325	68	393	0.3	3.9	0.9
Clothes drying	26	16	42	58	37	95	10.5	11.0	10.7
Refrigeration	32	84	116	5	179	184	-21.2	9.9	6.0
Air conditioning	nil	33	33	3	111	114	n.a.	16.3	16.3
Other	nil	202	202	nil	324	324	n.a.	6.1	6.1
Total	3,212	512	3,724	4,606	996	5,602	4.6	8.7	5.2
Commercial									
Space heating	599	nil	599	1,209	nil	1,209	9.1	n.a.	9.1
Water heating	350	48	398	422	60	482	2.4	2.8	2.5
Cooking	84	4	88	117	6	123	4.2	5.2	4.3
Air conditioning	23	138	161	97	265	362	19.7	8.5	10.6
Refrigeration	nil	133	133	nil	175	175	n.a.	3.5	3.5
Other	nil	36	36	nil	268	268	n.a.	28.5	28.5
Total	1,056	359	1,415	1,845	774	2,619	7.2	10.1	8.0
Industrial									
Process steam	3,869	--	3,869	5,797	--	5,797	5.2	n.a.	5.2
Electricity generation	177	-177	--	235	-235	--	3.6	-3.6	n.a.
Electric drive	--	862	862	--	1,353	1,353	n.a.	5.8	5.8
Electrolytic process	--	132	132	--	199	199	n.a.	5.2	5.2
Direct heat	1,869	52	1,921	2,771	92	2,863	5.1	7.3	5.1
Feedstock	372	--	372	455	--	455	2.6	n.a.	2.6
Other	--	32	32	--	56	56	nil	7.2	7.2
Total	6,287	901	7,188	9,258	1,465	10,723	5.0	6.2	5.2
Electric utility	Allocated			Allocated					
Transportation	359	13	372	610	10	620	6.8	-3.2	6.6
Total, all sectors	10,914	1,785	12,699	16,319	3,245	19,564	5.2	7.7	5.6

Note: n.a. = not applicable.

* Including heat wasted in production of electricity.

Sources: Bureau of Mines. Stanford Research Institute.

Table 10

GROWTH IN CONSUMPTION OF PETROLEUM PRODUCTS*
1960 and 1968
(Trillions of Btu)

	1960			1968			Average Annual Rate of Growth 1960-68 (percent)		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential									
Space heating	2,580	6	2,586	2,988	43	3,031	1.8%	27.5%	2.0%
Water heating	80	34	114	146	58	204	7.8	6.9	7.5
Cooking	39	16	55	49	25	74	2.9	5.8	3.8
Clothes drying	3	5	8	9	13	22	14.8	12.7	13.5
Refrigeration	nil	27	27	nil	65	65	n.a.	11.6	11.6
Air conditioning	nil	11	11	nil	40	40	n.a.	17.4	17.4
Other	nil	63	63	nil	118	118	n.a.	8.2	8.2
Total	2,702	162	2,864	3,192	362	3,554	2.1%	10.6%	2.7%
Commercial									
Space heating	1,489	nil	1,489	2,405	nil	2,405	6.2	--	6.2
Water heating	nil	16	16	nil	23	23	--	4.6	4.6
Cooking	nil	1	1	nil	2	2	--	8.0	8.0
Air conditioning	nil	43	43	nil	96	96	--	10.6	10.6
Refrigeration	nil	42	42	nil	63	63	--	5.2	5.2
Feedstock	734	nil	734	984	nil	984	3.7	--	3.7
Other	nil	11	11	nil	97	97	--	31.2	31.2
Total	2,223	113	2,336	3,389	281	3,670	5.4	12.0	5.8
Industrial									
Process steam	1,770	--	1,770	1,986	--	1,986	1.3	n.a.	1.3
Electricity generation	81	-81	--	80	-80	--	nil	nil	n.a.
Electric drive	--	292	292	--	488	488	n.a.	6.6	6.6
Electrolytic process	--	45	45	--	72	72	n.a.	6.1	6.1
Direct heat	823	18	841	808	33	841		7.6	nil
Feedstock	867	--	867	1,600	--	1,600	7.9	n.a.	7.9
Other	--	11	11	--	20	20	nil	7.7	7.7
Total	3,541	285	3,826	4,474	533	5,007	3.0	8.2	3.4
Electric utility	Allocated			Allocated					
Transportation	10,513	4	10,517	14,513	5	14,518	4.1	2.8	4.1
Total, all sectors	18,979	564	19,543	25,568	1,181	26,749	3.8	9.7	4.0

Note: n.a. = not applicable.

* Including heat wasted in production of electricity.

Sources: Bureau of Mines. Stanford Research Institute.

Table 11

GROWTH IN CONSUMPTION OF HYDROELECTRIC ENERGY*
1960 and 1968
(Trillions of Btu)

	1960			1968			Average Annual Rate of Growth 1960-68 (percent)		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential									
Space heating	--	6	6	--	27	27	--	20.7%	20.7%
Water heating	--	32	32	--	37	37	--	1.4	1.4
Cooking	--	16	16	--	16	16	--	--	--
Clothes drying	--	5	5	--	9	9	--	7.6	7.6
Refrigeration	--	26	26	--	42	42	--	30.5	30.5
Air conditioning	--	10	10	--	26	26	--	12.7	12.7
Other	--	61	61	--	75	75	--	2.6	2.6
Total	--	156	156	--	232	232	--	5.1	5.1
Commercial									
Space heating	--	nil	nil	--	nil	nil	--	n.a.	n.a.
Water heating	--	15	15	--	14	14	--	-0.9	-0.9
Cooking	--	1	1	--	1	1	--	--	--
Air conditioning	--	42	42	--	62	62	--	5.0	5.0
Refrigeration	--	41	41	--	41	41	--	--	--
Other	--	11	11	--	62	62	--	24.3	24.3
Total	--	110	110	--	180	180	--	6.3	6.3
Industrial									
Electric drive	--	221	221	--	273	273	--	2.8	2.8
Electrolytic process	--	34	34	--	40	40	--	1.8	1.8
Direct heat	--	13	13	--	18	18	--	4.2	4.2
Other	--	9	9	--	11	11	--	2.5	2.5
Total	--	277	277	--	342	342	--	2.7	2.7
Electric utility	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Transportation	--	4	4	--	3	3	--	-3.6	-3.6
Total, all sectors	--	547	547	--	757	757	-- --	4.1	4.1

Note: n.a. = not applicable.

* Including heat wasted in production of electricity.

Sources: Bureau of Mines. Stanford Research Institute.

Table 12

GROWTH IN CONSUMPTION OF NUCLEAR FUEL*
1960 and 1968
(Trillions of Btu)

	1960			1968			Average Annual Rate of Growth 1960-68 (percent)		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential									
Space heating	--	nil	nil	--	5	5	n.a.%	n.a.%	n.a.%
Water heating	--	1	1	--	7	7	n.a.	27.2	27.2
Cooking	--	nil	nil	--	3	3	n.a.	n.a.	n.a.
Clothes drying	--	nil	nil	--	1	1	n.a.	n.a.	n.a.
Refrigeration	--	nil	nil	--	7	7	n.a.	n.a.	n.a.
Air conditioning	--	nil	nil	--	4	4	n.a.	n.a.	n.a.
Other	--	1	1	--	13	13	n.a.	37.7	37.7
Total	--	2	2	--	40	40	n.a.	45.5	45.5
Commercial									
Space heating	--	nil	nil	--	nil	nil	n.a.	n.a.	n.a.
Water heating	--	nil	nil	--	2	2	n.a.	n.a.	n.a.
Cooking	--	nil	nil	--	nil	nil	n.a.	n.a.	n.a.
Air conditioning	--	1	1	--	11	11	n.a.	35.0	35.0
Refrigeration	--	nil	nil	--	7	7	n.a.	n.a.	n.a.
Other		nil	nil	--	11	11	n.a.	n.a.	n.a.
Total	--	1	1		31	31	n.a.	50.5	50.5
Industrial									
Electric drive	--	2	2	--	46	46	n.a.	48.0	48.0
Electrolytic process	--	1	1	--	7	7	n.a.	26.5	26.5
Direct heat	--	nil	nil	--	3	3	n.a.	n.a.	n.a.
Other	--	nil	nil	--	2	2	n.a.	n.a.	n.a.
Total	--	3	3	--	58	58	n.a.	45.0	45.0
Transportation	--	nil	nil	--	1	1	n.a.	n.a.	n.a.
Total, all sectors	--	6	6	--	130	130	n.a.	47.0	47.0

Note: n.a. = not applicable.

* Including heat wasted in production of electricity.

Sources: Bureau of Mines. Stanford Research Institute.

In the industrial sector, the average annual growth rate was 1.7% per year but this rate tends to be misleading because coal use by industry peaked in 1966 and then declined in 1967 and 1968. Furthermore, there has been no growth in the industrial use of coal through 1970, and probably through 1971. Thus, the more recent trend is a constant or slightly declining growth rate. Direct heat accounts for over half of the industrial use of coal (excluding electric utility consumption) and process steam for most of the rest.

Gas

The use of gas is much more widely spread among the various individual applications than coal, but the direct use of gas has much fewer applications than electricity. Gas is not much of a factor in refrigeration--this use actually declined between 1960 and 1968--or in air conditioning, and is not a factor in large and small appliances. Its use is heavily concentrated in space heating: about two-thirds of its residential and commercial use is for space heating.

Industrial use of gas is considerably larger than its combined use in residential and commercial applications, and gas has many applications in industrial processes.

Petroleum Products

Transportation accounts for over half the total consumption of petroleum products. Except for transportation, the uses of oil are more limited than gas. Over 80% of the residential and commercial consumption is for space heating.

In the industrial sector, over one-third the petroleum used is in the form of petrochemical feedstocks, which show a growth rate of almost 8% per year.

Hydro and Nuclear

There is no direct relationship between power generated by hydroelectric and nuclear plants and the classes of customers served. To obtain a total breakdown of energy consumption for all sources, it was necessary to make an arbitrary allocation.

III THE RESIDENTIAL SECTOR

Total Consumption of Energy

In 1968, the residential sector accounted for 19.2% of the total energy consumption of the United States, or 11,616 trillion Btu. This is 3,648 trillion Btu more than the sector consumed in 1960. Figures 6 and 7 show 1960 and 1968 residential energy consumption, by fuel and by end use, in terms of fuel input. Over this eight-year period, residential consumption of energy increased at an annual rate of 4.8% while energy consumption in general increased at a rate of 4.3%. The higher rate of growth in the residential sector reflects its growing share of the total electric energy consumed and the relatively large conversion losses associated with electricity.

Tables 13 and 14 show the growth of residential consumption, the former including the waste heat from electricity production and the latter excluding it. The year-by-year consumption (including this waste heat) is summarized in Table 15.

The relative importance of the various end uses is shown below as percentages of total residential consumption.

	1960	1968
Space heating	60.8%	57.5%
Water heating	14.5	14.9
Cooking	7.0	5.5
Refrigeration	4.6	6.0
Air conditioning	1.7	3.7
Television	2.0	3.0
Clothes drying	1.2	1.7
Food freezing	1.0	1.9
Other	7.2	5.8
Total	100.0%	100.0%

Four applications--space heating, water heating, cooking, and refrigeration--account for more than 80% of the energy used in households. Two

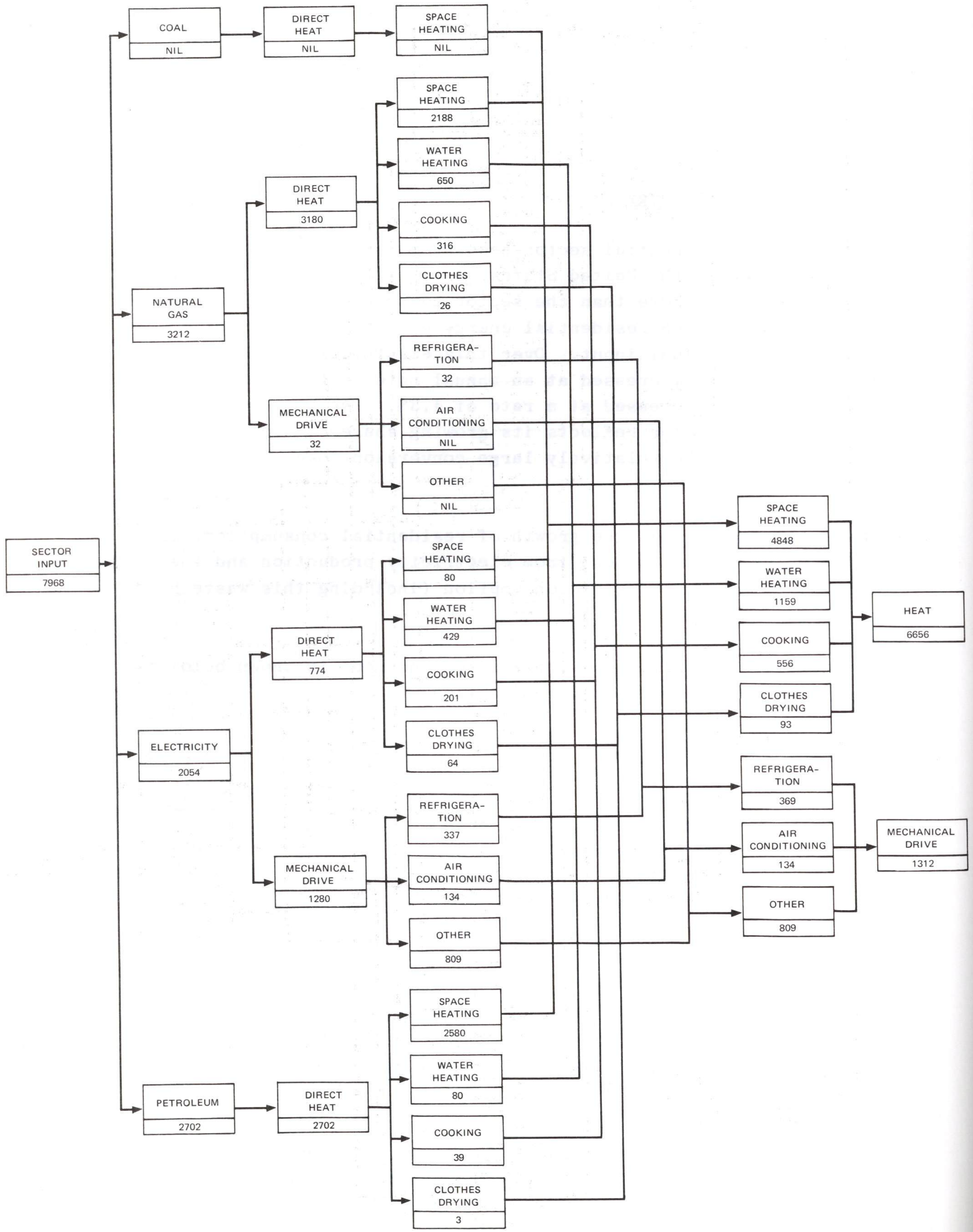

FIGURE 6 1960 RESIDENTIAL CONSUMPTION OF ENERGY (Trillions of Btu)

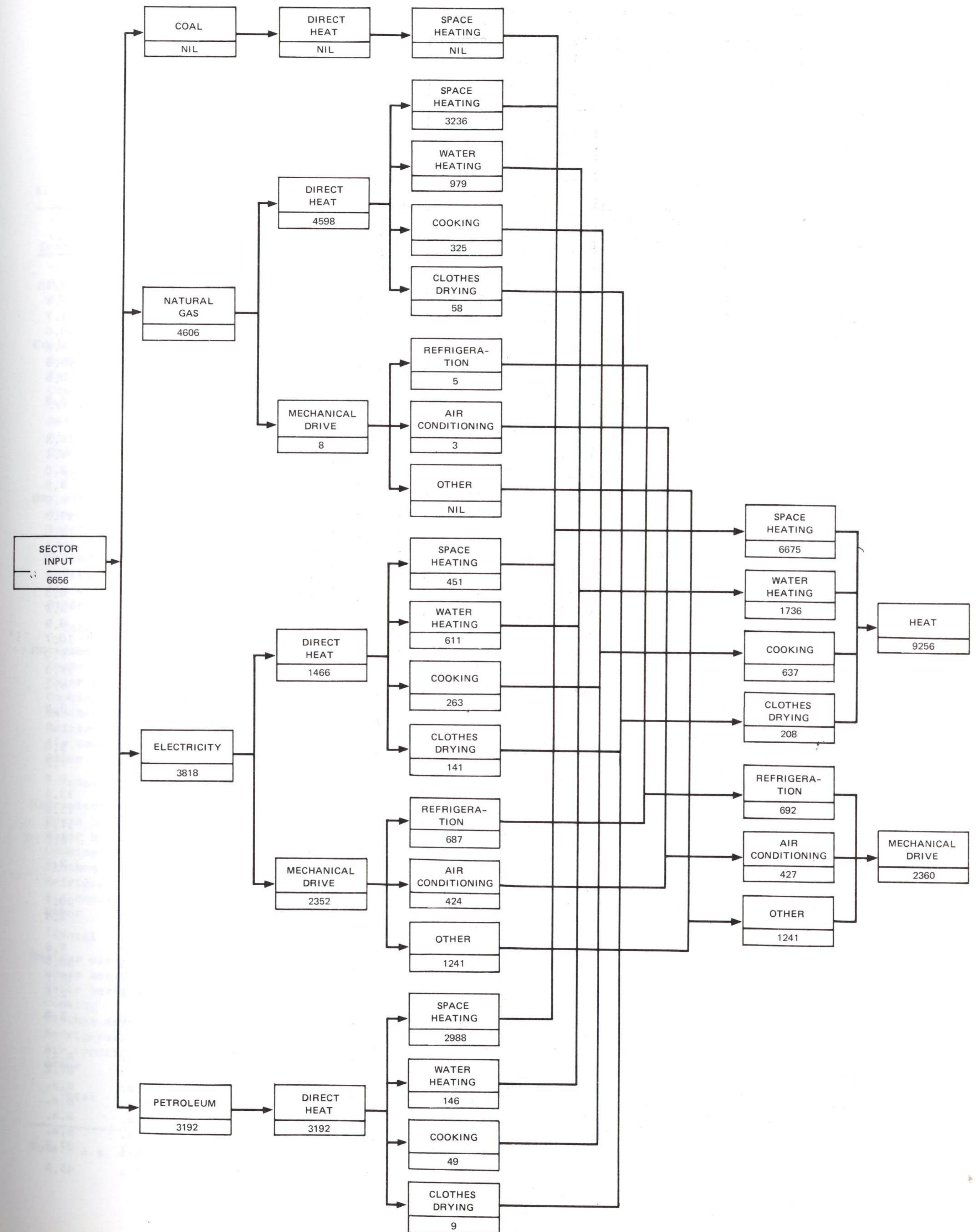

FIGURE 7 1968 RESIDENTIAL CONSUMPTION OF ENERGY (Trillions of Btu)

Table 13

GROWTH IN RESIDENTIAL ENERGY CONSUMPTION, INCLUDING WASTE HEAT IN ELECTRICITY PRODUCTION
1960-1968
(Trillions of Btu)

	1960			1968			Average Annual Growth Rate 1960-68 (percent)		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
All fuels									
Space heating	4,768	80	4,848	6,224	451	6,674	3.4%	24.5%	4.1%
Water heating	730	429	1,159	1,125	611	1,736	5.5	4.5	5.2
Cooking	355	201	556	374	263	637	0.6	3.4	1.7
Clothes drying	29	64	93	67	141	208	11.0	10.4	10.6
Refrigeration	32	337	369	5	687	692	-21.2	9.3	8.2
Air conditioning	--	134	134	3	424	427	n.a.	15.5	15.6
Other	--	809	809	--	1,241	1,241	--	5.5	5.5
Total	5,914	2,054	7,968	7,798	3,818	11,616	3.5	8.1	4.8
Coal									
Space heating	--	48	48	--	258	258	--	23.5	23.5
Water heating	--	255	255	--	350	350	--	4.1	4.1
Cooking	--	119	119	--	151	151	--	3.0	3.0
Clothes drying	--	38	38	--	81	81	--	9.9	9.9
Refrigeration	--	200	200	--	394	394	--	8.9	8.9
Air conditioning	--	80	80	--	243	243	--	14.9	14.9
Other	--	481	481	--	711	711	--	5.0	5.0
Total	--	1,221	1,221	--	2,188	2,188	--	7.6	7.6
Dry natural gas									
Space heating	2,188	20	2,208	3,236	118	3,354	5.0	24.0	5.3
Water heating	650	107	757	979	159	1,138	5.2	5.1	5.2
Cooking	316	50	366	325	68	393	0.3	3.9	0.9
Clothes drying	26	16	42	58	37	95	10.5	11.0	10.7
Refrigeration	32	84	116	5	179	184	-21.2	9.9	6.0
Air conditioning	--	33	33	3	111	114	n.a.	16.3	16.3
Other	--	202	202	--	324	324	--	6.1	6.1
Total	3,212	512	3,724	4,606	996	5,602	4.6	8.7	5.2
Petroleum products									
Space heating	2,580	6	2,586	2,988	43	3,031	1.8	27.5	2.0
Water heating	80	34	114	146	58	204	7.8	6.9	7.5
Cooking	39	16	55	49	25	74	2.9	5.8	3.8
Clothes drying	3	5	8	9	13	22	14.7	12.7	13.5
Refrigeration	--	27	27	--	65	65	--	11.6	11.6
Air conditioning	--	11	11	--	40	40	--	17.4	17.4
Other	--	63	63	--	118	118	--	8.2	8.2
Total	2,702	162	2,864	3,192	362	3,554	2.1	10.6	2.7
Hydroelectricity									
Space heating		6	6		27	27		20.7	20.7
Water heating		32	32		37	37		1.4	1.4
Cooking		16	16		16	16		nil	nil
Clothes drying		5	5		9	9		7.6	7.6
Refrigeration		26	26		42	42		30.5	30.5
Air conditioning		10	10		26	26		12.7	12.7
Other		61	61		75	75		2.6	2.6
Total	--	156	156	--	232	232		5.0	5.0
Nuclear electricity									
Space heating		--	--		5	5		n.a.	n.a.
Water heating		1	1		7	7		27.2	27.2
Cooking		--	--		3	3		n.a.	n.a.
Clothes drying		--	--		1	1		n.a.	n.a.
Refrigeration		--	--		7	7		n.a.	n.a.
Air conditioning		--	--		4	4		n.a.	n.a.
Other		1	1		13	13		37.7	37.7
Total	--	2	2	--	40	40		45.5	45.5

Note: n.a. = not applicable.

Table 14

GROWTH IN RESIDENTIAL ENERGY CONSUMPTION, EXCLUDING WASTE HEAT IN ELECTRICITY PRODUCTION
1960-1968
(Trillions of Btu)

	1960			1968			Average Annual Growth Rate 1960-68 (percent)		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
All fuels									
Space heating	4,768	29	4,797	6,224	164	6,388	3.4%	24.3%	3.6%
Water heating	730	155	885	1,125	223	1,348	5.5	4.6	5.4
Cooking	355	73	428	374	96	470	0.6	3.4	1.2
Clothes drying	29	23	52	67	51	118	11.0	10.4	10.7
Refrigeration	32	122	154	5	250	255	-21.2	9.3	6.5
Air conditioning	--	48	48	3	154	157	n.a.	15.6	16.0
Other	--	292	292	--	452	452	--	5.6	5.6
Total	5,914	742	6,656	7,798	1,390	9,188	3.5	8.2	4.1
Coal									
Space heating	--	15	15	--	83	83	--	23.5	23.5
Water heating	--	79	79	--	113	113	--	4.6	4.6
Cooking	--	37	37	--	49	49	--	3.6	3.6
Clothes drying	--	11	11	--	26	26	--	11.3	11.3
Refrigeration	--	62	62	--	127	127	--	9.3	9.3
Air conditioning	--	24	24	--	78	78	--	15.9	15.9
Other	--	149	149	--	231	231	--	5.6	5.6
Total	--	377	377	--	707	707	--	8.2	8.2
Dry natural gas									
Space heating	2,188	6	2,194	3,236	38	3,274	5.0	26.0	5.2
Water heating	650	33	683	979	52	1,031	5.2	5.8	5.3
Cooking	316	16	332	325	22	347	0.3	4.1	0.6
Clothes drying	26	5	31	58	12	70	10.5	11.5	10.6
Refrigeration	32	26	58	5	58	63	-21.2	10.5	1.0
Air conditioning	--	10	10	3	36	39	n.a.	17.3	18.5
Other	--	62	62	--	104	104	--	6.6	6.6
Total	3,212	158	3,370	4,606	322	4,928	4.6	9.3	4.9
Petroleum products									
Space heating	2,580	2	2,582	2,988	15	3,003	1.8	28.5	1.9
Water heating	80	11	91	146	19	165	7.8	7.0	7.7
Cooking	39	5	44	49	8	57	2.9	6.1	3.3
Clothes drying	3	2	5	9	4	13	14.7	9.1	12.7
Refrigeration	--	8	8	--	21	21	--	12.8	12.8
Air conditioning	--	3	3	--	13	13	--	20.0	20.0
Other	--	20	20	--	38	38	--	8.3	8.3
Total	2,702	51	2,753	3,192	118	3,310	2.1	11.0	2.4
Hydroelectricity									
Space heating		6	6		27	27		20.7	20.7
Water heating		32	32		37	37		1.8	1.8
Cooking		15	15		16	16		0.8	0.8
Clothes drying		5	5		9	9		7.6	7.6
Refrigeration		26	26		42	42		6.2	6.2
Air conditioning		11	11		26	26		11.3	11.3
Other		61	61		75	75		2.6	2.6
Total	--	156	156	--	232	232		5.1	5.1
Nuclear electricity									
Space heating		--	--		1	1		n.a.	n.a.
Water heating		--	--		2	2		n.a.	n.a.
Cooking		--	--		1	1		n.a.	n.a.
Clothes drying		--	--		nil	nil		nil	nil
Refrigeration		--	--		2	2		n.a.	n.a.
Air conditioning		--	--		1	1		n.a.	n.a.
other		--	--		4	4		n.a.	n.a.
Total	--	nil	nil	--	11	11		n.a.	n.a.

Note: n.a. = not applicable.

Table 15

GROWTH IN RESIDENTIAL ENERGY CONSUMPTION

1960-1968

(Trillions of Btu)

	1960	1961	1962	1963	1964	1965	1966	1967	1968
Fuel									
Dry natural gas	3,212	3,362	3,756	3,713	3,917	4,038	4,283	4,464	4,606
Light oil	1,850	1,865	1,890	1,865	1,820	1,985	1,990	2,040	2,060
Liquefied gases	404	412	450	483	495	510	543	594	686
Kerosene	448	444	467	453	404	449	433	388	446
Electricity	742	785	847	910	988	1,062	1,155	1,274	1,390
Subtotal	6,656	6,868	7,410	7,424	7,624	8,044	8,404	8,760	9,188
Allocated electrical conversion losses	1,312	1,353	1,436	1,559	1,688	1,805	2,015	2,190	2,428
Total	7,968	8,221	8,846	8,983	9,312	9,849	10,419	10,950	11,616
End use									
Space heating	4,848	5,013	5,461	5,402	5,550	5,895	6,126	6,397	6,675
Water heating	1,159	1,205	1,282	1,326	1,401	1,484	1,576	1,628	1,736
Cooking	556	557	568	575	584	595	608	613	637
Refrigeration	369	399	431	469	508	549	597	636	692
Air conditioning	134	150	167	196	231	273	312	363	427
Television	163	172	186	203	225	251	288	315	352
Clothes drying	93	101	111	121	136	152	170	185	208
Food freezing	83	95	108	122	141	157	178	196	220
Other	563	528	531	567	536	499	563	614	669
Total	7,968	8,220	8,845	8,981	9,312	9,855	10,418	10,947	11,616

residential uses of energy--air conditioning and clothes drying--substantially increased their share but still account for only a small portion of the total. Since the market for both of these types of appliances is far from saturated, further large increases may be expected in the future.

Methodology

The estimates of residential consumption of energy by functional use are based on the estimated number of appliances in use and their unit consumption. The number of units in use for individual years was usually based on Census of Housing data for 1960; to determine the number of each appliance in service for each year, a percentage of domestic sales was added to the total in service at the end of the previous year. Those not added to the previous year total were taken to be replacements.

Unit consumption of electrical energy for individual years was calculated using straight line interpolation between 1961 and 1969. For those years, Edison Electric Institute (EEI) estimates of typical annual consumption of selected appliances are available. Unit consumption for gas appliances was estimated using straight line interpolation between 1962 and 1969, for which years American Gas Association, Inc. (AGA) estimates are available.

Household consumption of petroleum products is shown in Table 16. Table 16 assumes that all light oil and kerosene were used for space heating (in rural areas kerosene may be used occasionally as tractor fuel). Liquefied petroleum gas was assumed to meet the same needs as natural gas; that is, except for refrigeration and air conditioning, which are too small to be of consequence, gas consumption for various applications was split between natural gas and LPG in proportion to total consumption.

Natural gas consumption in residential applications developed as shown in Table 17; most of the growth was accounted for by space and water heating. Petroleum products and natural gas were used primarily for space and water heating in residential applications.

Electricity consumption was more diversified; no individual end use accounted for as much as 20% of total residential electrical consumption (Table 17). Space heating and air conditioning increased most rapidly.

Table 16

RESIDENTIAL CONSUMPTION OF PETROLEUM PRODUCTS, BY END USE
1960-1968
(Trillions of Btu)

	1960	1961	1962	1963	1964	1965	1966	1967	1968
Space heating*	2,580	2,594	2,674	2,664	2,576	2,793	2,808	2,846	2,988
Water heating†	80	84	89	93	98	105	111	126	146
Cooking†	39	39	40	40	40	41	41	43	49
Clothes drying†	3	4	4	4	5	5	6	7	9
Total	2,702	2,721	2,807	2,801	2,719	2,944	2,966	3,022	3,192

* All light oil and kerosene plus a share of LPG.
† LPG only.

Space Heating

Energy is used for space heating either directly as fuel or as electricity. Since coal consumption in the residential sector is limited, consumption of energy for residential space heating in general is confined to natural gas, petroleum products, and electricity.

Electricity as an energy source for space heating has grown most rapidly, and electric heat is estimated to account for 20% of installations in all new homes. In 1968, 3.4 million homes were electrically heated compared with 0.7 million in 1960, as shown in Table 18. This represents an annual growth rate in excess of 20%.

Although 509,000 households acquired electric heat in 1969, only 449,000 were actually added to the 1968 total, which means that 60,000 households must have changed from electric heat to another fuel, probably natural gas.

Consumption of natural gas and petroleum products for residential space heat was calculated on the assumption that the natural gas and petroleum product that could not otherwise be identified was used in space heating. The resulting total energy consumption for residential space heating is shown in Table 19.

Table 17

RESIDENTIAL CONSUMPTION OF NATURAL GAS AND ELECTRICITY, BY END USE
(Trillions of Btu)
1960-1968

	1960	1961	1962	1963	1964	1965	1966	1967	1968
Natural gas									
Space heating	2,188	2,316	2,666	2,589	2,755	2,816	3,000	3,157	3,236
Water heating	650	677	719	753	791	847	902	923	979
Cooking	316	314	318	318	319	321	323	323	325
Clothes drying	26	29	32	36	39	44	49	53	58
Refrigeration	32	26	21	16	12	9	7	6	5
Air conditioning	--	--	--	1	1	1	2	2	3
Total	3,212	3,362	3,756	3,713	3,917	4,038	4,283	4,464	4,606
Electricity*									
Refrigeration	122	137	152	167	183	200	215	232	250
Water heating	155	163	176	177	189	197	205	213	223
Space heating	29	38	45	55	81	106	116	145	164
Air conditioning	48	55	62	72	85	99	113	133	154
Television	59	63	69	75	83	93	105	116	128
Cooking	73	75	78	80	83	86	89	91	96
Food freezer	30	35	40	45	52	58	65	72	80
Clothes drying	23	25	28	30	34	38	42	46	51
Other†	203	194	197	209	198	185	205	226	244
Total	742	785	847	910	988	1,062	1,155	1,274	1,390

* At 3,413 Btu per kwh.
† Dishwashers, washing machines, miscellaneous small appliances, and lighting.

Table 18

RESIDENTIAL CONSUMPTION OF ELECTRIC HEAT*

	Dwellings with Electric Heat† (thousands)	Average Annual Consumption per Dwelling‡ (kwh)	Total Consumption	
			Billions of kwh	Trillions of Btu
1960	719	11,908	8.6	80
1961	913	12,150	11.1	103
1962	1,058	12,397	13.1	121
1963	1,254	12,906	16.2	149
1964	1,910	12,460	23.8	219
1965	2,378	13,031	31.0	286
1966	2,698	12,652	34.1	318
1967	3,040	13,951	42.4	394
1968	3,388	14,153	48.0	451

* Includes ceiling cable, baseboards, furnaces, wall units, radiant ceiling panel, and boilers.

† All numbers are from "Electric Heat and Air Conditioning;" 1960 number is 3% less than 1960 Census figure for households with electric heat.

‡ Electric Heat and Air Conditioning for 1962 to 1968; SRI estimate for 1960 to 1961.

Table 19

RESIDENTIAL CONSUMPTION OF ENERGY FOR SPACE HEATING
(Trillions of Btu)
1960-1968

	Natural Gas	Petroleum Products	Electricity	Total
1960	2,188	2,588	80	4,856
1961	2,316	2,594	103	5,013
1962	2,666	2,674	121	5,461
1963	2,589	2,664	149	5,402
1964	2,755	2,576	219	5,550
1965	2,816	2,793	286	5,895
1966	3,000	2,808	318	6,126
1967	3,157	2,846	394	6,397
1968	3,236	2,988	451	6,675

Water Heating

In 1968 only 8% of all households were without a gas or electric water heater compared with 26% in 1960 as shown in Table 20. Despite a faster rate of growth of electric water heaters, gas water heaters outnumber electric water heaters by almost 3 to 1.

Estimates of total water heater installations were based on saturation data. Of all water heaters in use, gas water heaters were estimated to have accounted for three-fourths.

Table 20

SATURATION OF WATER HEATERS IN RESIDENCES
1960-1968

	Number of Households* (millions)	Percentage Saturation†		Number of Water Heaters in Use (millions)	
		Gas	Electric	Gas	Electric
1960	53.0	54%	20%	28.6	10.6
1961	53.3	56	21	29.8	11.2
1962	54.7	58	22	31.7	12.0
1963	55.2	59	22	32.7	12.2
1964	56.0	61	23	34.2	12.9
1965	57.3	63	23	36.1	13.2
1966	58.1	65	23	37.8	13.7
1967	58.8	66	24	38.8	14.1
1968	60.4	68	24	41.2	14.5

* Statistical Abstract of the United States, various years; household count as of March of years shown; mobile homes are included.

† Merchandising Week; 1960 Census, Gas Appliance Manufacturers Association, and SRI estimates.

The per unit and total energy consumption for gas and electric water heaters is shown in Table 21. The increased per unit consumption for both gas and electric water heaters may be explained by the fact that households

Table 21

RESIDENTIAL ENERGY CONSUMPTION FOR WATER HEATING

	Electricity				Gas			
			Total Consumption					
	Units (millions)	Consumption* (kwh)	Billions of kwh	Trillions of Btu	Units (millions)	Unit Consumption† (millions of Btu)	Total Consumption‡ (trillions of Btu)	Total Energy Consumption (trillions of Btu)
1960	10.6	4,272	45.3	429	28.6	25.5	730	1,159
1961	11.2	4,272	47.8	444	29.8	25.5	761	1,205
1962	12.0	4,290	51.6	474	31.7	25.5	808	1,282
1963	12.2	4,300	51.7	480	32.7	25.8	846	1,326
1964	12.9	4,320	55.6	512	34.2	26.0	889	1,401
1965	13.2	4,390	57.8	532	36.1	26.4	952	1,484
1966	13.7	4,400	60.1	563	37.8	26.8	1,013	1,576
1967	14.1	4,420	62.4	579	38.8	27.0	1,049	1,628
1968	14.5	4,490	65.4	613	41.2	27.2	1,125	1,738

* Source is Edison Electric Institute with SRI estimates.
† Source is American Gas Association with SRI estimates.
‡ Both natural and liquefied petroleum gas.

are using increasing quantities of hot water because of dishwashers and automatic washing machines.

Cooking

In 1960, about 96% of all households were equipped with gas or electric ranges. Taking into account the sales of new ranges and assuming an equal rate of replacement for gas and electric ranges, the distribution between the two types is as shown in Table 22. Electric ranges increased their share substantially from 33% in 1960 to almost 40% in 1968.

Table 22

DISTRIBUTION OF RESIDENTIAL RANGES BY GAS AND ELECTRIC

	Number of Households* (millions)	Sales of New Ranges† (thousands)		Total Number of Ranges in Households (millions)			
		Gas	Electric	Gas	Electric	Other	Total
Base‡				33.5	16.8	2.2	52.5
1960	53.0	1,814	1,495	33.5	17.4	2.1	53.0
1961	53.3	1,830	1,530	33.3	17.9	2.1	53.3
1962	54.7	1,981	1,675	33.8	18.8	2.1	54.7
1963	55.2	2,072	1,870	33.8	19.4	2.0	55.2
1964	56.0	2,170	1,965	33.9	20.1	2.0	56.0
1965	57.3	2,267	2,065	34.3	21.0	2.0	57.3
1966	58.1	2,163	2,029	34.4	21.8	1.9	58.1
1967	58.8	2,123	1,910	34.6	22.4	1.8	58.8
1968	60.4	2,286	2,307	35.1	23.6	1.7	60.4

* Statistical Abstract of the United States, various years; household count as of March of years shown; mobile homes are included.
† Statistical Abstract of the United States, various years.
‡ 1960 Census of Housing.

The average per unit energy consumption of electric ranges* decreased over the nine-year period by some 45 kwh per year, despite added features such as self-cleaning ovens, built-in clocks, and automatic timers. The per unit energy consumption of gas ranges is reported to have remained stable. Total energy consumption for ranges is detailed in Table 23.

One important development is microwave cooking. Studies by the American Gas Association show that microwave ovens use an average 96.5% fewer Btu than gas ovens and 71.4% fewer Btu than electric ovens. However, the current price of microwave ovens ($700 to $800) is not competitive. Industry sources believe that a price of $400 to $450 for the entire range will be necessary before sales could begin to penetrate the residential market to any significant extent.

Refrigerators

The number of refrigerators in use was computed assuming that all new housing will be equipped with one refrigerator and that the difference between sales and new housing starts constitutes replacements. The implied saturation of households with refrigerators therefore was 96% in 1969 as shown in Table 24. The lifetime of a refrigerator is 15 to 20 years.

Although gas refrigerators are basically no longer sold in this country, there are apparently some units still in operation. According to a French study,† in 1968, there were 350,000 gas refrigerators in use in the United States (compared with 2.6 million in 1960) using 4.8 trillion Btu. Total energy consumption for refrigeration is detailed in Table 25.

The unit consumption of electric refrigerators was calculated using the following averages as reported by the Edison Electric Institute with the breakdown by size indicated:

---

* Ranges include both surface units and ovens.

† The Domestic Gas Market: 1960-68, Report by the French Delegation, International Colloquium on Gas Marketing, 1970 Congress of the International Gas Union.

Table 23

RESIDENTIAL ENERGY CONSUMPTION FOR COOKING

	Electric				Gas*			
	Number of Ranges (millions)	Unit Consumption† (kwh)	Total Consumption Billions of kwh	Total Consumption Trillions of Btu	Number of Ranges (millions)	Unit‡ Consumption (millions of Btu)	Total Consumption (trillions of Btu)	Total Energy Consumption (trillions of Btu)
1960	17.4	1,225	21.3	202	33.5	10.6	355	557
1961	17.9	1,220	21.8	204	33.3	10.6	353	557
1962	18.8	1,215	22.8	210	33.8	10.6	358	468
1963	19.4	1,200	23.5	217	33.8	10.6	358	575
1964	20.1	1,205	24.2	225	33.9	10.6	359	584
1965	21.0	1,200	25.2	232	34.3	10.6	363	595
1966	21.8	1,195	26.1	244	34.4	10.6	364	608
1967	22.4	1,190	26.7	247	34.6	10.6	366	613
1968	23.6	1,180	28.0	264	35.1	10.6	374	638

* Including LPG.

† Source is Edison Electric Institute with SRI estimates.

‡ Source is American Gas Association with SRI estimates.

Table 24

SATURATION OF ELECTRICAL REFRIGERATORS* IN RESIDENCES
1959-1969

	Sales† (thousands)	New Housing‡ (thousands of dwellings)	Implied Replacement (thousands)	In Use (thousands)	Number of Households (thousands)	Percent of Saturation
1959				44,635§		
1960	3,241	1,296	1,945	45,931	53,021	87%
1961	3,273	1,365	1,908	47,296	53,291	89
1962	3,588	1,492	2,096	48,788	54,652	89
1963	3,969	1,641	2,328	50,429	55,189	91
1964	4,381	1,590	2,791	52,019	55,996	93
1965	4,782	1,510	3,272	53,529	57,251	93
1966	5,110**	1,196	3,605	54,725	58,092	94
1967	5,905**	1,322	3,240	56,047	58,845	95
1968	5,584**	1,545	3,481	57,592	60,444	96

* Includes refrigerators with freezer compartments.

† Source is Current Industrial Reports, Bureau of the Census; excludes imports and exports.

‡ Includes multilevel housing; the source is Housing Construction Statistics 1889-1969, Bureau of the Census.

§ Source is Consumer Buying Indicators.

** Includes imports.

Table 25

RESIDENTIAL ENERGY CONSUMPTION FOR REFRIGERATION

	Electric				Gas			
	Number of Units (millions)	Unit Consumption (kwh)	Total Consumption: Billions of kwh	Total Consumption: Trillions of Btu	Number of Units (millions)	Unit Consumption (millions of Btu)	Total Consumption (trillions of Btu)	Total Energy Consumption (trillions of Btu)
1960	45.9	790	35.8	338	2.5	13	32	370
1961	47.3	850	40.2	373	2.0	13	26	399
1962	48.8	910	44.5	410	1.6	13	21	431
1963	50.4	970	48.9	453	1.2	13	16	469
1964	52.0	1,030	53.5	496	0.9	13	12	508
1965	53.5	1,090	58.4	540	0.6	14	9	549
1966	54.7	1,150	62.9	590	0.5	14	7	597
1967	56.0	1,210	67.7	630	0.4	14	6	636
1968	57.6	1,270	73.2	687	0.4	14	5	692

* Source is Edison Electric Institute with SRI estimates.

† Source is SRI estimates based on data reported in "The Domestic Gas Market," op. cit.

	Average Unit Consumption (kwh/year)	Estimated Share of Refrigerators in Use
1969		
Refrigerator		
12 cu ft	728	1/6
12 cu ft (frostless)	1,217	1/3
Refrigerator-freezer		
14 cu ft	1,137	1/6
14 cu ft (frostless)	1,829	1/3
1961		
Refrigerator	460	2/3
Refrigerator-freezer	1,625	1/3

Increased unit consumption may be attributed to increased size and new mechanisms such as automatic temperature control, automatic ice cube makers, and automatic defrosting. In 1968, the most popular models of new frost-free refrigerator freezers ranged from 13.5 cu ft to 17.0 cu ft of capacity, with electric energy consumption ranging from 900 kwh/year to 2000 kwh/year.*

Clothes Drying

Clothes dryers are somewhat of a luxury item, and it is estimated that only 40% of all households were equipped with them in 1969; probably no household is equipped with more than one dryer. Sales of clothes dryers, estimated replacements (assumed at 20% of sales†), and resulting in-use figures for clothes dryers for 1960 to 1969 are shown in Table 26. The ratio of electric to gas dryers in use, as well as new sales, has remained relatively stable at 2:1.

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* Consumer Reports, the Buying Guide Issue, Dec. 1968, Vol. 33, No. 12.

† Federal Government Statistics Related to Home Laundry Industry, American Home Laundry Manufacturers Association, Section 11.

Table 26

SATURATION OF CLOTHES DRYERS IN RESIDENCES
(Thousands of Units)
1960-1969

	Sales*		Replacements†		New		In Use		Percent Saturation	
	Gas	Electric	Gas	Electric	Gas	Electric	Gas	Electric	Gas	Electric
Base‡							2,777	6,308		
1960	442	818	86	160	356	658	3,133	6,966	6%	13%
1961	449	854	88	155	361	699	3,494	7,665	7	14
1962	485	935	95	185	390	750	3,884	8,415	7	15
1963	537	1,060	108	208	429	852	4,313	9,267	8	16
1964	682	1,194	134	238	548	956	4,861	10,223	9	18
1965	706	1,376	141	275	565	1,101	5,426	11,324	9	20
1966	767	1,593	153	319	614	1,274	6,040	12,598	10	22
1967	825	1,302	165	260	660	1,042	6,700	13,640	11	23
1968	873	1,963	175	393	698	1,570	7,398	15,210	12	25
1969	901	2,093	180	419	721	1,674	8,119	16,884	13	27

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* Source is Current Industrial Reports, Bureau of the Census, no import figures are available; figures include exports.

† Estimated at 20% of sales.

‡ Source is 1960 Census of Housing.

Despite greater average utilization of dryers, the unit consumption of gas dryers has declined, as shown in Table 27. The reason for the decline is the gradual replacement of gas pilots (which account for nearly 50% of the total energy consumption in gas dryers) with electric pilots. Total energy consumption for clothes drying is shown in Table 27.

Home Freezers

Increasing sales of larger refrigerators with large freezer compartments have adversely affected sales of individual freezers, and freezer sales increased at an average annual rate of only 1.7% from 1960 through 1969.

Since a freezer has few moving parts, its life expectancy is relatively long and replacements are assumed at only 30% of sales. The unit electricity consumption, as shown in Table 28, was calculated using EEI estimates for 1961 and 1969 as follows:

	Average Wattage	Annual Consumption (kwh)
1969		
Food freezer (15 cu ft)	341	1,195
Food freezer (15 cu ft frostless)	440	1,761
Average		1,478
1961		
Food freezer	300	915

Television

Almost all households own one television set, and a substantial number owns two or more. Saturation exceeds 90% for all sets and 30% for color sets. Assuming that 40% of all sets sold replace old sets, the number of sets in use was developed as shown on Table 29. The replacement percentage may be high for color sets because they have been marketed only since 1954, but low for monochrome sets. Some estimates indicate as much as 55% of sales are to replace old sets. The average life span is about 8 to 10 years for both color and black and white sets.

Table 27

RESIDENTIAL CONSUMPTION OF ENERGY FOR CLOTHES DRYING

	Electric				Gas*			
	Number of Units (millions)	Unit Consumption† (kwh)	Total Consumption Billions of kwh	Total Consumption Trillions of Btu	Number of Units (millions)	Unit Consumption‡ (millions of Btu)	Total Consumption (trillions of Btu)	Total Energy Consumption (trillions of Btu)
1960	7.0	960	6.7	64	3.1	9.3	29	93
1961	7.7	960	7.4	68	3.5	9.3	33	101
1962	8.4	965	8.4	75	3.9	9.2	36	111
1963	9.3	970	9.0	81	4.3	9.2	40	121
1964	10.2	975	10.0	92	4.9	9.1	44	136
1965	11.3	980	11.1	103	5.4	9.05	49	152
1966	12.6	980	12.3	115	6.0	9.05	55	170
1967	13.6	985	13.4	125	6.7	9.0	60	185
1968	15.2	990	15.1	140	7.4	9.0	67	207

* Including LPG.
† Source is Edison Electric Institute with SRI estimates.
‡ Source is American Gas Association with SRI estimates.

Table 28

RESIDENTIAL CONSUMPTION OF ENERGY IN FOOD FREEZERS

	Sales* (thousands)	Replacements† (thousands)	New Units (thousands)	Units in Use (thousands)	Unit‡ Consumption (kwh)	Total Consumption Billions of kwh	Total Consumption Trillions of Btu
Base§				9,757			
1960	998	299	699	10,456	845	8.8	83
1961	1,015	303	712	11,168	915	10.2	95
1962	1,039	311	728	11,896	985	11.7	108
1963	1,059	317	742	12,638	1,055	13.3	122
1964	1,164	349	815	13,453	1,125	15.1	141
1965	1,124	337	787	14,240	1,195	17.0	157
1966	1,073	322	751	14,991	1,265	19.0	178
1967	1,082	324	758	15,749	1,335	21.1	196
1968	1,110	332	778	16,527	1,405	23.3	220

* Source is Current Industrial Reports, Bureau of the Census.

† At 30% of sales.

‡ Source is Edison Electric Institute with SRI estimates.

§ Source is 1960 Census of Housing.

Table 29

SATURATION OF TELEVISION SETS IN RESIDENCES
(Thousands of Units)

	Sales* Monochrome	Sales* Color	Replacements† Monochrome	Replacements† Color	Sets in Use Monochrome	Sets in Use Color
Base‡					44,924	1,389
1960	5,605	117	2,242	47	48,287	1,459
1961	6,047	144	2,419	58	51,915	1,545
1962	6,460	438	2,584	175	55,791	1,808
1963	7,141	749	2,856	300	60,076	2,257
1964	8,542	1,541	3,417	616	65,201	3,182
1965	8,954	2,827	3,582	1,131	70,573	4,878
1966	7,904	5,549	3,162	2,220	75,315	8,207
1967	5,384	6,496	2,154	2,598	78,545	12,105
1968	6,296	7,865	2,518	3,146	82,323	16,824
1969	7,270	6,607	2,908	2,643	86,685	20,788

* Source is Current Industrial Reports, Bureau of the Census.

† Assumed at 40% of sales.

‡ Source is National Survey of Television Sets in U.S. households, June 1967, Advertising Research Foundation.

Color sets consume 30% to 40% more energy than monochrome sets. Larger picture tubes and features such as "instant picture" have increased the average energy consumption per set over the years, despite the fact that the average use per set declined because of extra sets in many households. Total energy consumption of television sets is shown in Table 30.

Air Conditioning

One of the most rapidly growing uses of energy in households is for air conditioning; in 1968, almost 25 million air-conditioning units were in operation.

Table 30

RESIDENTIAL ENERGY CONSUMPTION FOR TELEVISION

	Monochrome Sets			Color Sets			Total Energy Consumption	
	Number of Units (millions)	Unit Consumption* (kwh)	Total Consumption (billions of kwh)	Number of Units (millions)	Unit Consumption (kwh)	Total Consumption (billions of kwh)	Billions of kwh	Trillions of Btu
1960	48.2	345	16.6	1.5	450	0.7	17.3	163
1961	51.9	345	17.9	1.5	450	0.7	18.6	172
1962	55.8	346	19.3	1.8	455	0.8	20.1	186
1963	60.1	349	21.0	2.3	460	1.1	22.1	203
1964	65.2	350	22.8	3.2	465	1.5	24.3	225
1965	70.6	352	24.9	4.9	470	2.3	27.2	251
1966	75.3	356	26.8	8.2	475	3.9	30.7	288
1967	78.5	359	28.2	12.1	482	5.8	34.0	315
1968	82.3	360	29.6	16.8	490	8.2	37.8	352

* Source is Edison Electric Institute with SRI estimates.

All room air conditioners were assumed to operate in residences, since sales records do not show how many are used in small commercial establishments. Air-conditioning units in use were estimated as shown in Table 31. Replacements as a share of total sales or shipments were assumed at 50% for room air conditioners (life expectancy probably less than 10 years) and 30% for electric central air conditioners which are still relatively small in number and have a somewhat longer average life. Central gas air conditioners, with fewer moving parts than electric units, have a longer lifetime of about 20 years and were assumed to constitute incremental units.

The average energy consumption for room air conditioners was reported by EEI for 1969 and 1961. Increases are the result of a larger unit size of 1,600 watts in 1969 compared with 1,300 watts in 1961; data for intermediate years were interpolated.

Central air-conditioning units, both electric and gas, have been assumed to average three tons of refrigeration (36,000 Btu per hour of heat removal capacity). Electric units were estimated to consume 3,600 kwh per year on the average, and gas to average 60% of the efficiency of an electric unit.

Total energy consumption for residential air conditioning is shown in Table 32.

Other Large Appliances

Other large appliances include dishwashers and washing machines. Total residential consumption was about 5 billion kwh for each in 1969. Despite this low level of energy consumption, they are included here because both appliances consume large quantities of hot water and the energy consumption for heating this water is included in water heating. Thus dishwashers and washing machines are substantial consumers of energy if this indirect use of energy is included. Dishwashers, particularly, will increase in relative importance since only an estimated 20% of all households are equipped with them--as shown in Table 33; energy consumption in dishwashers, excluding energy for heating water, is shown on Table 34.

On the other hand, three-quarters of all households have washing machines and sales have grown only to the extent that the number of households have grown, as shown in Table 35. Energy consumption, as shown in Table 36, for the period 1960 through 1968 increased only to the extent that the number of households and unit consumption increased.

Table 31

SATURATION OF AIR-CONDITIONING UNITS IN RESIDENCES
(Thousands of Units)
1960-1968

	Electric Room Air Conditioners				Electric Central Air Conditioners				Gas Central Air Conditioners	
	Sales*	Replacement Units (50%)	Incremental Units (50%)	Units in Use	Shipments†	Replacement Units (30%)	Incremental Units (70%)	Units in Use	Sales‡	Units in Use
Base§				7,126				996		
1960	1,402	701	701	7,827	312	94	218	1,214		
1961	1,327	663	664	8,491	366	110	256	1,470		
1962	1,445	722	723	9,214	467	140	327	1,797		15**
1963	1,868	934	934	10,148	580	174	406	2,203	11	26
1964	2,565	1,282	1,283	11,431	701	210	491	2,694	17	43
1965	2,755	1,377	1,378	12,809	828	248	580	3,274	20	63
1966	3,101	1,550	1,551	14,360	960	288	672	3,946	29	92
1967	3,839	1,919	1,920	16,280	1,047	314	733	4,679	29	121
1968	3,747	1,873	1,874	18,154	1,165	350	815	5,494	39	160

* Source is Current Industrial Reports, Bureau of the Census.
† Source is Current Statistical Review, Metal Products Manufacturing.
‡ Source is H. R. Linden, "Current Trends in U.S. Gas Demand and Supply," Public Utilities Fortnightly.
§ Source is 1960 Census of Housing.
** SRI estimate.

Table 32

RESIDENTIAL ENERGY CONSUMPTION FOR AIR CONDITIONING

	Electric								Gas			Total Energy Consumption (trillions of Btu)
	Room Air Conditioning			Central Air Conditioning			Total Consumption		Central Air Conditioning			
	Units (millions)	Unit Consumption* (kwh)	Total Consumption (billions of kwh)	Units (thousands)	Unit Consumption† (kwh)	Total Consumption (billions of kwh)	Billions of kwh	Trillions of Btu	Units (thousands)	Unit Consumption (millions of Btu)	Total Consumption (trillions of Btu)	
1960	7.8	1,250	10	1,214	3,600	4	14	133	--	--	--	133
1961	8.5	1,265	11	1,470	3,600	5	16	150	--	--	--	150
1962	9.2	1,280	12	1,797	3,600	6	18	167	15	20	--	167
1963	10.1	1,295	13	2,203	3,600	8	21	195	26	20	1	196
1964	11.4	1,310	15	2,694	3,600	10	25	230	43	20	1	231
1965	12.8	1,325	17	3,274	3,600	12	29	272	63	20	1	273
1966	14.4	1,340	19	3,946	3,600	14	33	310	92	20	2	312
1967	16.3	1,360	22	4,679	3,600	17	39	361	121	20	2	363
1968	18.2	1,375	25	5,494	3,600	20	45	423	160	20	3	426

* Source is Edison Electric Institute with SRI estimates.
† SRI estimate.

Table 33

SATURATION OF DISHWASHERS IN RESIDENCES
(Thousands of Units)

	Sales*	Replacement†	New	In Use	Percentage Saturation
Base‡				2,537	
1960	531	80	451	2,988	6%
1961	590	88	502	3,490	6
1962	691	104	587	4,077	7
1963	841	126	715	4,792	9
1964	1,035	155	880	5,672	10
1965	1,208	181	1,027	6,699	12
1966	1,453	218	1,235	7,934	14
1967	1,532	230	1,302	9,236	16
1968	1,915	287	1,628	10,864	18
1969	2,072	311	1,761	12,625	20

* Source is Current Industrial Reports, Bureau of the Census. Excludes exports; no imports available.

† Source is "Consumer Buying Indicators," Census Population Reports (p. 65).

‡ Estimated at 15%.

Table 34

RESIDENTIAL ENERGY CONSUMPTION FOR DISHWASHERS

	Units (millions)	Unit Consumption* (kwh)	Total Consumption: Billions of kwh	Total Consumption: Trillions of Btu
1960	3.0	338	1	8
1961	3.5	340	1	11
1962	4.1	342	1	13
1963	4.8	345	2	16
1964	5.7	348	2	19
1965	6.7	351	2	22
1966	7.9	354	3	27
1967	9.2	357	3	30
1968	10.9	360	4	36

* Source is Edison Electric Institute with SRI estimates.

Table 35

SATURATION OF WASHING MACHINES IN RESIDENCES
(Thousands of Units)

	Sales*: Washers	Sales*: Washer Dryer Combos	Total Sales	Replacement†	New	In Use	Percentage Saturation
Base‡						38,967	
1960	3,269	151	3,420	2,736	681	39,648	75%
1961	3,350	94	3,444	2,755	689	40,337	76
1962	3,710	44	3,754	3,003	751	41,088	75
1963	3,950	32	3,982	3,186	796	41,884	75
1964	4,087	29	4,116	3,293	823	42,707	76
1965	4,345	39	4,384	3,507	877	43,584	76
1966	4,329	39	4,368	3,494	874	44,458	76
1967	4,222	43	4,265	3,412	853	45,311	77
1968	4,365	38	4,403	3,522	881	46,192	76
1969	4,287	43	4,330	3,461	866	47,058	76

* Source is Statistical Highlights, Gas Appliances Manufacturers Association, 1960 to 1969.

† Estimated at 80%.

‡ Source is 1960 Census of Housing.

Table 36

RESIDENTIAL ENERGY CONSUMPTION IN WASHING MACHINES

	Units (thousands)	Unit* Consumption (kwh)	Total Energy Consumption: Billions of kwh	Total Energy Consumption: Trillions of Btu
1960	39,648	65	3	25
1961	40,337	65	3	25
1962	41,088	69	3	30
1963	41,884	73	3	27
1964	42,707	77	3	30
1965	43,584	82	4	32
1966	44,458	86	4	36
1967	45,311	92	4	41
1968	46,192	98	5	41

* Source is Edison Electric Institute with SRI estimates.

Lighting and Small Appliances

The remaining electric energy used in households was for lighting and miscellaneous small appliances. Little detail is available on lamps, and estimates on consumption of electricity by small appliances--as shown in Table 2--is controversial.

In 1968, a total of 669 trillion Btu of electric energy was unaccounted for. Assuming that an average five 100 watt bulbs burned 4 hours per day in each household (2 kwh per day), the accounted for energy can be divided as follows.

	Trillions of Btu
Dishwashing	36
Washing machine	41
Lighting	412
Miscellaneous small appliances*	180
	669

* Remainder.

IV THE COMMERCIAL SECTOR

Total Consumption of Energy

The commercial sector is difficult to define. In negative terms, the commercial sector may be defined as those activities that are not classified as mining, manufacturing, transportation, and residential. In using this negative definition, the commercial sector becomes an agglomeration of various--and often unrelated--activities. They include commercial farms, fisheries, construction contractors, wholesale and retail trade, finance and insurance companies, real estate and law offices, hotels and restaurants, repair services, health services, motion pictures and other recreational services, schools, museums, art galleries, and all governmental institutions. From this list of activities, it is evident that factual information on end uses of energy is impossible to obtain (for all practical purposes) and that analysis of such uses of energy must rely more on deduction than calculation.

Therefore, this section attempts to explain total energy consumption of the commercial sector by assigning individual fuels (i.e., coal, oil) to individual end uses (i.e., heat, feedstocks) and by hypothesizing about consumption of gas and electricity in other uses such as air conditioning, water heating, cooking, and refrigeration.

In 1968, estimated consumption of energy by commercial sector accounted for 8.8 trillion Btu or 14.5% of the total U.S. energy consumption compared with 5.7 trillion or 13.3% of the total in 1960. Energy consumption by the commercial sector in 1960 and 1968 is summarized in Figures 8 and 9, which show the breakdown by fuel and by end use.

As in the residential sector, a major reason for the increased commercial share is the growing use of electricity and the conversion losses associated with electricity--see Table 37. Except for coal and asphalt and road oil, all fuels have increased their share as shown below.

	1960	1968
Coal	17.8%	6.5%
Heavy oil	13.7	14.1
Light oil	12.2	13.4
Asphalt and road oil	12.8	11.2
Natural gas	18.4	21.0
Electricity	25.1	33.8
Total	100.0%	100.0%

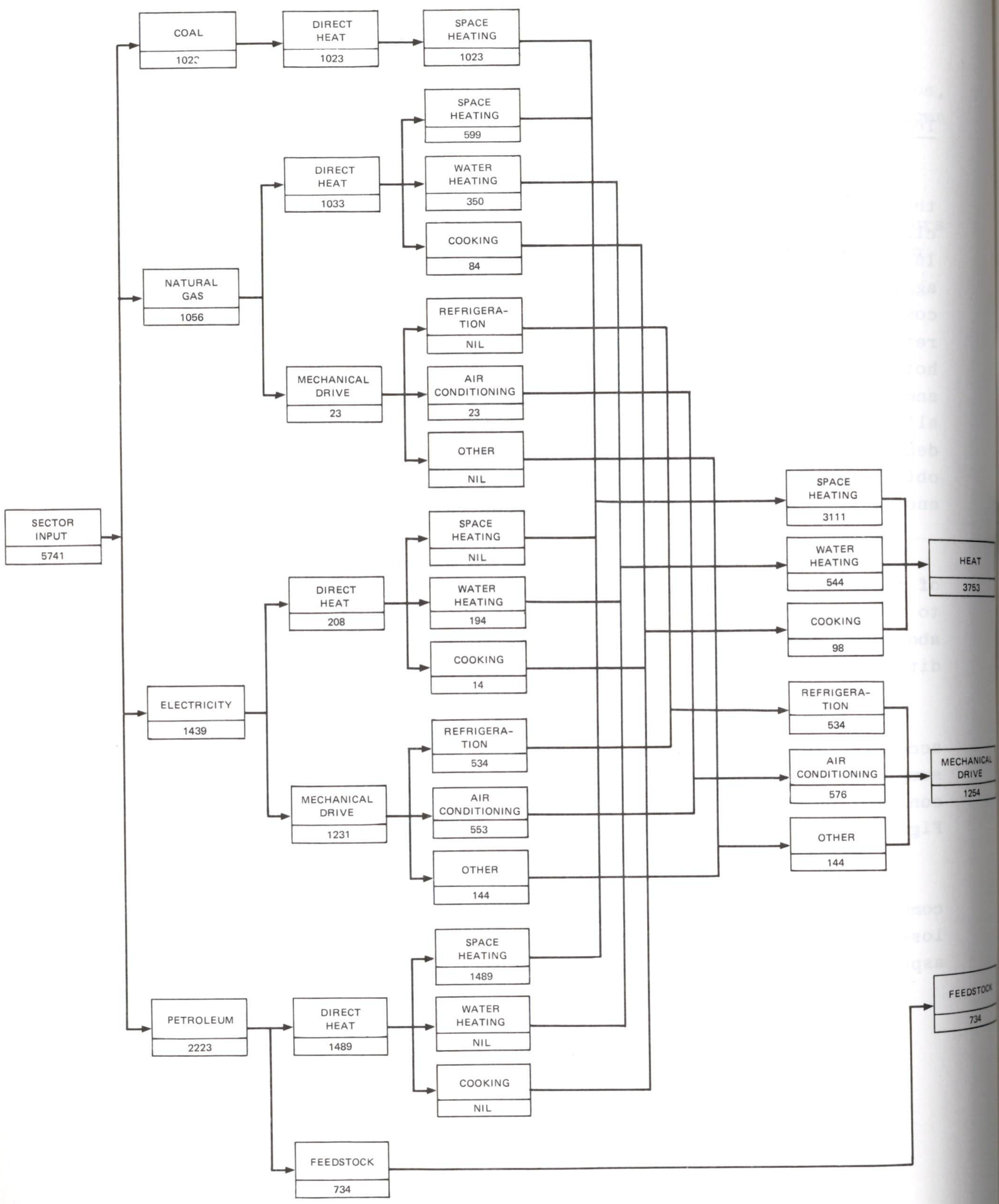

FIGURE 8 1960 COMMERCIAL CONSUMPTION OF ENERGY (Trillions of Btu)

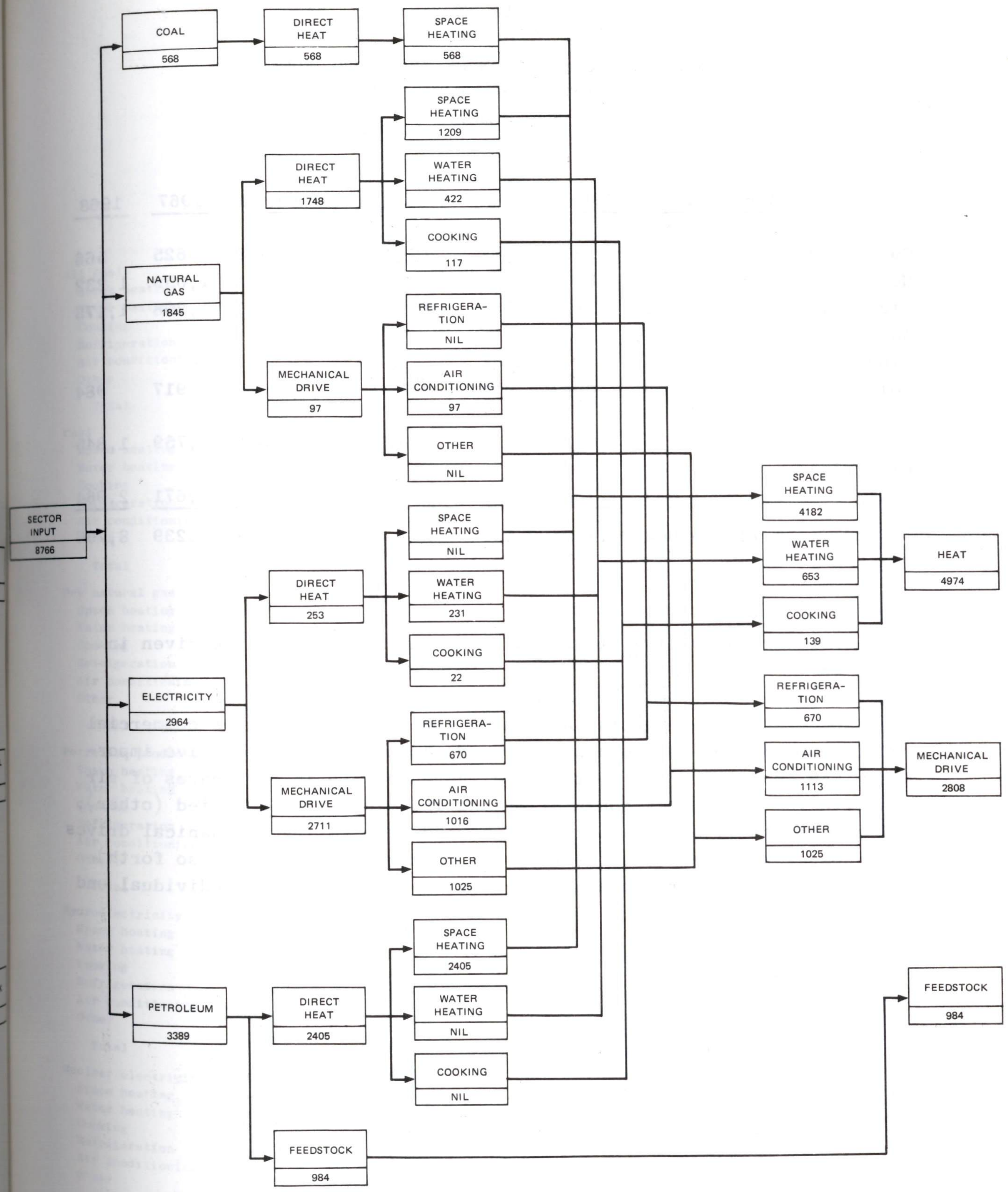

FIGURE 9 1968 COMMERCIAL CONSUMPTION OF ENERGY (Trillions of Btu)

Table 37

COMMERCIAL CONSUMPTION OF ENERGY BY FUEL
(Trillions of Btu)
1960-1968

	1960	1961	1962	1963	1964	1965	1966	1967	1968
Coal	1,023	912	920	774	751	714	718	625	568
Heavy oil	788	763	829	846	838	984	1,132	1,059	1,232
Light oil	701	792	789	788	795	817	733	1,208	1,173
Asphalt and road oil	734	753	804	824	841	891	936	917	984
Natural gas	1,056	1,114	1,093	1,314	1,426	1,479	1,662	1,759	1,845
Electricity	1,439	1,634	1,734	1,993	2,186	2,391	2,597	2,671	2,964
Total	5,741	5,968	6,169	6,539	6,837	7,276	7,778	8,239	8,766

Growth rates of individual fuels by functional uses are given in Table 38.

Space and water heating accounted for two-thirds of the commercial energy consumption as shown in Table 39; however, their relative importance has declined. The most marked increases are in the shares of air conditioning and energy consumption not individually classified (other), which consists of electric energy consumed in lighting, mechanical drives (for computers, elevators, escalators, office machinery, and so forth) and perhaps as electric heat. The relative importance of individual end uses is shown below.

	1960	1968
Space heating	54.2%	47.7%
Asphalt and road oils	12.8	11.2
Water heating	9.5	7.5
Air conditioning	10.0	12.7
Refrigeration	9.3	7.6
Cooking	1.7	1.6
Other	2.5	11.7
Total	100.0%	100.0%

Table 38

RATE OF GROWTH OF FUEL CONSUMPTION BY END USE
IN THE COMMERCIAL SECTOR
1960-1968
(Trillions of Btu)

	1960			1968			Average Annual Growth Rate 1960-68 (percent)		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
All fuels									
Space heating	3,111	--	3,111	4,182	--	4,182	3.8%	--%	3.8%
Water heating	350	194	544	422	231	653	2.4	2.2	2.3
Cooking	84	14	98	117	22	139	4.2	5.8	4.4
Refrigeration	--	534	534	--	670	670	--	2.9	2.9
Air conditioning	23	553	576	97	1,016	1,113	19.7	7.9	8.6
Other	734	144	878	984	1,025	2,009	3.7	27.5	10.9
Total	4,302	1,439	5,741	5,802	2,964	8,766	3.8	9.4	5.4
Coal									
Space heating	1,023	--	1,023	568	--	568	-7.1	--	-7.1
Water heating	--	115	115	--	132	132	--	1.7	1.7
Cooking	--	8	8	--	13	13	--	6.2	6.2
Refrigeration	--	318	318	--	384	384	--	2.4	2.4
Air conditioning	--	329	329	--	582	582	--	7.3	7.3
Other	--	86	86	--	587	587	--	27.2	27.2
Total	1,023	856	1,879	568	1,698	2,266	-7.1	8.9	2.4
Dry natural gas									
Space heating	599	--	599	1,209	--	1,209	9.1	--	9.1
Water heating	350	48	398	422	60	482	2.4	2.8	2.5
Cooking	84	4	88	117	6	123	4.2	5.2	4.3
Refrigeration	--	133	133	--	175	175	--	3.5	3.5
Air conditioning	23	138	161	97	265	362	19.7	8.5	10.6
Other	--	36	36	--	268	268	--	28.5	28.5
Total	1,056	359	1,415	1,845	774	2,619	7.2	10.1	8.0
Petroleum products									
Space heating	1,489	--	1,489	2,405	--	2,405	6.2	--	6.2
Water heating	--	16	16	--	23	23	--	4.6	4.6
Cooking	--	1	1	--	2	2	--	8.0	8.0
Refrigeration	--	42	42	--	63	63	--	5.2	5.2
Air conditioning	--	43	43		96	96	--	10.6	10.6
Other	734	11	745	984	97	1,081	3.7	31.5	31.5
Total	2,223	113	2,336	3,389	281	3,670	5.4	12.0	5.8
Hydroelectricity									
Space heating		--	--		--	--			
Water heating		15	15		14	14		-0.9	-0.9
Cooking		1	1		1	1		n.a.	n.a.
Refrigeration		41	41		41	41		n.a.	n.a.
Air conditioning		42	42		62	62		5.0	5.0
Other		11	11		62	62		24.3	24.3
Total	--	110	110	--	180	180		6.3	6.3
Nuclear electricity									
Space heating		--	--		--	--			
Water heating		nil	nil		2	2		n.a.	n.a.
Cooking		nil	nil		nil	nil		nil	nil
Refrigeration		nil	nil		7	7		n.a.	n.a.
Air conditioning		1	1		11	11		35.0	35.0
Other		nil	nil		11	11		n.a.	n.a.
Total	--	1	1	--	31	31		50.5	50.5

Note: n.a. = not applicable.

Table 39

COMMERCIAL CONSUMPTION OF ENERGY BY END USE
(Trillions of Btu)
1960-1968

	1960	1961	1962	1963	1964	1965	1966	1967	1968
Space heating	3,111	3,100	3,138	3,209	3,266	3,435	3,658	4,046	4,182
Asphalt and road oil	734	753	804	824	841	891	936	917	984
Water heating	544	563	561	581	604	604	629	627	653
Air conditioning	577	607	652	718	774	851	952	1,027	1,113
Refrigeration	534	542	550	570	585	599	626	638	670
Cooking	98	101	105	111	114	119	125	130	139
Other	143	302	359	526	653	777	852	854	1,025
Total	5,741	5,968	6,169	6,539	6,837	7,276	7,778	8,239	8,766

Space Heating

It was assumed that all coal and all heavy and light oil was used for space heating. Also those portions of natural gas consumption not identified for water heating, cooking, and air conditioning were assumed to have been consumed in space heating. A presumably small amount of natural gas has undoubtedly been consumed in other functions than those listed (for example, in lighting), and space heating from natural gas is probably somewhat overstated. The excess space heating from gas, however, is offset by assuming no space heating by electricity. Some electric space heating is probably used by commercial establishments (for example, in new motels and shopping centers where higher electric heating costs may be offset by lower electric air-conditioning costs because of electric rate structures), but no information is available on the actual amounts, which are presumably small.

Consumption of energy for space heating of commercial establishments, therefore, was estimated as shown in Table 40.

Table 40

COMMERCIAL CONSUMPTION OF ENERGY
FOR SPACE HEATING
(Trillions of Btu)
1960-1968

	Coal	Petroleum Products	Natural Gas	Total
1960	1,023	1,489	599	3,111
1961	912	1,555	633	3,100
1962	920	1,618	600	3,138
1963	774	1,634	801	3,209
1964	751	1,633	882	3,266
1965	714	1,801	920	3,435
1966	718	1,865	1,075	3,658
1967	625	2,267	1,154	4,046
1968	568	2,405	1,209	4,182

Water Heating

Energy consumption for water heating in commercial establishments was estimated as shown in Table 41.

The estimates are based on total water consumption by commercial establishments and a 20% share for heating water. Total commercial water consumption has been estimated at 30% of residential water consumption, an estimate that is based on reports of the American Waterworks Association for selected rural and urban areas.

Some 70% of the heated water was allocated to gas heating, 20% to electric heating, and 10% to water heating coincidental with space heating where a coil is run through a heating furnace. In the last case, all energy consumption has been allocated to space heating. Shares of total water heating have been kept constant from 1960 through 1968 in the absence of information; however, the share of water heating coincidental to space heating probably has declined over the period and electric water heating is likely to have increased over the period.

The unit consumption (heat per gallon of water heated) has been calculated assuming that water temperature will increase by 80°F on average; efficiency has been estimated at 92% for electrically heated water and 64% for gas heated water.

Air Conditioning

Commercial consumption of energy for air conditioning was estimated as shown in Table 42.

The estimates were developed assuming that some 40% of all commercial floor space was air conditioned in 1960 and that 90% of the incremental floor space built after 1960 was air conditioned. It was also assumed that each year air conditioning would be installed in 2% of the nonair-conditioned floor space. The total commercial floor space was calculated assuming an average of 250 square feet per employee.

Air-conditioning capacity appropriate to remove excess heat generated in commercial buildings was estimated at 36 Btu per hour per square foot.*

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* This is the average for office buildings given in "Air-Conditioning Refrigerating Data Book," The American Society of Refrigerating Engineers, N. Y., 1955.

Table 41

COMMERCIAL ENERGY CONSUMPTION FOR WATER HEATING

1960-1968

	Annual Water Consumption* (trillions of gallons)	Heated Water† (trillions of gallons)	Electric: Heated Water‡ (billions of gallons)	Electric: Unit Consumption§ (thousands of Btu per gallon)	Electric: Total Consumption (trillions of Btu)	Natural Gas: Heated Water‡ (billions of gallons)	Natural Gas: Unit Consumption** (thousands of Btu per gallon)	Natural Gas: Total Consumption (trillions of Btu)	Total Energy Consumption (trillions of Btu)
1960	2.4	0.48	96	2.0	192	336	1.04	350	542
1961	2.5	0.50	100	2.0	200	350	1.04	364	564
1962	2.5	0.50	100	2.0	200	350	1.04	364	564
1963	2.6	0.52	104	2.0	208	364	1.04	378	586
1964	2.7	0.54	108	2.0	216	378	1.04	393	609
1965	2.7	0.54	108	2.0	216	378	1.04	393	609
1966	2.8	0.56	112	2.0	224	392	1.04	407	631
1967	2.8	0.56	112	2.0	224	392	1.04	407	631
1968	2.9	0.58	116	2.0	232	406	1.04	422	654

* Estimated at 30% of residential consumption; source is American Waterworks Association, with SRI estimates.

† At 20% of total water consumed.

‡ 20% electric, 70% gas, 10% other.

§ 80°F average increase in water temperature; 92% efficiency.

** 80°F average increase in water temperature; 64% efficiency.

Table 42

COMMERCIAL CONSUMPTION OF ENERGY FOR AIR CONDITIONING

	Commercial Employees* (millions)	Commercial Area† (billions of square feet)	Commercial Area Air-Conditioned‡ (billions of square feet)	Air-Conditioning Capacity Required (Btu/hr): Total§ (billions of Btu)	Of Which: Gas** (billions of Btu)	Of Which: Electric (billions of Btu)	Energy Consumption: Gas†† (trillions of Btu)	Energy Consumption: Electric‡‡ (trillions of Btu)	Energy Consumption: Total (trillions of Btu)
1960	29.8	7.45	2.98	107	7	100	23	554	577
1961	30.3	7.58	3.19	115	9	106	30	577	607
1962	31.2	7.80	3.48	125	11	114	37	615	652
1963	32.2	8.05	3.80	137	12	125	40	678	718
1964	33.3	8.33	4.13	149	16	133	53	721	774
1965	34.9	8.73	4.57	165	19	146	63	788	851
1966	36.7	9.18	5.06	182	22	160	74	878	952
1967	38.4	9.60	5.52	199	26	173	87	940	1,027
1968	39.9	9.98	5.94	214	29	185	97	1,016	1,113

* Total employees on nonagricultural payrolls excluding mining, construction, manufacturing, transportation, and public utilities. Source is the Handbook of Labor Statistics 1970, U.S. Department of Labor.

† Estimated at 250 square feet per employee.

‡ Estimated at 40% of the total in 1960 and 90% of the incremental area each year plus 2% of the nonair-conditioned area converted each year.

§ At 36 Btu per square foot; the source is Air-Conditioning Refrigerating Data Book, American Society of Refrigerating Engineers.

** Source is Gas Association Monthly, October 1969.

†† At 1,000 hours per year and 30% efficiency.

‡‡ At 1,000 hours per year and 50% efficiency.

The total air-conditioning capacity as calculated consists of both gas and electric units; the capacity of commercial gas units in use was estimated by the American Gas Association and the difference between the calculated total and gas air-conditioning capacity constitutes electric air-conditioning capacity.

Both gas and electric air-conditioning equipment were estimated to operate at 1,000 hours full load equivalent per year. The operating time estimate of 1,000 hours is based on a metered study of actual air-conditioning requirements of commercial buildings shown in Table 43. The efficiency of heat removal has been assumed at 50% for electric equipment and at 30% for gas equipment.

Cooking

The nature, size, and equipment of commercial establishments that use energy for cooking are diverse. Establishments include hotels, hospitals, restaurants, cafeterias, drive-in and drive-through fast food service locations, and places preparing carry-out food such as the popular chicken and pizza chains and even supermarkets. Sizes range from the small breakfast corner place with counter service only to colleges, which averaged 2,636 customer transactions per day in 1966.* The equipment depends on the size and nature of the establishment and the frequency of equipment use.

Rather than determining the energy consumption for commercial cooking by counting units and establishing average per unit consumption, consumption of energy for commercial cooking was determined from its relationship to consumption of energy for residential cooking. This was based on the following assumptions:

(1) 17.5% of all meals in 1968 were prepared in commercial establishments.

(2) 15.0% of all meals in 1960 were prepared in commercial establishments.

* According to The Food Service Industry: Its Structure and Characteristics, 1966, Marketing Economics Division, Economic Research Service, U.S. Department of Agriculture, Statistical Bulletin 416, Washington, D.C., February 1968.

Table 43

AIR-CONDITIONING REQUIREMENTS AT DIFFERENT TEMPERATURE AND LOAD LEVELS
FOR SELECTED TYPES OF COMMERCIAL BUILDINGS*

Type of Building	Operating Schedule: Days per Week	Operating Schedule: Hours per Day	Temperature at Which Air Conditioning Is Required (°F min)	Operating Hours: One-Quarter	Operating Hours: One-Half	Operating Hours: Three-Quarters	Operating Hours: Full Load	Operating Hours: Total	Equivalent of Full Load Operating Hours
Hospital	7	24	60	610	1,472	1,212	155	3,449	2,053
Hotel	7	24	65	499	1,205	992	128	2,824	1,595
			70	365	881	724	93	2,063	1,168
Office	5-1/2	12	55	418	684	404	71	1,577	820
			60	359	588	347	61	1,355	701
Department store	6	12	55	26	901	655	138	1,720	1,087
			60	22	775	563	118	1,478	934
College	7	13	60	495	811	478	84	1,868	972
Library	7	13	65	405	664	392	69	1,530	996
			70	296	485	286	50	1,117	581

Source: Gas Engineers Handbook, The Industrial Press, First Edition, 1966.

(3) Food preparation in commercial establishments is more efficient in energy utilization than in households; commercial energy consumption per meal is therefore taken to be 0.75 of the residential energy consumption per meal.

(4) 12% of all commercial meals are cooked electrically.*

(5) Gas cooking consumes twice the energy of electric cooking (gas = 0.5 x efficiency of electricity).

The results of this estimate are shown in Table 44.

Table 44

COMMERCIAL ENERGY CONSUMPTION
FOR COOKING
(Trillions of Btu)
1960-1968

	Gas	Electric	Total
1960	84	14	98
1961	87	14	101
1962	92	13	105
1963	95	16	111
1964	98	16	114
1965	103	16	119
1966	106	19	125
1967	111	19	130
1968	117	22	139

* Share of commercial establishments having electric cooking equipment factored by annual sales; the source is The Food Service Industry, op cit.

Refrigeration

Refrigeration and frozen food storage occur in supermarkets, public eating places, and institutions. Public eating places and institutions were surveyed by the Department of Agriculture,* and estimates of energy consumption for refrigeration in the food service industry in 1966 are given in Tables 45, 46, and 47. It was further assumed that energy consumption from 1960 through 1968 increased at 4% annually on the average, which compares with a 5% average annual increase in sales volume for all drinking and eating places.†

Energy consumption for refrigeration in supermarkets was estimated as shown in Table 48. The estimates are based on refrigeration needed by type of product and the share of total supermarket sales that these products account for.

Total energy consumption for refrigeration is shown in Table 49.

* The Food Service Industry, op. cit.

† From U.S. Department of Commerce, Bureau of the Census, U.S. Census of Business, 1958, 1963, and 1967.

Table 45

COMMERCIAL ELECTRICAL CONSUMPTION BY WALK-IN REFRIGERATORS
IN PUBLIC EATING PLACES AND INSTITUTIONS
1966

	Average Cubic Feet per Place	Total Kilowatt Hours per Place	Total Number of Places (thousands)	Total Annual Consumption (millions of kwh)
Public eating places				
Separate eating places	460.3	222,752	66.7	14,857
Separate drinking places	436.8	209,035	16.9	3,533
Drug or proprietary stores	204.2	97,985	4.0	392
Department stores	358.2	173,107	0.8	138
Limited variety stores	111.2	53,565	1.8	96
Confectionary stores	773.3	374,303	0.7	262
Retail bakeries	211.3	102,871	0.8	82
Hotels	609.2	295,261	2.4	709
Motels	436.7	210,994	2.2	464
Motor hotels	1,130.9	547,409	0.8	438
Bowling, pool, billiard estab.	468.1	226,672	2.4	544
Movie theaters	368.6	178,986	0.8	143
Recreation or amusement places	627.9	305,060	3.1	946
Civic, social, and fraternal organizations	599.8	290,035	1.3	377
Other public	674.7	326,617	2.6	849
Subtotal public				23,830
Institutions				
Hospitals	1,402.0	678,709	2.6	1,764
Convalescent homes	1,167.7	565,047	2.3	1,300
Other homes	966.5	467,715	1.9	889
Colleges and professional schools	2,532.5	1,226,119	1.2	1,471
Fraternity and sorority houses	--	--	--	--
Religious organizations	637.2	308,326	2.2	678
Camps	527.7	255,414	1.0	255
Community programs	--			
Other institutions	770.0	372,343	0.4	149
Subtotal institutional				6,506
Total				30,336

Sources: Department of Agriculture. Supermarket Institute. Frozen Food Age. Stores Operations. Equipment manufacturers. Stanford Research Institute.

Table 46

COMMERCIAL ELECTRICAL CONSUMPTION BY REACH-IN REFRIGERATORS
IN PUBLIC EATING PLACES AND INSTITUTIONS
1966

	Average Cubic Feet per Place	Total Kilowatt Hours per Place	Total Number of Places (thousands)	Total Annual Consumption (millions of kwh)
Public eating places				
Separate eating places	69.6	33,968	187.9	6,383
Separate drinking places	36.9	17,570	47.7	838
Drug or proprietary stores	38.8	18,944	11.2	212
Department stores	118.1	56,831	2.2	125
Limited variety stores	71.6	34,621	5.2	180
Confectionary stores	48.3	23,516	1.9	44
Retail bakeries	66.8	32,008	2.1	67
Hotels	75.0	35,928	6.8	244
Motels	76.0	36,581	6.2	227
Motor hotels	119.0	57,484	2.3	132
Bowling, pool, billiard places	73.7	35,928	6.6	237
Movie theaters	22.7	11,105	2.3	25
Recreation or amusement places	65.0	31,355	8.8	276
Civic, social, and fraternal organizations	40.9	19,597	3.7	72
Other public	81.8	39,847	7.4	295
Subtotal public				9,357
Institutions				
Hospitals	168.8	81,654	5.2	425
Convalescent homes	77.6	37,234	4.7	175
Other homes	56.0	26,782	3.8	102
Colleges and professional schools	306.3	148,284	2.5	371
Fraternity and sorority houses	90.0	43,767	2.1	92
Religious organizations	49.4	24,170	4.5	109
Camps	56.3	26,782	1.9	51
Community programs	40.9	19,597	0.38	7
Other institutional	48.1	22,863	0.7	16
Subtotal institutional				1,348
Total				10,705

Sources: Department of Agriculture. Supermarket Institute. Frozen Food Age. Stores Operations. Equipment manufacturers. Stanford Research Institute.

Table 47

COMMERCIAL ELECTRICAL CONSUMPTION BY FREEZERS
IN PUBLIC EATING PLACES AND INSTITUTIONS
1966

	Average Cubic Feet per Place	Total Kilowatt Hours per Place	Total Number of Places (thousands)	Total Annual Consumption (millions of kwh)
Public eating places				
Separate eating places	78.7	37,887	84.9	3,217
Separate drinking places	40.9	19,597	21.5	421
Drug or proprietary stores	55.4	26,782	5.0	134
Department stores	126.9	61,396	1.1	67
Limited variety stores	56.8	27,436	1.0	27
Confectionary stores	72.2	34,621	0.9	31
Retail bakeries	48.2	22,863	1.0	23
Hotels	141.9	68,989	3.1	213
Motels	116.9	56,831	2.8	159
Motor hotels	241.4	116,929	1.0	117
Bowling, pool, billiard places	40.2	19,597	3.0	59
Movie theaters	34.2	16,331	1.0	16
Recreation or amusement places	80.1	38,541	4.0	154
Civic, social, and fraternal organizations	82.4	39,847	2.3	92
Other public	160.7	77,672	3.4	264
Subtotal public				4,994
Institutions				
Hospitals	351.7	170,494	2.5	426
Convalescent homes	112.6	54,218	2.3	125
Other homes	112.6	68,589	1.8	123
Colleges and professional schools	803.1	388,674	1.2	466
Fraternity and sorority houses	30.1	14,371	1.0	14
Religious organizations	106.9	51,605	2.2	113
Camps	116.9	56,831	0.9	51
Community programs	19.2	9,145	0.2	2
Other institutional	203.6	98,638	0.4	39
Subtotal institutional				1,359
Total				6,353

Sources: Department of Agriculture. Supermarket Institute. Frozen Food Age. Store Operations. Equipment manufacturers. Stanford Research Institute.

Table 48

ELECTRICAL CONSUMPTION FOR REFRIGERATION IN SUPERMARKETS, BY SALES VOLUME
1963-1969

(Millions of Kilowatt Hours)

Annual Sales Volume (dollars)	1963	1964	1965	1966	1967	1968	1969
$75,000-$100,000	12,439	12,042	11,883	11,637	11,319	11,231	10,428
$100,000-$150,000	1,706	1,652	1,571	1,706	1,715	1,787	1,791
$150,000-$300,000	1,831	1,630	1,668	1,706	1,774	1,543	1,678
$300,000-$500,000	1,278	1,725	1,741	1,773	1,821	2,157	2,156
$500,000-$1,000,000	3,221	3,598	3,653	3,714	3,914	3,797	3,755
$1,000,000-$2,000,000	4,174	4,538	4,724	4,861	5,185	5,398	5,517
$2,000,000 and over	3,564	3,662	3,760	3,998	4,301	4,946	5,668
Total	28,213	28,847	29,000	29,395	30,029	30,859	30,993

Sources: Progressive Grocer. Supermarket Institute. Equipment manufacturers. Stanford Research Institute.

Table 49

COMMERCIAL ENERGY CONSUMPTION FOR REFRIGERATION
1960-1968

	Super Markets (billions of kwh)	Public Eating Places and Institutions (billions of kwh)	Total	
			Billions of kwh	Trillions of Btu
1960	27.0	29.6	56.6	534
1961	27.5	30.8	58.3	542
1962	27.8	32.0	59.8	550
1963	28.2	33.3	61.5	570
1964	28.8	34.6	63.4	585
1965	29.0	36.0	65.0	599
1966	29.4	37.4	66.8	626
1967	30.0	39.0	69.0	638
1968	30.9	40.5	71.4	670

V THE INDUSTRIAL SECTOR

Total Consumption of Energy

In 1968 the industrial sector accounted for 41.2% of the total energy consumption in the United States. Summaries of the 1960 and 1968 industrial energy consumption are shown in Figures 10 and 11.

Over this eight-year period, industrial consumption of energy increased at 3.9%--0.4 percentage points below the rate of increase of the total U.S. energy consumption. Table 50 shows the growth in consumption of individual fuels by end uses.

Six SIC groups accounted for two-thirds of the 1968 industrial consumption of energy. Their total energy consumption together with a breakdown by fuel is shown below (in trillions of Btu).

Industry Group	Coal	Natural Gas	Petroleum Products	Electricity	Total Energy
Primary metal industries	2,838	863	306	1,291	5,298
Chemicals and allied products	666	1,219	1,426	1,626	4,937
Petroleum refining and related industries	*	1,012	1,589	225	2,826
Food and kindred products	263	593	134	338	1,328
Paper and allied products	467	341	211	280	1,299
Stone, clay, glass, and concrete products	406	449	87	280	1,222
Subtotal	4,640	4,477	3,753	4,040	16,910
All other industries	976	4,781	721	1,572	8,050
Total	5,616	9,258	4,474	5,612	24,960

* Included in all other industries.

Source: 1968 Minerals Yearbook, U.S. Department of Interior, Bureau of Mines.

Methodology

The fuels used, as well as end uses, vary from industry to industry. Only industries that are large enough consumers of energy to warrant detailed analysis are included here.

Standard industrial classifications (SICs) provide a convenient basis for subdividing the industrial sector. Consequently, the sector was divided into 20 major groups beginning with 20 and ending with 39. Figure 12 shows the energy consumption for each group as extracted from the 1963 census of manufactures. The definition of the 20 SICs are given in Appendix C.

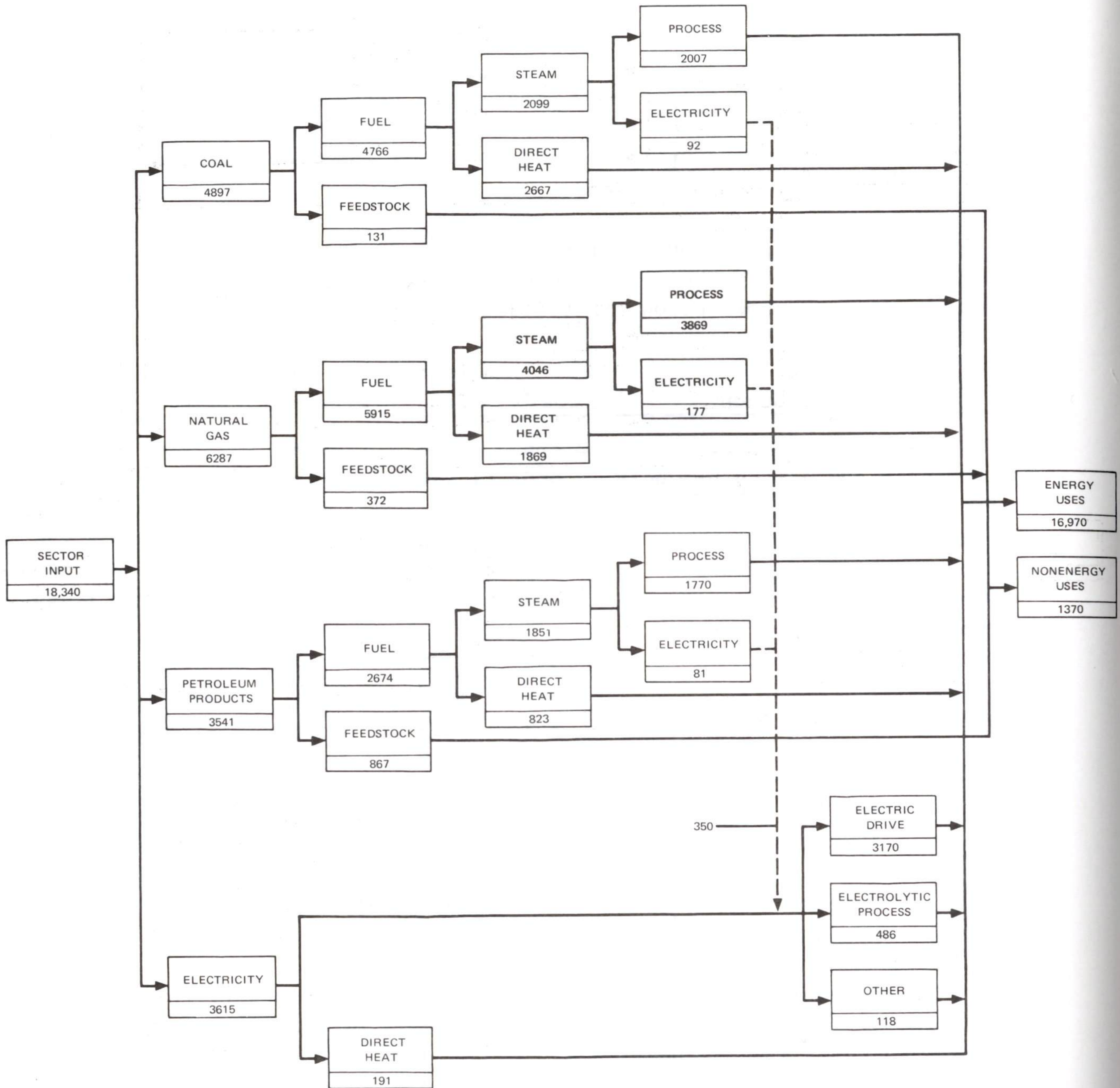

FIGURE 10 1960 INDUSTRIAL CONSUMPTION OF ENERGY (Trillions of Btu)

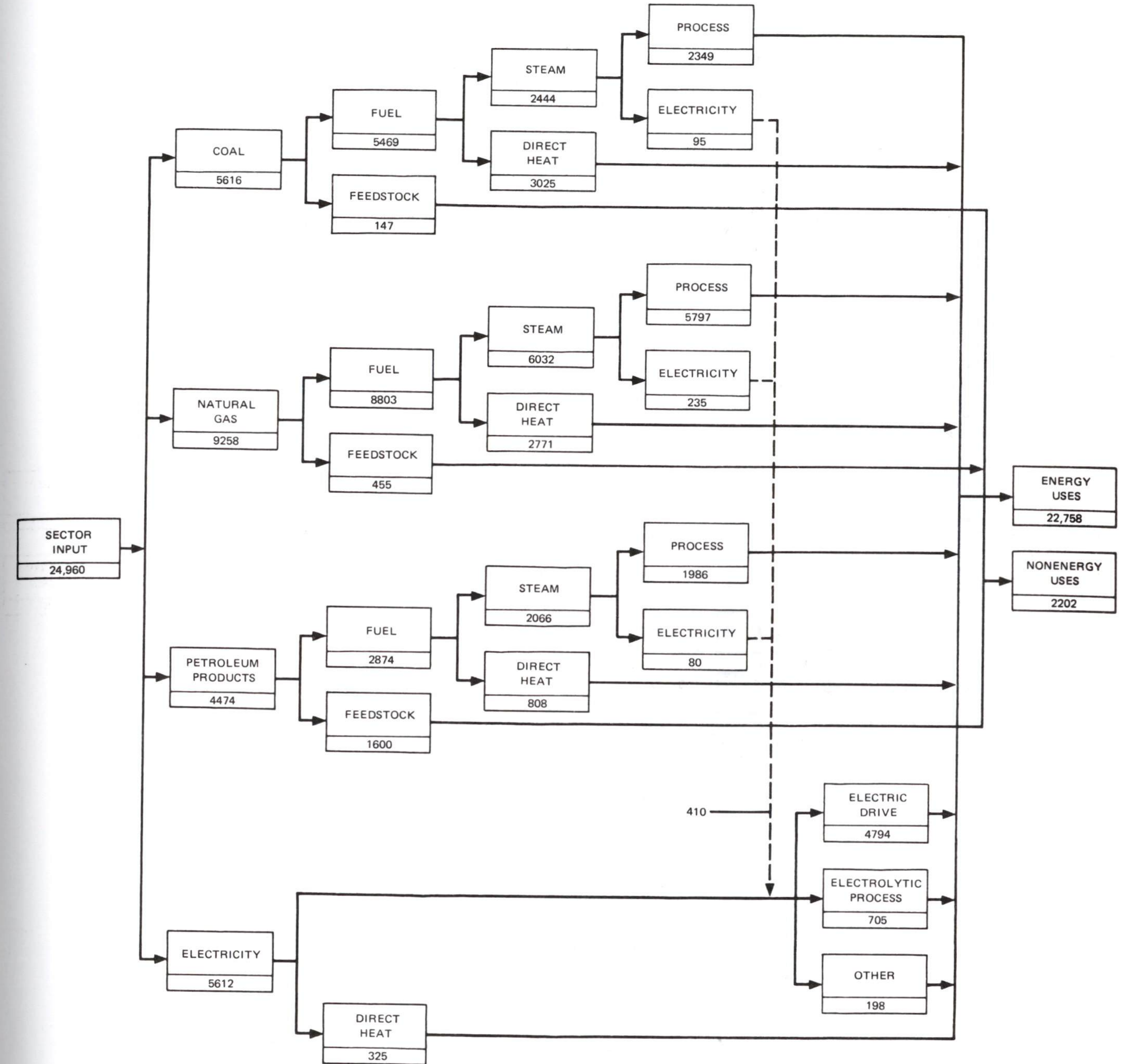

FIGURE 11 1968 INDUSTRIAL CONSUMPTION OF ENERGY (Trillions of Btu)

Table 50

RATE OF GROWTH OF FUEL CONSUMPTION IN THE INDUSTRIAL SECTOR, BY END USE
1960-1968
(Trillions of Btu)

	1960			1968			Average Annual Growth Rate 1960-68 (percent)		
	Direct	Electrical Energy	Total	Direct	Electrical Energy	Total	Direct	Electrical Energy	Total
All fuels									
Process steam	7,646	--	7,646	10,132	--	10,132	3.6%	--%	3.6%
Electricity generation	350	-350	--	410	-410	--	2.0	-2.0	--
Electric drive	--	3,170	3,170	--	4,794	4,794	--	5.3	5.3
Electrolytic process	--	486	486	--	705	705	--	4.7	4.7
Direct heat	5,359	191	5,550	6,604	325	6,929	2.7	6.9	2.8
Feed stock	1,370	--	1,370	2,202	--	2,202	6.1	--	6.1
Other	--	118	118	--	198	198	--	6.8	6.7
Total all fuels	14,725	3,615	18,340	19,348	5,612	24,960	3.5	5.7	3.9
Coal									
Process steam	2,007	--	2,007	2,349	--	2,349	2.0	--	2.0
Electricity generation	92	-92	--	95	-95	--	0.4	--	0.4
Electric drive	--	1,793	1,793	--	2,634	2,634	--	4.9	4.9
Electrolytic process	--	274	274	--	388	388	--	4.4	4.4
Direct heat	2,667	108	2,775	3,025	179	3,204	1.6	6.5	1.8
Feed stock	131	--	131	147	--	147	1.4	--	1.4
Other	--	67	67	--	109	109	--	6.2	6.2
Total coal	4,897	2,150	7,047	5,616	3,215	8,831	1.7	5.2	2.9
Dry natural gas									
Process steam	3,869	--	3,869	5.797	--	5,797	5.2	--	5.2
Electricity generation	177	-177	--	235	-235	--	3.6	-3.6	n.a.
Electric drive	--	862	862	--	1,353	1,353	--	5.8	5.8
Electrolytic process	--	132	132	--	199	199	--	5.2	5.2
Direct heat	1,869	52	1,921	2,771	92	2,863	5.1	7.3	5.1
Feed stock	372	--	372	455	--	455	2.6	--	2.6
Other	--	32	32	--	56	56	--	7.2	7.2
Total natural gas	6,287	901	7,188	9,258	1,465	10,723	4.9	6.2	5.2
Petroleum products									
Process steam	1,770	--	1,770	1,986	--	1,986	1.3	--	1.3
Electricity generation	81	-81	--	80	-80	--	-0.4	--	-0.4
Electric drive	--	292	292	--	488	488	--	6.6	6.6
Electrolytic process	--	45	45	--	72	72	--	6.1	6.1
Direct heat	823	18	841	808	33	841	-0.2	7.6	0
Feed stock	867	--	867	1,600	--	1,600	7.9	--	7.9
Other	--	11	11	--	20	20	--	7.7	7.7
Total petroleum products	3,541	285	3,826	4,474	533	5,007	3.0	8.2	3.4
Hydroelectricity									
Electric drive	--	221	221	--	273	273	--	2.8	2.8
Electrolytic process	--	34	34	--	40	40	--	1.8	1.8
Direct heat	--	13	13	--	18	18	--	4.2	4.2
Other	--	9	9	--	11	11	--	2.5	2.5
Total hydroelectricity	--	276	276	--	341	341	--	2.7	2.7
Nuclear electricity									
Electric drive	--	2	2	--	46	46	--	48.0	48.0
Electrolytic process	--	1	1	--	7	7	--	26.5	26.5
Direct heat	--	nil	nil	--	3	3	--	n.a.	n.a.
Other	--	nil	nil	--	2	2	--	n.a.	n.a.
Total nuclear electricity	--	3	3	--	58	58	--	45.0	45.0

Note: n.a. = not applicable. Because of rounding the figures in this table may not total exactly.

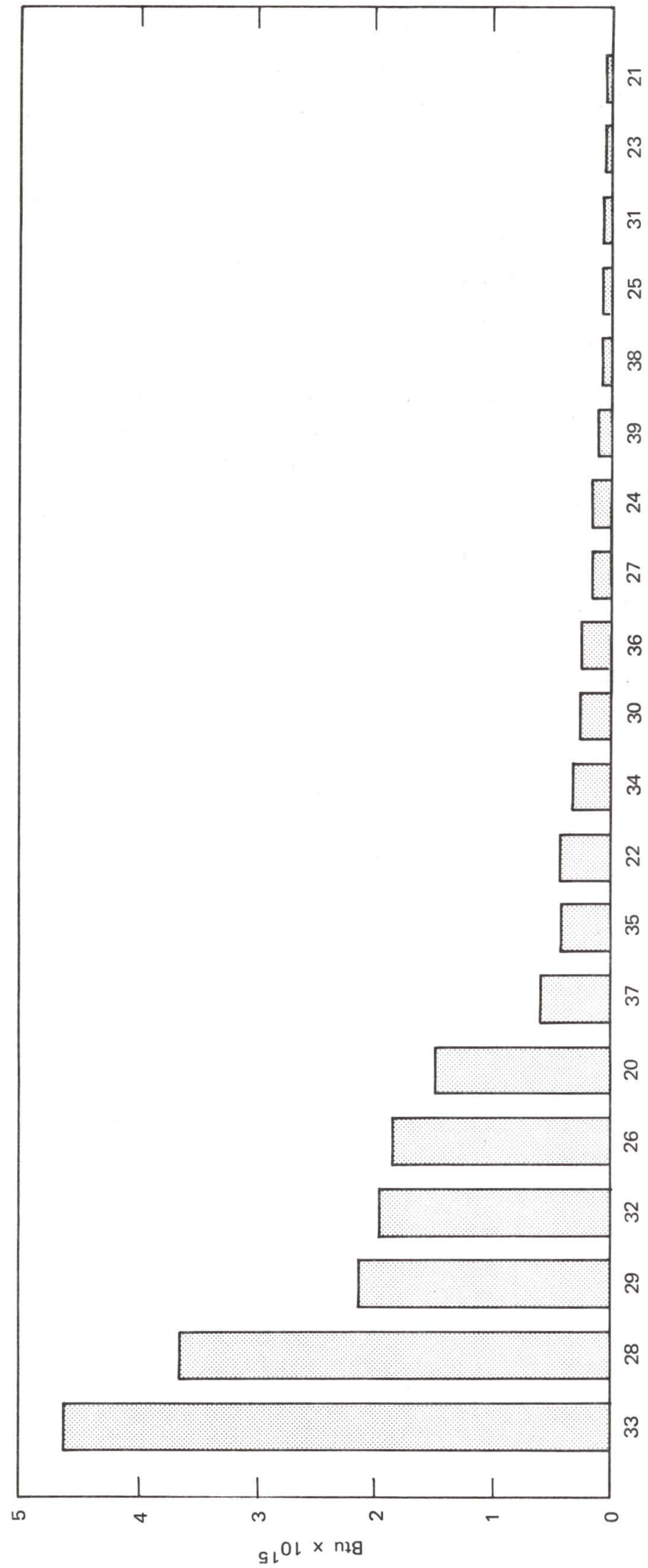

FIGURE 12 DISTRIBUTION OF INDUSTRIAL ENERGY CONSUMPTION, BY STANDARD INDUSTRIAL CLASSIFICATION

Information on the six major groups was analyzed to determine:

(1) Fuels utilized in each major group

(2) End uses of fuel in each major group

a. Used to produce steam

- Steam used for process
- Steam used to generate electricity

b. Used to provide direct heat.

(3) End uses of fuel as feedstock in each major group

(4) End uses of electricity in each major group

a. Used for electric drive

b. Used for electrolytic processes

c. Used for other uses such as lighting and air conditioning.

Each of the six energy intensive major groups is analyzed in detail below.

Primary Metals

Background

Estimates* of the U.S. Bureau of the Census indicate that the primary metal industries consumed the largest share of purchased fuels and electric energy used in the industrial sector.

Estimates† of the Bureau of Mines of total energy inputs to the primary metal industries during 1968 are shown below in trillions of Btu.

Coal	2,838
Gas	863
Oil	306
Electricity	1,291
Total	5,298

* 1963 Census of Manufactures, "Fuels and Electric Energy Consumed in Manufacturing Industries, 1962."
† 1968 Minerals Yearbook, U.S. Department of the Interior, Bureau of Mines.

During 1968, consumption of energy by blast furnaces, steel works, and rolling and finishing mills (referred to as the iron and steel industry in this report) was about 64% of the Bureau of Mines estimate for the total primary metal industries. Because of the relative importance of the iron and steel industry segment, it is analyzed in depth in this section of the report. Other sectors of the primary metal industries are relatively less important in terms of energy consumption.

Energy Use in the Iron and Steel Industry

The principal uses of fuels, oxygen, and electric power in the iron and steelmaking processes are:

- Firing of coke ovens for conversion of coal to coke and coke by-products
- Sintering of fine ores and dusts to produce blast furnace sinter
- Smelting of iron ores and agglomerates in blast furnaces
- Steelmaking from blast furnace iron and ferrous scrap
- Steam raising for compressing blast and for generating electricity
- Reheating, annealing, and heat treating of steel
- Driving of mills, forges, and process lines.

Coke Use in the Steel Industry--Table 51 presents AISI (American Iron and Steel Institute) data on coke use in the steel industry during the 1959-69 period. As in subsequent tables, volumes in net tons of 2,000 pounds have been converted to energy equivalents in Btu when appropriate. Differing energy equivalents of coal and coke appear in the literature, but the use of different factors would not alter the significance of the energy series. Comments on the data are presented below.

- The volume of coke used in blast furnaces increased because of the increase in blast furnace output,* whereas the volumes of coke produced for foundry consumption and miscellaneous uses not delineated declined.

* The primary product of the blast furnace is referred to as molten iron, hot metal, or pig iron. Molten iron generally is charged to steelmaking furnaces, while pig iron is often sold to independent foundries.

Table 51

COKE USE IN THE STEEL INDUSTRY
1959-1969

	Volume of Coke Consumed (thousands of net tons)				
	Blast Furnace Coke	Foundry Coke	Coke for Other Uses	Total	Energy Value of Coke Consumed (trillions of Btu)
1959	49,012	115	360	49,487	1,297
1960	51,935	97	432	52,464	1,375
1961	46,771	32	437	47,240	1,238
1962	46,245	30	450	46,725	1,224
1963	48,870	33	319	49,222	1,290
1964	57,063	31	464	57,558	1,508
1965	59,072	24	422	59,518	1,559
1966	59,637	21	269	59,927	1,570
1967	56,205	14	216	56,435	1,479
1968	56,238	15	179	56,432	1,479
1969	60,176	14	235	60,425	1,583

Note: Blast furnace coke includes the relatively small volume (675,000 tons in 1969) of coke used to produce ferroalloys in blast furnaces. Energy of coke = 13,100 Btu per pound and 26.2 million Btu per net ton.

Sources: Coke volumes from AISI. Energy values computed by Stanford Research Institute.

- Because of increased blast furnace operating efficiency, the volume of coke consumed and the related energy value did not increase as rapidly as the production of pig iron. This relationship is shown in Table 52.

- Between 1959 and 1969, blast furnace output increased 57% while net coke consumption (coke charged less coke fines recovered) increased only 24%. Thus the tons of coke consumed per ton of metal produced declined 21% from .80 to .63. There are several reasons for this trend toward increased efficiency in coke use including (1) improved operating practice; (2) the use of better and more uniform coke and iron-bearing materials plus greater attention to burden preparation; and (3) the use of larger blast furnaces, higher blast temperatures, high top pressure, and fuel injection.

- In terms of total energy value, the gross consumption of Btu by blast furnaces (total based on coal) increased 26% between 1959 and 1969. The computed coal equivalent of coke use increased at the same rate as coke use--23% between 1959 and 1969. A constant yield of coke from natural weight coal (.658) was used to convert from coke use to coal equivalent in tons, and each ton of coal was assumed to contain 26.2 million Btu. However, the use of injected fuel oil and natural gas caused total energy consumption to increase 26%, somewhat more rapidly than the increase in the energy value of coal during the 1959-69 period. (Part of the differential between 26% and 23% probably results from the absence of data relating to fuel oil and natural gas consumption in 1959.)

- In terms of total gross energy consumed per ton of metal produced, there has been a decline every year except one (1965) during the 1959-69 period. On the basis of the energy value of coal, fuel oil, and natural gas, energy consumption per ton of metal produced was 20% lower in 1969 than in 1959. If the energy value of coke is substituted for coal (a less meaningful approach for purposes of this analysis), the 1959-69 decline was 18%.

The steel industry normally does not produce all of the coke it consumes. In 1964, for example, consumption exceeded production by 2.7 million tons. Coke is purchased from merchant coke producers, and some steelmakers produce coke for sale outside the industry.

Table 52

BLAST FURNACE OUTPUT RELATED TO CONSUMPTION OF SELECTED TYPES OF ENERGY
1959-1969

	Blast Furnace Metal Output (millions of net tons)			Net Coke Consumption (millions of net tons)			Tons of Coke Consumed per Ton of Blast Furnace Metal Output			Energy Value of Fuels Consumed by Blast Furnaces (trillions of Btu)						Millions of Btu per Ton of Metal	
	Pig Iron	Ferro-alloys	Total	Pig Iron	Ferro-alloys	Total	Pig Iron	Ferro-alloys	Total	Coke	Coal Equivalent of Coke	Fuel Oil	Natural Gas	Total Based on Coke	Total Based on Coal	Total Based on Coke	Total Based on Coal
1959	60.2	0.6	60.8	47.6	1.0	48.6	0.790	1.7	0.80	1,284	1,951	n.a.	n.a.	1,284	1,951	21.1	32.1
1960	66.5	0.8	67.3	49.9	1.3	51.2	0.750	1.6	0.76	1,361	2,068	n.a.	n.a.	1,361	2,068	20.2	30.7
1961	64.9	0.7	65.6	45.8	1.0	46.8	0.706	1.4	0.71	1,225	1,862	n.a.	n.a.	1,225	1,862	18.7	28.4
1962	65.6	0.7	66.3	45.2	0.9	46.1	0.689	1.3	0.70	1,212	1,842	n.a.	n.a.	1,212	1,842	18.3	27.8
1963	71.8	0.5	72.3	48.2	0.8	49.0	0.671	1.6	0.68	1,280	1,945	5	28	1,313	1,978	18.2	27.4
1964	85.4	0.6	86.0	55.8	1.0	56.8	0.653	1.7	0.66	1,495	2,272	7	39	1,541	2,318	17.9	27.0
1965	88.2	0.7	88.9	57.8	1.2	59.0	0.655	1.7	0.66	1,548	2,353	8	47	1,603	2,408	18.0	27.1
1966	91.3	0.7	92.0	59.0	1.0	60.0	0.646	1.4	0.65	1,562	2,374	8	52	1,622	2,434	17.6	26.5
1967	86.8	0.7	87.5	55.3	1.1	56.4	0.637	1.6	0.64	1,473	2,239	10	44	1,527	2,293	17.5	26.2
1968	88.8	0.6	89.4	55.5	0.9	56.4	0.625	1.5	0.63	1,473	2,239	12	47	1,532	2,298	17.5	25.7
1969	95.0	0.5	95.5	59.5	0.7	60.2	0.626	1.4	0.63	1,577	2,397	17	44	1,638	2,458	17.2	25.7
1959-69 percent change			+57%			+24%			-21%	+23%	+23%			+28%	+26%	-18%	-20%

n.a. = not available.

Sources: Pig iron output and related coke consumption from the Bureau of Mines for 1959-68 and from AISI for 1969. Ferroalloy output and related coke consumption from AISI. Energy value of fuels by Stanford Research Institute, based on AISI data.

Coal Use in the Steel Industry--Table 53 presents AISI data on coal use in the steel industry. Comments on the data are presented below.

- The volume of coal that was carbonized was essentially stable during the past five years, but the amount of coal used for steam, electric power, and other purposes (primarily sinter production) declined.
- Table 53 includes an adjustment to reflect the estimated coal equivalent (natural rather than dry basis) of net coke purchases. Conceptually, the table accounts for total coal use on a weight and on an energy value basis.

Natural Gas Use in the Steel Industry--The use of natural gas in the steel industry is shown in Table 54. Total consumption doubled between 1959 and 1969, while the Btu per ton of raw steel produced increased from 3.4 million to 4.5 million. Although the volume of natural gas consumed as a substitute for coking coal in blast furnaces grew steadily until the past few years, this use represented only 7.3% of total steel industry gross energy consumption in 1969. A significant portion of the "other uses" category consists of sinter plant consumption.

Fuel Oil Use in the Steel Industry--The use of fuel oil in the steel industry is shown in Table 55. Between 1959 and 1969, the energy value of fuel oil consumed declined 29%. The Btu consumed per ton of raw steel produced declined 54% (from 2.8 million in 1959 to 1.3 million in 1969). Apparently there has been some substitution of natural gas for fuel oil in heating and annealing furnaces as well as a declining need for fuel oil in the production of raw steel in open hearth furnaces.

Liquefied Petroleum Gas Use in the Steel Industry--The use of LPG (liquefied petroleum gas) in the steel industry is shown in Table 56. Compared with that of other sources of energy, the use of LPG is insignificant. Between 1959 and 1969, its use increased gradually from 7,900 Btu per ton of raw steel produced to 9,100 Btu per ton, with a peak of 12,600 Btu per ton in 1965.

Electric Power Use in the Iron and Steel Industry--The use of electric power in the iron and steel industry is shown in Table 57. In 1969, purchased power use accounted for 76% of total electric power consumption or 125 trillion Btu. Total electric power consumed increased from 0.99 million Btu per ton in 1959 to 1.17 million Btu per ton in 1969. During the same period, purchased electric power consumption increased from

Table 53

COAL USE IN THE STEEL INDUSTRY
1959-1969

	Volume of Coal (thousands of net tons)						
	Used in Production of Coke	Used for Steam and Electric Power	Used for Other Purposes	Total Reported Use	Adjustment for Net Purchases of Coke	Adjusted Total Use	Energy Value of Coal (trillions of Btu)
1959	69,017	6,106	713	75,835	1,522	77,357	2,027
1960	71,369	6,677	660	78,706	3,470	82,176	2,153
1961	65,029	6,687	548	72,265	2,310	74,575	1,954
1962	65,994	6,458	536	72,988	912	73,900	1,936
1963	67,928	6,185	697	74,810	1,971	76,781	2,012
1964	78,698	6,329	715	85,743	4,102	89,845	2,354
1965	83,930	6,688	684	91,302	1,370	92,672	2,428
1966	85,520	6,632	760	92,911	421	93,332	2,445
1967	82,698	6,098	781	89,577	-1,565	88,012	2,306
1968	81,245	6,106	669	88,021	-850	87,171	2,284
1969	84,065	5,362	531	89,958	3,373	93,331	2,445

Note: Reports through 1963 indicate coal volumes include an annual consumption of 686,000 to 771,000 tons of anthracite coal. Adjustment for net purchases of coke was developed from the AISI series on steel industry production and consumption of coke, by multiplying annual differences by 1.52 to convert to coal equivalent (natural basis). Energy value of coal is 13,100 Btu per pound and 26.2 million Btu per ton.

Sources: AISI and Stanford Research Institute computations.

Table 54

NATURAL GAS USE IN THE STEEL INDUSTRY
1959-1969

	Blast Furnaces (billions of cubic feet)	Other Uses in Blast Furnace Area (billions of cubic feet)	Steel Melting Furnaces (billions of cubic feet)	Heating and Annealing Furnaces and Ovens (billions of cubic feet)	Other Uses (billions of cubic feet)	Total (billions of cubic feet)	Energy Value (trillions of Btu)
1959	n.a.	n.a.	n.a.	178	76*	317	317
1960	n.a.	n.a.	n.a.	199	89*	361	361
1961	n.a.	n.a.	n.a.	208	92	399	399
1962	n.a.	n.a.	n.a.	225	97	434	434
1963	28	5	95	237	100	464	464
1964	39	9	109	257	101	513	513
1965	47	6	106	277	112	547	547
1966	52	6	96	265	99	517	517
1967	44	6†	86	283	116	534	534
1968	47	6†	102	304	128	587	587
1969	44	7†	92	342	148	635	635

n.a. = not available. In total, n.a. = 112 in 1962, 99 in 1961, 72 in 1960, and 64 in 1959.

Notes: Details may not add to totals because of rounding.
Energy factor = 1,000 Btu per cubic foot of natural gas.

* Includes small volume of gas used in rod-heating ovens.

† Includes coke oven underfiring.

Source: Stanford Research Institute, based on AISI data.

Table 55

FUEL OIL USE IN THE STEEL INDUSTRY
1959-1969

	Blast Furnaces (millions of gallons)	Other Uses in Blast Furnace Area (millions of gallons)	Steel Melting Furnaces (millions of gallons)	Subtotal (millions of gallons)	Heating and Annealing Furnaces and Ovens (millions of gallons)	Other Uses (millions of gallons)	Total (millions of gallons)	Energy Value (trillions of Btu)
1959	n.a.	n.a.	n.a.	1,130	410	195	1,735	257.8
1960	n.a.	n.a.	n.a.	1,065	367	267	1,699	252.5
1961	n.a.	n.a.	n.a.	993	339	211	1,543	229.3
1962	n.a.	n.a.	n.a.	884	339	195	1,418	210.7
1963	34	4	921	959	396	220	1,575	234.0
1964	46	14	1,008	1,068	396	215	1,678	249.4
1965	53	12	890	955	449	207*	1,611	239.4
1966	53	21†	722	796	462	193*	1,451	215.6
1967	67	14	568	649	403	202*	1,254	186.3
1968	81	16	550	647	370	268	1,284	190.8
1969	117	17	505	639	315	286	1,238	184.0

n.a. = not available.

Notes: Details may not add to totals because of rounding.
Energy factor = 148,600 Btu per gallon of residual fuel oil.

* Includes small volume of oil used to heat ovens for wire rod processing.
† Includes coke oven underfiring.

Source: Stanford Research Institute, based on AISI data.

Table 56

LIQUEFIED PETROLEUM GAS USE IN THE STEEL INDUSTRY
1959-1969

	Heating and Annealing Furnaces (millions of gallons)	Other Uses (millions of gallons)	Total (millions of gallons)	Energy Value (trillions of BTU)
1959	5	3	8	0.732
1960	6	3	9	0.824
1961	5	3	8	0.732
1962	6	1	7	0.641
1963	9	2	11	1.007
1964	8	3	11	1.007
1965	14	4	18	1.647
1966	10	4	14	1.281
1967	11	4	15	1.372
1968	7	7	14	1.281
1969	7	7	14	1.281

Note: Energy factor = 91,500 Btu per gallon of commercial propane.

Source: Stanford Research Institute, based on AISI data.

Table 57

ELECTRIC POWER USE IN THE STEEL INDUSTRY
1959-1969

	Power Use (billions of kwh)			Energy Value (trillions of Btu)				
				Consumption Basis		Production Basis		
	Generated	Purchased	Total	Purchased	Total	Generated	Purchased	Total
1959	10.0	17.1	27.1	58.4	92.5	102.1	175.2	277.5
1960	10.3	19.4	29.7	66.2	101.4	105.3	198.9	304.2
1961	10.0	19.8	29.8	67.6	101.7	102.3	202.8	305.1
1962	9.9	21.2	31.1	72.4	106.1	101.1	217.2	318.3
1963	10.0	23.6	33.6	80.5	114.7	102.6	241.5	344.1
1964	12.8	26.0	38.8	88.7	132.4	131.1	266.1	397.2
1965	12.2	28.0	40.2	95.5	137.2	125.1	286.5	411.6
1966	12.1	29.9	42.0	102.0	143.3	123.9	306.0	429.9
1967	12.0	30.6	42.6	104.4	145.4	123.0	313.2	436.2
1968	12.7	33.4	46.1	114.0	157.3	129.9	342.0	471.9
1969	11.7	36.7	48.4	125.3	165.2	119.7	375.9	495.6

Notes: Details may not add to totals because of rounding.
Energy factor = 3,413 Btu per kwh.

Source: Stanford Research Institute, based on AISI data.

0.63 to 0.89 million Btu per ton. Since Institute projections indicate a steady growth in the proportion of steel produced in electric furnaces, the growth in electric power consumption per ton of raw steel produced by all processes combined should persist in future years.

Summary of Gross Energy Consumption in the Iron and Steel Industry--Fuel and electric power consumption in the iron and steel industry is summarized in Table 58. Only purchased power is included since the power generated by the steel industry is reflected in fuel consumption data. Table 58 also shows raw steel output by type of furnace and the relationship between energy consumption and total raw steel output. Between 1960 and 1968, the energy required to produce a ton of raw steel declined by 13%, from 30.0 to 26.0 million Btu. This decline is likely to persist in the future, primarily (but not exclusively) as a result of more efficient energy use by blast furnaces.

Primary Metals Other Than Iron and Steel

If SRI estimates of iron and steel industry energy consumption are deducted from the total 1968 energy use mix estimated by the Bureau of Mines, an approximation of the energy use mix in trillions of Btu is obtained for primary metal industries other than iron and steel, as shown below.

Coal	554
Gas	276
Oil	114
Electricity	949
Total	1,893

An analysis of 1967 Census of Manufactures data concerning gas and electric power consumption for primary metal industries other than iron and steel, approximates the 1,391 trillion Btu shown for 1968 in the tabulation above. Therefore, the Census data for gas and electrical energy were used and are shown in Table 59. The corresponding Census data for coal, coke, and fuel oil were not used because of omissions and apparent underreporting.

In spite of certain energy data problems entailed in evaluating the primary metal industries other than iron and steel, the coal and oil consumption data gap apparently is on the order of only 668 trillion Btu,

Table 58

CONSUMPTION OF SELECTED TYPES OF ENERGY IN THE IRON AND STEEL INDUSTRY
RELATED TO RAW STEEL OUTPUT
1960-1968

	Gross Energy Consumption (trillions of Btu)							Raw Steel Output (millions of net tons)					Energy Used per Ton of Raw Steel Produced (millions of Btu)		
	Fuels					Purchased Electric Power	Fuel and Electric Power								
	Coal	Natural Gas	Fuel Oil	LPG	Total			Basic Oxygen	Electric	Open Hearth	Bessemer	Total	Fuels	Power	Total
1960	2,153	361	253	1	2,768	199	2,967	3	8	86	1	99	28.0	2.0	30.0
1961	1,954	399	229	1	2,583	203	2,786	4	9	85	1	98	26.4	2.1	28.5
1962	1,936	434	211	1	2,582	217	2,799	6	9	83	1	98	26.3	2.2	28.5
1963	2,012	464	234	1	2,711	242	2,953	9	11	89	1	109	24.9	2.2	27.1
1964	2,354	513	249	1	3,117	266	3,383	15	13	98	1	127	24.5	2.1	26.6
1965	2,428	547	239	2	3,216	287	3,503	23	14	94	1	131	24.5	2.2	26.7
1966	2,445	517	216	1	3,179	306	3,485	34	15	85	*	134	23.7	2.3	26.0
1967	2,306	534	186	1	3,027	313	3,340	41	15	71	*	127	23.8	2.5	26.3
1968	2,284	587	191	1	3,063	342	3,405	49	17	66	*	131	23.4	2.6	26.0

* Less than 500,000 net tons.

Source: Stanford Research Institute, based on AISI data.

Table 59

APPROXIMATE GAS AND ELECTRIC ENERGY CONSUMPTION FOR HEAT AND POWER
BY SELECTED PRIMARY METAL INDUSTRIES
1962 AND 1967

	Gas Consumption*				Electric Power Purchased† and Generated for Consumption				Total Gas and Electricity		
	Billions of Cubic Feet		Trillions of Btu		Millions of kwh		Trillions of Btu		Trillions of Btu		1967 as Percent of 1962
	1962	1967	1962	1967	1962	1967	1962	1967	1962	1967	
Iron and steel foundries	39	55	40	57	3,628	5,996	32	54	72	111	154%
Nonferrous metal production	181	207	187	214	40,875	60,000‡	377	557	564	771	137
Nonferrous metal rolling and drawing	48	66	49	68	6,000‡	8,493	54	79	103	147	143
Nonferrous foundries	18	23	19	24	918	1,421	8	14	27	38	141
Primary metal industries n.e.c.	28	40	29	41	1,160	1,969	11	19	40	60	150
Total	314	391	324	404	52,581	77,879	482	723	806	1,127	140

* One cubic foot of gas equals 1,032 Btu.
† One kilowatt hour equals 3,413 Btu.
‡ Estimates by Stanford Research Institute; certain totals also reflect these estimates.

Source: Bureau of the Census unless otherwise indicated.

or 15% of the estimated 4,477 trillions of Btu total use by the primary metal industries estimated by the Bureau of Mines for 1968.

Table 60 provides some perspective on the physical output of the primary metal industries other than iron and steel for 1962 and 1967 (Census years), 1960 and 1969 (a ten-year span), and 1968 (the year corresponding to Bureau of Mines estimates of energy consumption). Examination of Table 60 suggests that aluminum production and processing is the most important energy consuming segment. (The ferrous foundry industry produces more tons of product annually but the operation consists primarily of melting and casting scrap and refining and casting the pig iron obtained from iron and steel industry blast furnaces.) This observation is apparently supported by Census data for 1962 that shows $478.8 million as the cost of purchased fuels and electric energy for primary metal industries other than iron and steel, with 36% of the total attributed to the production, rolling and drawing, and casting of aluminum; 27% attributed to ferrous foundries; and 12% to copper processing. On the basis of the relative growth rates of output in these sectors between 1962 and 1969, aluminum processing increased its share of the total sector's energy consumption. Trends in physical output and energy consumption in the various industry classifications shown in Table 60 are discussed briefly below.

- Between 1960 and 1969 the output of ferrous castings increased 36%, somewhat less than both the 49% increase in steel forgings output and the 42% increase in raw steel production (not shown in Table 60). Ferrous castings production has suffered from (1) the gradual inroads of forgings and fabricated rolled steel products and (2) a decreased growth rate in demand for ferrous castings. The 48% gain in gas and electricity energy consumption between 1962 and 1967 is not necessarily representative of total energy consumption since part of the increase may have been the result of the substitution of one fuel for another. Since industry output increased only 24% between 1962 and 1967, nongas and nonelectricity energy consumption apparently grew less rapidly than physical output. [The Census of Manufactures reported a decline in the purchase of coke and breeze from 1.5 million tons in 1962 to 1.3 millions tons in 1967, but the Bureau of Mines annual surveys showed an increase in coke sales (exclusive of breeze) by producers to foundries from 2.5 million tons in 1962 to 2.9 million tons in 1967.]

Table 60

U.S. PRODUCTION OF SELECTED METALS
1960-1969

	Thousands of Net Tons					1967 as Percent	1969 as Percent
	1960	1962	1967	1968	1969	of 1962	of 1960
Ferrous castings							
Gray iron including ductile	11,594	11,553	14,328	15,035	15,667	124%	135%
Malleable iron	821	868	1,040	1,094	1,133	120	138
Steel	1,392	1,423	1,857	1,730	1,978	131	142
Total	13,807	13,844	17,225	17,859	18,778	124	136
Nonferrous metals							
Primary smelting and refining							
Copper	1,519	1,611	1,133	1,437	1,743	70	115
Lead	385	376	389	487	655	103	170
Zinc	872	879	939	1,021	1,041	107	119
Aluminum	2,014	2,118	3,269	3,255	3,793	154	188
Total	4,790	4,984	5,730	6,200	7,232	115	151
Secondary recovery							
Copper	429	416	483	521	575	116	134
Lead	470	472	554	551	604	117	129
Zinc	69	59	74	80	71	125	103
Aluminum	329	400	698	817	856	175	260
Total	1,297	1,347	1,809	1,969	2,106	134	162
Rolling and drawing							
Copper wire and brass mills	1,315	1,559	1,890	1,842	2,023	121	154
Aluminum	1,499	1,906	3,175	3,500	3,743	167	250
Total	2,814	3,465	5,065	5,342	5,766	146	205
Castings							
Brass ingot consumed	232	246	251	268	280	102	121
Aluminum	376	463	767	794	849	166	226
Total	608	709	1,018	1,062	1,129	144	186
Forgings							
Steel	877	982	1,233	1,262	1,305	126	149
Nonferrous	39	44	87	87	81	198	208
Total	916	1,026	1,320	1,349	1,386	129	151

Sources: Bureau of Mines. Forging Industry Association.

- Between 1960 and 1969, the output of nonferrous metal by primary smelters and refiners increased 51%. Aluminum accounted for 73% of the total increase (primary aluminum production in 1969 was 88% above the 1960 level, whereas the production of copper, lead, and zinc combined in 1969 was only 24% above the 1960 level). Census data on gas and electricity energy consumption by the nonferrous metal group showed about a 28% increase between 1962 and 1967, but it should be noted that (1) these forms of energy accounted for only 63% of total energy consumption implied by 1962 Census data and (2) the 1967 level of electric power use was estimated by SRI because Census data are lacking. It appears from 1962 Census data that primary aluminum accounted for 71% of total energy consumption in the smelting and refining of primary and secondary nonferrous metals, and based on changes in levels of physical output since 1962, primary aluminum probably represented an even larger share in subsequent years regardless of any changes in the efficiency of energy use. Table 59 indicates that nonferrous metal production consumed 70% of the total gas and electricity consumed by the nonsteel portion of primary metal industries in 1962 and 68% in 1967.

- Between 1960 and 1969, the secondary recovery of nonferrous metals increased 62%, slightly faster than primary smelting and refining. However, in 1969, the tons of secondary output were equivalent to only 29% of the volume of primary output. In 1962, the proportion was 27% and Census data for that year indicated that secondary output consumed only 3.5% as much energy in the form of coal, coke, fuel oil, gas, and electricity combined as did primary output. (On the basis of the total cost of purchased fuels and electric energy including gasoline, LPG, wood, and steam, the secondary nonferrous metals category consumed only 7% as much as the primary metals category in 1962, well below both the tonnage and the amount of energy relationships cited above.)

- Between 1960 and 1969, the rolling and drawing of aluminum and copper (wire and brass mills) increased 105%, compared with 64% increase in the output of primary and secondary aluminum and copper. In terms of the total cost of purchased fuels and electric energy, 1962 Census data indicate that rolling and drawing of aluminum and copper consumed 45% as much energy as the production of primary aluminum and copper. In terms of the amount of energy used, rolling and drawing probably accounted for a significantly lower proportion than 45%.

- Between 1960 and 1969, the output of aluminum castings and the consumption of brass ingot for casting increased 86%. In terms of the total cost of purchased fuels and electric energy, 1962 Census data indicate that the production of aluminum, copper, bronze, and brass castings consumed only 15% as much energy as the production of primary aluminum and copper. The cost of energy consumption for these castings represented only 4.5% of the cost of energy consumption for nonsteel portion of the primary metal industries.

- Between 1960 and 1969, the output of steel and nonferrous forgings increased 51%. In terms of the total cost of purchased fuels and electric energy, 1962 Census data indicate that the cost of energy consumption for forgings represented only 7.4% of the cost of energy consumption for the nonsteel portion of the primary metal industries.

Trends Affecting Energy Use in the Ferrous Foundry Industry

Table 60 shows that between 1960 and 1969 ferrous castings shipments increased 36%. During this period, the number of foundries in operation declined significantly, meaning that the output per average foundry increased. This trend in itself probably had a more favorable impact on air pollution control than energy use per unit of output. However, energy use was affected during the period to the extent that the amount of scrap consumed in foundry furnaces increased while the amount of pig iron decreased. The volumes of metallics charged to iron and steel foundry furnaces annually are shown in Tables 61 and 62.

- The changes between 1960 and 1969 are summarized below (in millions of tons).

	1960	1969	1969 as a Percentage of 1960
Scrap charged	13.0	18.1	139%
Pig Iron charged	3.7	3.0	81
Total scrap and pig iron	16.7	21.1	126
Ferrous castings shipments	13.8	18.8	136
Metallic charge as a percentage of shipments	121%	112%	

Table 61

IRON CASTINGS INDUSTRY SHIPMENTS AND METALLICS CHARGE BY FURNACE TYPE
1959-1969
(Thousands of Net Tons)

		Metallics Charge by Type of Furnace											
		Electric			Cupola			All Other			Total		
	Shipments	Scrap	Total Scrap plus Pig Iron	Scrap as a Percentage of Total	Scrap	Total Scrap plus Pig Iron	Scrap as a Percentage of Total	Scrap	Total Scrap plus Pig Iron	Scrap as a Percentage of Total	Scrap	Total Scrap plus Pig Iron	Scrap as a Percentage of Total
1959	13,224	207	230	90.0%	9,438	13,377	70.6%	1,004	1,196	84.0%	10,649	14,803	71.9%
1960	11,415	166	187	88.8	8,830	12,250	72.1	1,254	1,406	89.2	10,250	13,843	74.0
1961	11,547	180	204	88.2	8,425	11,523	73.1	1,162	1,290	90.1	9,767	13,017	75.0
1962	12,421	159	190	83.7	9,516	12,653	75.2	1,325	1,455	91.0	11,000	14,298	76.9
1963	13,697	175	205	85.4	10,597	13,892	76.3	1,158	1,278	90.6	11,930	15,375	77.6
1964	15,317	220	255	86.3	11,837	15,193	77.9	1,359	1,486	91.5	13,416	16,934	79.2
1965	16,849	255	290	87.9	12,931	16,384	78.9	1,445	1,567	92.2	14,631	18,241	80.2
1966	16,847	309	353	87.5	13,490	16,850	80.0	1,479	1,611	91.8	15,278	18,814	81.2
1967	15,368	682	736	92.7	12,404	15,332	80.9	1,115	1,225	91.0	14,201	17,293	82.1
1968	16,129	1,243	1,313	94.7	12,492	15,097	82.7	301	378	79.6	14,036	16,788	83.6
1969	16,800	1,767	1,844	95.8	12,782	15,533	82.3	284	359	79.1	14,833	17,736	83.6

Source: U.S. Bureau of Mines, Minerals Yearbook, various issues.

Table 62

STEEL CASTING INDUSTRY SHIPMENTS AND METALLICS CHARGE BY FURNACE TYPE
1959-1969
(Thousands of Net Tons)

		Metallics Charge by Type of Furnace											
		Electric			Open Hearth			All Other			Total		
	Shipments	Scrap	Total Scrap plus Pig Iron	Scrap as a Percentage of Total	Scrap	Total Scrap plus Pig Iron	Scrap as a Percentage of Total	Scrap	Total Scrap plus Pig Iron	Scrap as a Percentage of Total	Scrap	Total Scrap plus Pig Iron	Scrap as a Percentage of Total
1959	1,413	1,639	1,670	98.1%	638	753	84.7%	777	848	91.6%	3,054	3,271	93.3%
1960	1,392	1,480	1,511	97.9	589	713	82.6	657	724	90.7	2,726	2,948	92.4
1961	1,217	1,531	1,560	98.1	458	537	85.3	553	611	90.5	2,542	2,708	93.9
1962	1,423	1,734	1,765	98.2	548	638	85.9	609	666	91.4	2,891	3,069	94.2
1963	1,504	1,832	1,864	98.3	626	704	89.0	596	656	90.9	3,054	3,224	94.7
1964	1,835	2,192	2,230	98.3	754	845	89.2	581	644	90.2	3,527	3,718	94.8
1965	1,961	2,478	2,517	98.4	749	840	89.2	569	628	90.6	3,796	3,985	95.2
1966	2,156	2,557	2,595	98.5	700	793	88.3	612	666	91.9	3,869	4,054	95.4
1967	1,857	2,364	2,403	98.4	601	682	88.1	504	548	92.0	3,469	3,633	95.5
1968	1,730	1,965	1,999	98.3	492	565	87.1	541	565	95.8	2,998	3,129	95.8
1969	1,978	2,466	2,508	98.3	454	504	90.1	423	443	95.5	3,343	3,455	96.8

Source: U.S. Bureau of Mines, Minerals Yearbook, various issues.

Several aspects of this tabulation should be noted.

- The volume of metallics melted per ton of finished castings shipped declined significantly, meaning that greater operating efficiencies resulted in a declining yield loss. The improved yield to finished product should have resulted in lower energy consumption per average ton of finished product.

- The volume of scrap charged increased at the expense of pig iron charged, thus the energy consumed at steel industry blast furnaces to produce foundry pig iron declined. Within the foundry industry itself, however, the proportion of metallics charged to electric furnaces increased from 10.2% of total metallics in 1960 to 20.5% in 1969 (from 51.3% in 1960 to 72.6% in 1969 in steel foundries and from 1.4% in 1960 to 10.4% in 1969 in iron foundries). Since each Btu of electric power consumed requires about 3 Btu to generate, the relatively rapid growth in electric furnace output would have caused gross energy consumption attributable to melting furnaces to increase more than 26% (the increase in the volume of metal charged to all furnaces) between 1960 and 1969.

Useful data on energy consumption in the highly fragmented foundry industry are lacking for the most part, particularly in regard to the actual average amount of energy required to melt a ton of ferrous metal for casting. Energy requirements can vary widely according to the type of melting equipment and operating practice. For example* one observer states that the amount of coke required to melt 2,000 pounds of cast iron in a refractory-lined, cold blast cupola varies from 220 pounds (2.9 million Btu) to achieve a tapping temperature of 2600° F to 340 pounds (4.5 million Btu) to achieve a temperature of 2800° F. Since the latter represents 55% more Btu than the former, it would be hazardous to choose a single industry estimate representing some type of average within so wide a range for a given year or series of years. Another observer,† without being specific about types and capacities of furnaces, published some interesting estimates that help explain differences between furnace types in energy consumption per ton of ferrous metallics melted. The estimates are shown below, converted to Btu by SRI.

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* See J. E. Rehder, "Metabolism of the Cupola," Foundry, December 1966.

† See H. W. Lownie, Jr., "Comparing Melting Energy Costs," Foundry, December 1967.

	Cupola	Electric Induction	Electric Arc
Heating equipment efficiency			
To preheat and melt to 2300° F	60%	60%	75%
To superheat from 2300° F to 2700° F	7	60	25
Millions of Btu to preheat, melt, and superheat 1 ton of cast iron			
Theoretical	1.10	1.10	1.10
Actual			
Preheat and melt	1.60	1.59	1.28
Superheat	2.04	0.24	0.57
Total	3.64	1.83	1.85

Lownie made a case for "duplexing," by showing that the minimum energy cost would be encountered by preheating and melting in a cupola and superheating in an induction furnace.* With respect to the amount of energy consumed, however, the most economical combination would be preheating and melting in an electric arc furnace and superheating in an electric induction furnace--a total of 1.52 million Btu. Capital investment and other considerations generally have precluded the use of combinations of furnace types. Although the energy input to an electric furnace is approximately half that of the cupola, if the energy consumed in generating the power is counted, the electric induction furnace in the tabulation above is in effect consuming 5.49 million Btu, 1.5 times as much as the 3.64 million Btu consumed by the cupola.

Previous studies by the Institute indicate that the output of both iron and steel castings by the foundry industry will increase modestly during the next decade. The output of electric furnaces should more than double, however, because of relatively favorable capital and operating costs (including the cost of pollution control and the cost of attaining product quality objectives). The output of furnaces other than electric

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* Energy cost per ton of metal was $0.40 to $0.50 less for electricity than for coke in the article cited, and pollution control is more economic for electric furnaces than for cupolas, but these factors and others such as capital and labor costs are not considered here.

is likely to decline during the next decade, resulting in reduced requirements for pig iron and coke from the steel industry, but the related reduction in coke and natural gas consumption will be more than offset by greater electric power consumption by electric furnaces. In summary, the gross energy consumption by the foundry industry should continue to increase slowly, particularly if the energy required to generate power for melting furnaces is taken into account.

Trends Affecting Energy Use for Copper Smelting and Refining

Copper smelting and refining processes are summarized briefly below.

- Smelting typically consists of reverberatory furnacing and converting. In some cases, roasting precedes these steps but roasters have not been installed in some of the newer smelters. The reverberatory furnace fueled with oil, gas, or pulverized coal is the most widely used means of producing matte (35% to 45% copper), although blast furnaces fueled by coke were used formerly and electric furnaces reportedly are planned for use at three installations. A recent estimate of energy requirements for smelting* includes 375 kwh of electric power and 32,000 cubic feet of natural gas (or the fuel oil equivalent) per ton of anode copper. However, smelting costs and energy use vary widely by installation, because of a number of variables, particularly variations in the grade of copper concentrate smelted.

- Crude copper is refined to remove impurities. Most copper is refined by electrolytic deposition of copper from anodes onto cathodes followed by the melting of the cathodes in electric arc or fuel-fired reverberatory or shaft furnaces to refine the copper to a minimum purity of 99.90%. An alternative method, fire refining, entails furnace processing only. A recent estimate of energy requirements for electrolytic refining† includes 615 kwh of electric power and 4,700 cubic feet of natural gas (or the fuel oil equivalent) per ton of refined copper.

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* See "Copper, Lead, Zinc," Pacific Northwest Economic Base Study for Power Markets, Vol II, Part 7c, U.S. Dept. of the Interior, Bonneville Power Administration, p. 91.

† Op. cit.

- Energy consumption in smelting of a ton of anode copper by the most widely used process is about 33.3 million Btu, and the subsequent electrolytic refining consumes an additional 6.8 million Btu for a total of 40.1 million Btu. In 1969, the primary production of copper was 1,743,000 tons and at 40 million Btu per ton the total energy consumption would have been about 70 trillion Btu. This is only an order of magnitude estimate, however, because there evidently is no typical energy use factor in the copper industry. The same estimating problem exists in regard to the recovery of secondary copper, which can entail smelting old scrap, remelting new scrap, and further refining it electrolytically or by fire refining.

Changes in technology in the domestic copper industry are likely to be substantial during the next decade in response to air pollution control efforts. Several installations reportedly plan to expand capacity by means of electric smelting in spite of doubts of some observers that pollution control requirements can be met. Electric furnaces would have a lower energy input per ton of metal output than reverberatory furnaces because of an advantage in combustion efficiency. According to one expert,* alternatives to conventional practice that could lead to lower smelting costs with improved pollution control include (1) bypassing the reverberatory step; (2) flash smelting to minimize the need for converting, by producing a high grade matte (say 60% copper), and (3) autogenous smelting using oxygen enrichment of the converter blast to increase conversion rates and decrease fuel consumption. One copper producer reportedly had invested more than $30 million in a nearly completed reverberatory smelter only to commit about $50 million to the alternative flash smelting process.

Trends affecting Energy Use for Lead Smelting and Refining

Lead smelting, resulting in a product containing about 97% to 99% lead, consists of:

- Sintering lead ore concentrate (or scrap in the case of secondary lead production) with fluxes and coke breeze. Natural gas or oil is used for the ignition flame.

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* See C. L. Milliken, "What is the Future of the Copper Smelter?" Journal of Metals, August 1970

- Reducing the sinter (lead oxide) to lead bullion in the coke-fueled blast furnace. In addition to lead bullion, a slag is formed containing lead, zinc, iron, and sulfur. Lead and zinc are recovered from the slag in a slag-fuming furnace heated by powdered coal.

- Drossing the bullion in a reverberatory furnace to skim off copper compounds.

Lead refining typically consists of:

- Softening the lead in a reverberatory furnace and oxidizing and skimming off antimony, arsenic, and tin.

- Adding zinc dust to combine with gold and silver and removing these metals by skimming them from the surface of the bullion.

- Removing surplus zinc by preferential distillation under vacuum.

- Adding caustic soda to remove remaining impurities.

Seven standard grades of pig lead range from 99.73% to 99.94% lead. Some Mississippi Valley lead does not require refining, and one company uses an electrolytic refining method similar to that used for copper. However, most primary and scrap lead is processed as described above. According to one source,* energy consumption per ton of refined lead is approximately as tabulated below, although it is likely that there are wide variations in energy use per unit of output among establishments.

		Millions of Btu
Coke	0.45 tons	11.8
Coal	0.40 tons	10.5
Natural Gas	8,000 cubic feet	8.0
Electric power	300 kwh	1.0
Total		31.3

* op. cit.

The 1,259,000 tons of primary and secondary lead produced in 1969 would have required about 39.4 trillion Btu (41.9 trillion Btu counting the energy required to generate the electric power).

Trends Affecting Energy Use for Zinc Smelting and Refining

In 1968, about 36% of the nation's zinc output was produced electrolytically, 57% was obtained by distillation methods, and about 7% was redistilled secondary zinc. The six standard grades of slab zinc range from about 98.3% to more than 99.99% zinc. Many processes exist for metallurgical extraction of zinc but only two, with widely varying practices, are used in the United States:

- Distillation entails heating a mixture of the roasted zinc ore concentrate (45% to 65% zinc) and coal or coke to obtain a zinc vapor that is condensed to molten metal. After roasting, which can consume 1 million Btu per ton of contained zinc, heating is done electrothermically or with fossil fuels. The electrothermic method reportedly consumes about 20.6 million Btu of coal and coke and 10.8 million Btu of electricity (a total of 31.4 million Btu per ton of distilled zinc) at the Josephtown plant of the St. Joseph Lead Company.* The vertical retort process reportedly consumes about 36 million Btu of coal and coke for briquettes plus about 10 million Btu of coal for fuel firing, a total of 46 million Btu per ton of distilled zinc at New Jersey Zinc Company retorts.†

- The electrolytic process consists of (1) leaching roasted concentrate to convert lead oxide to lead sulfate and precipitating impurities that combine with zinc dust, (2) depositing metallic zinc on aluminum cathodes by electrolysis, (3) stripping off the zinc and melting it in an electric or reverberatory furnace, and (4) casting the zinc into slabs. The Bonneville Power Administration study shows energy consumption per ton of zinc produced at 18 million Btu of natural gas and 33.8 million Btu of electricity, a total of 51.8 million Btu.

* See F. G. Wheaton, "The Electrothermic Process of the St. Joseph Lead Company," Zinc, American Chemical Society Monograph Series, 1959, Reinhold Publishing Corp., New York.

† G. F. Halfacre, "The Vertical Retort Process," op. cit.

Energy requirements for refining scrap zinc and primary zinc reportedly are similar in order of magnitude. Air pollution control is such a serious problem for retort smelters that their output is likely to decline in the future, and the share of zinc produced electrolytically should increase.

Trends Affecting Energy Use for Aluminum Production

Aluminum is produced by electrolysis of alumina in a molten cryolite bath. The reduction cell consists of a carbon-lined steel shell containing a pad of molten aluminum that serves as the cathode, a carbon anode, and an electrolyte of molten cryolite in which the alumina is dissolved. The alumina is reduced to aluminum at the cathode and carbon is oxydized to carbon dioxide at the anode. Most aluminum ingot is at least 99.5% pure. Electric power is the primary form of energy consumed, and a majority of plants have 80,000 to 100,000 ampere reduction cells with a voltage drop of 4.5 to 5.0 volts across a single cell. Aluminum plants in the United States are based on thermal or hydroelectric power, or a combination of both. The tabulation below shows the 1960-69 industry trend in the power base (annual capacity increased from 2,469,000 tons at year-end 1960 to 3,843,000 tons at year-end 1969).

	Percentage Share	
	1960	1969
Thermal	46.8%	40.9%
Hydroelectric	39.1	48.3
Combination	14.1	10.8
Total	100.0%	100.0%

The following points cover, in general terms, the utilization of energy in the production of aluminum.

- The use of power for electrolytic smelting of aluminum varies by plant but the industry average is about 46.7 million Btu per ton at 3,413 Btu per kwh.
- The use of fuel by primary aluminum producers to melt aluminum ingot and scrap for casting probably averages about 4.7 million Btu per ton.
- Other process power, steam, and miscellaneous energy use probably accounts for an additional 3.6 million Btu per ton.

- Total power and fuel consumed is about 55 million Btu per ton (carbonaceous materials such as petroleum coke, coal tar pitch, and carbon blocks for anodes, pot linings, and so forth probably add another 20 million Btu per ton). Thus the 3.8 million tons of primary aluminum produced in 1969 would have required some 285 trillion Btu.
- The production of secondary aluminum (made from aluminum scrap) consumes about 8.5 million Btu per ton, and the 860 thousand tons produced in 1969 would have required some 7 trillion Btu.
- The processing of wrought aluminum (e.g., rolling and extruding) consumes approximately 12 million Btu per ton of finished (fabricated) products, so the 3.7 million tons produced in 1969 would have required some 45 trillion Btu.

Chemical Industry

In this report, the chemical industry is defined as that grouping that the Bureau of the Census designates SIC 28--Chemicals and Allied Products. This classification includes the manufacture of basic, intermediate, and end chemicals. Drugs and pharmaceuticals are included, but other industries that use chemical process technology--such as petroleum refining--are excluded.

The boundaries of the industry have always been diffuse because its common bond is a broad and complex technology. It lacks the simplicity of other industries, where the bond may be a common single product such as steel.

The chemical industry's traditional role has been that of a "middleman"; that is, a purchaser of raw materials and services from numerous supplying industries and a provider of higher value products to a host of consuming industries. Because of the complexity of its operations, it is its own best customer.

Some 215--43%--of the 500 largest industrial corporations in the United States are now active in some aspect of the manufacture and sale of chemicals. Only one-third of these are usually thought of as chemical companies. Manufacture of chemicals is especially attractive to producers of raw materials and finished goods that can complement their existing operations or satisfy a portion of their materials needs.

Petroleum refiners have been moving into the industry to capitalize fully on their strong raw material and process technology positions. Since petrochemicals now account for 30% of the tonnage and more than 60%

of the value of all organic chemicals produced in the United States, the importance of the oil and gas companies' position is obvious.

The chemical industry's raw materials needs amount to more than $2 billion per year and are primarily focused on the minerals and elements found in the earth's crust, water bodies, and atmosphere. At present, slightly more than half these materials needs are directed to the production of organic chemicals and the remainder to inorganics.

Historically, coal and coal tar served as the raw material bases for the production of most primary aromatic organic chemicals. Aliphatic chemicals were derived almost exclusively from natural sources, using processes such as fermentation. Within the past 25 years, however, (especially within the last decade), the growing replacement of coal and natural sources by petroleum and natural gas as the dominant raw materials led to the development of the petrochemical industry.

This replacement resulted from several economic and technological factors. The supply of coal-based primary chemicals started with the coking process. The demand for coke, however, depends on steel production, which was affected by growth factors not related to chemicals. Thus, over the long term, the organic chemical industry could not remain dependent on coking of coal for its raw material needs. The demand for aromatics rose more rapidly than their production could have risen if it had been based on coal. Furthermore, the large volume production of today's organic chemical industry is based on aliphatic raw materials, while coal and its derived products, although rich in aromatics, are poor in aliphatic compounds. Production of the aliphatic compounds from natural sources could not match the growth in demand and was economically infeasible in many cases. Many primary chemicals such as propylene could not be derived from coal at all or only at considerable expense.

The development of the petroleum industry made the necessary materials increasingly available. The output of coal little more than doubled from 1910 to 1965, while petroleum output increased thirtyfold. The great increase in petroleum and natural gas production has been connected with increasing motorization, shifts from coal to oil and gas in the growing thermal fuel markets, large new crude oil discoveries, and development and expansion of efficient transport systems.

Petroleum and natural gas became major raw materials for organic chemical production earlier in the United States than elsewhere because of their availability and the more rapid development of large scale markets for petrochemical products after World War II. A similar trend has been occurring outside the United States in recent years.

Petrochemical feedstocks--hydrocarbons derived from natural gas and crude oil--include natural gas itself, natural gas liquids (e.g., ethane, propane, and butanes), field condensate, refinery gas, naphtha, gas oil, and many other petroleum fractions. Feedstocks such as natural gas and natural gas liquids have a simple chemical composition, since natural gas is methane. Refinery gas and liquids, however, constitute a broad range of chemical mixtures covering a spectrum of aliphatic and aromatic hydrocarbons.

Energy demand is the prime determinant of petrochemical feedstock availability and price. Since use of hydrocarbons for energy exceeds their use for feedstock, it has generally been the practice to choose as raw materials those feedstocks that are valued least in energy uses.

The sources of some raw materials change as supplying industries grow or decline--the rise of petroleum and natural gas at the expense of coal is an example. The shift in fossil fuels consumption has helped to create petrochemicals, which are organic chemicals produced from petroleum and natural gas hydrocarbons rather than coal.

The development of new chemical processes can greatly influence the demand for raw materials. Thus, improved processes for producing synthetic glycerine, rubber, and methyl alcohol resulted in a decline in demand for naturally occurring fats, rubber, and wood.

Some shift is anticipated in the kinds of raw materials needed in the manufacture of chemicals, principally in the organics. Use of petroleum and natural gas hydrocarbons will continue to expand as organic chemicals assume a still greater role. However, as the costs of these raw materials rise, attention will return to the use of coal as a possibly less expensive raw material source. (Little change is expected in the basic raw materials needed for manufacture of inorganic chemicals.)

The research efforts of the chemical industry have been highly effective. Its products now number in the thousands, and research produces 400 "new products" each year.

Chemicals can be classified according to their role and use--basic, intermediate, and end chemicals. Basic chemicals are normally consumed by other chemical processes--both within and without the chemical industry--and have a fairly long market life expectancy. Intermediate chemicals also are used chiefly in chemical process operations, sometimes in several different processes. End chemicals are usually sold to other industries, and their market life is sometimes brief. Some end chemicals such as pharmaceuticals are delivered to the ultimate consumer without further modification; others, such as synthetic fibers, become a basic input to another industry.

The chemical industry is the second largest consumer of energy in the industrial sector of the U.S. economy. However, analysis of energy consumption patterns is complicated by the fact that there are literally hundreds of chemical products and many of these products are produced by more than one process.

Some of the processes are highly energy-intensive and some are not. In some cases, substantial amounts of energy materials are used as feedstocks. Table 63 shows the energy consumed in the production of 11 selected products. These products account for approximately two-thirds of the energy consumed in the entire chemical sector.

In some cases, the consumption of energy materials as feedstock is far greater than the consumption for energy purposes.

Petroleum Refining

Introduction

Petroleum products are a major source of energy for today's society. In the manufacture of these products, energy is consumed in converting crude oil to the forms usable for energy sources.

Throughout the United States there are more than 200 different crude oils, more than 100 individual refining processes to select from, and a market demand for more than 1,000 types of products. As a result, no two of the more than 260 petroleum refineries throughout the United States are alike.

To determine the functional uses of energy that represent the overall U.S. petroleum refining industry, it is necessary to consider:

- A large portion of the U.S refining capacity
- Widespread geographical coverage of crude oil supply, refinery locations, and product marketing areas

Energy Uses

As an average, petroleum refining in the U.S. uses about 710,000 to 715,000 Btu of energy per barrel of crude oil run to stills. This amounts to approximately 11% of the total energy input to refineries, counting both crude oil and auxiliary fuels. The four largest sources of energy

Table 63

ENERGY CONSUMPTION BY END USE IN THE CHEMICAL INDUSTRY
1967
(Trillions of Btu)

	Space Heating			Process Heat			Mechanical Drive			Electrical Uses††				
	Fuel	Steam	Electric	Fuel	Steam	Electric	Fuel	Steam	Electric	Lighting	Electrolysis	Other	Total	Feedstock
Chlorine - caustic soda	--	--	--	--	69	--	--	--	1	*	80	--	150	--
Soda ash (synthetic)	--	--	--	124	57	--	--	--	Negl	Negl	--	--	181	--
Acetylene (hydrocarbon source)	--	--	--	--	9	--	--	--	1	Negl	--	--	10	45
Oxygen	--	--	--	--	--	--	--	36	13	Negl	--	--	49	--
Carbon black	--	--	--	4	--	--	--	--	--	Negl	--	--	4	212
Ammonia	--	--	--	85	113	--	--	--	2	Negl	--	--	200	299
Aluminum oxide (excluding natural)	--	--	--	24	52	--	--	--	1	Negl	--	--	77	--
Phosphorus	--	--	--	1	--	--	--	--	*	*	26	--	27	20
Methanol	--	--	--	13	13	--	--	--	1	*	--	--	27	39
Sulfur (frasch)	--	--	--	72	--	--	--	--	--	*	--	--	72	--
Ethylene, propylene, butadiene, aromatics, C_2, C_3, and C_4	--	--	--	5	25	--	--	--	5	*	--	--	35	1,200
Subtotal				328	338			36	24		106		832	1,815
Space heating		20											20	--
													852	1,815
Balance of industry		60		170	500	--		220†	367	21‡	12		1,350	--
Industry total		80§		498	838			256	391	21	118		2,202	1,815

* Included in electrolytic load.
† Energy used for electrical generation highly integrated with process steam production.
‡ Taken to be 5% of total electric load after deduction for electrolytic consumption.
§ Taken to be 5% of total direct and steam input.
†† 1 kWh = 3,413 Btu.

are: natural gas, 38% (.26 Mcf per barrel of crude); refinery gas, 34% (.25 Mcf per barrel of crude); petroleum coke, 13% (.003 tons per barrel of crude); and fuel oil, 10% (.01 barrel per barrel of crude).

The bulk of the energy used in petroleum refining is for direct heat--about 60% of the total energy consumption. Of the balance, about 34% is used for process steam and 6% for electrical generation.

Most of the direct heat production results from burning oil and gas in direct fired heaters. A small amount of energy is used as fuel for mechanically driven equipment (i.e., fuel gas driven compressors associated with catalytic cracking plants).

The next largest end use in petroleum refining is the production of process steam--about 34% of the total energy used. This apparently varies widely between refining companies, because of processes used in each refinery, the type of crude oil processed, and the products manufactured.

In general petroleum refineries have a central steam supply or boiler plant that supplies high pressure steam for mechanical equipment drives as well as for heat supply through heat exchangers. Exhaust steam from these facilities is used in refining processes as stripping steam or as the inert carrier to assist in separation of high temperature boiling point petroleum fractions. As an overall average, the energy use of steam as a heat source is about 6% of all energy consumption in the industry; 8% is used for mechanical drives, and 20% is used for processes.

When the cost of purchased electric power is high relative to the cost of self-generated electric power, petroleum refineries install power generating facilities. In these instances, the central steam supply or boiler plant may include a high pressure steam supply that powers a turbine-electric generation system. The exhaust steam from this system may then be used to power mechanical drives or provide process heat or process steam throughout the refinery.

The bulk of the electrical energy is used for mechanical drives--or about 6% of the energy used in refining. Other uses of electrical energy are negligible by comparison. These other small uses include miscellaneous uses such as air conditioning or space heating, lighting, and cathodic protection of equipment.

Petroleum refineries are typically outdoor installations. A relatively small amount of protection from adverse weather is provided for operating personnel and instrumentation. In these areas and in areas of extreme weather conditions, a minor amount of energy is used for space heating and air conditioning. The use of electrical power for lighting and for cathodic protection of some water-cooled equipment is also minor.

These amounts of energy use are insignificant on a U.S. petroleum refining industrywide basis.

Trends

Only small changes in the end use of energy in petroleum refining have occurred over the past 10 years. The petroleum refining industry is highly competitive and there is a strong pressure to improve the economics of operations. In general, this is achieved by upgrading the mix of products produced, which requires the use of expensive and complex high temperature refining processes. This has caused the proportion of energy used as direct heat to increase from 59% of the total energy consumption 1959 to only 60% in 1970. This apparently was offset by a corresponding drop in the energy used to produce process steam and electrical energy.

Types of Refineries

Refineries may be classified as simple, complex, or fully integrated depending on the processes they perform. In general, the refining processes in a simple refinery consume the least amount of energy in converting the raw crude oil to saleable products. The processes in this instance are primarily crude oil distillation, catalytic reforming, and treating. The range of products, however, is relatively limited: liquefied petroleum gas, automotive fuel, kerosene, gas oil, diesel fuel, and fuel oil.

A more complex refinery will require additional processes, and as a result will use a greater amount of energy in processing. Additional processes generally include vacuum distillation, catalytic cracking with gas recovery, polymerization, alkylation, and asphalt oxidation. The gases recovered from cracking processes may form part of the feed to polymerization and alkylation processes to produce high octane gasolines for automotive and aviation fuel or they may form part of the feed to petrochemical processing. Vacuum distillation residue will become feedstock for asphalt manufacture. As a result, the complex refinery has a greater range of products, but correspondingly uses a greater amount of energy in processing.

A fully integrated refinery includes an additional number of complex processing units to make a full range of petroleum products, including lubricating oils, greases, waxes, and the products of sulfur and coke if a market exists for them. A few of these processes include high vacuum fractionation, solvent extraction, deasphalting, dewaxing, and treating units. As a result, the fully integrated refinery uses an even greater degree of energy in processing.

To illustrate the requirements for energy in petroleum refining a simplified flow diagram of a refinery is shown in Figure 13. In nearly all of the processing units shown, energy is required in the form of direct heat to raise the temperature of the oil being processed. Additional energy is required for mechanical drives to force the oil through the process.

The Pulp and Paper Industry

Background

Paper and allied products accounted for more than 5% of the 1967 industrial (mining and manufacturing) consumption of energy. In the past the industry increased its share of total industrial energy consumption as follows.

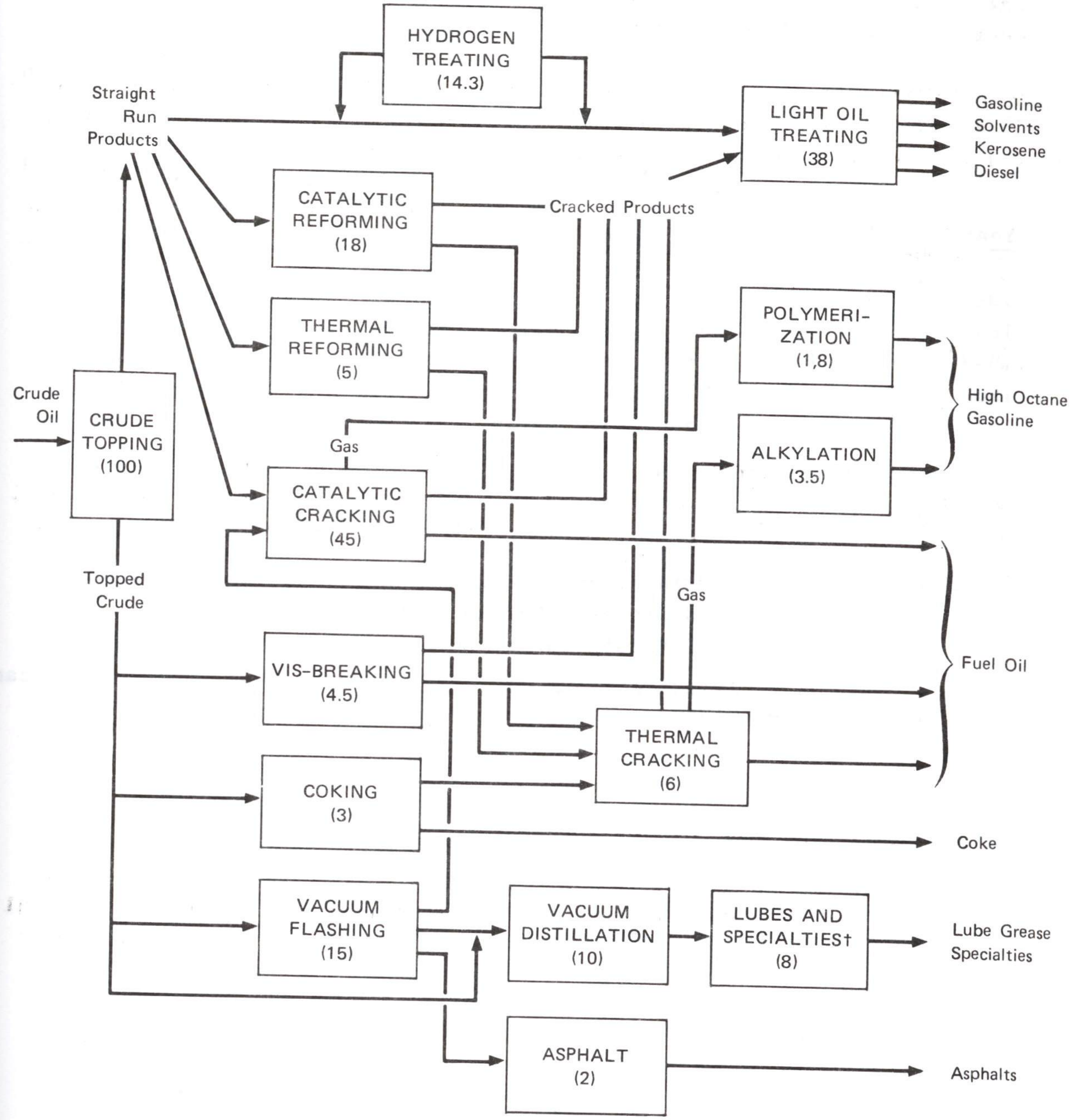
1947	4.1%
1954	4.5
1958	5.0
1962	5.2
1967	5.4

The relatively greater energy consumption of the paper industry is attributable to an over average production growth in that industry; total energy consumption and production of paper and paperboard is shown in Table 64.

In 1967, the individual fuels and purchased electricity accounted for the shares of the total shown below.

Gas	31.8%
Coal	30.5
Residual fuel oil	17.6
Distillate fuel oil	5.0
Purchased electricity*	7.2
Other fuels	7.9
Total	100.0%

* kwh equals 3,413 Btu.



NOTES: *Process capacity indices (with crude topping = 100) applicable to all complete processing refineries.
†Including naphthenic lubes and specialties processes.

SOURCE: Estimating Production and Repair Effort in Blast-damaged Petroleum Refineries by Frank E. Walker, July 1969.

FIGURE 13 PETROLEUM REFINING PROCESSES

Table 64

ENERGY CONSUMPTION FOR PAPER AND ALLIED PRODUCTS
1947-1967
(Trillions of Btu)

Year	Coal	Coke	Fuel Oil	Gas	Other Fuels	Purchased Elec- tricity*	Total	Production of Paper and Paperboard (millions of pounds)
1947	389	Negl	74	72	17	21	573	42,204
1954	329	Negl	139	121	102	37	728	53,752
1958	379	Negl	157	220	48	43	847	61,646
1962	397	3	193	274	48	58	973	75,082
1967	334	n.a.	248	348	86	79	1,095	93,786

* 1 kwh = 3,413 Btu.

Sources: Warren E. Morrison, and Charles L. Reading, "An Energy Model for the United States," Bureau of Mines, IC8384, 1968. 1967 Census of Manufactures, Bureau of the Census, MC 67(2) - 26 A-C. The Statistics of Paper, 1968-69 Supplements, American Paper Institute.

Over the 1947-67 period, gas increased its share from 13% to 32% and fuel oil from 13% to 23%, whereas coal declined in importance from 68% to 31%.

The unit consumption of energy, which remained relatively stable between 1947 and 1958, declined rather significantly--by 15%--between 1958 and 1967 as shown in Table 65. Several trends and developments during this nine-year period resulted in this composite reduction:

(1) Increased use of the sulphate (kraft) pulping process, which is--generally--a less energy consuming process than other pulping processes. Kraft pulp increased its share of total pulp production from 56% in 1958 to 63% in 1967.

(2) Increased use of continuous digesters instead of batch digesters. Kamyr continuous digesters are estimated by the manufacturer to reduce the steam requirement of cooking by 40% and that of evaporation by 15% to 20%. Kamyr continuous digesters increased their share of U.S. pulping capacity from less than 5% in 1958 to more than 30% in 1967.

Table 65

ENERGY CONSUMPTION IN THE PRODUCTION OF PAPER
AND ALLIED PRODUCTS
1947-1967
(Btu per Pound)

Year	Coal	Coke	Fuel Oil	Gas	Other Fuels	Purchased Electricity*	Total
1947	9,220	Negl	1,750	1,710	400	500	13,580
1954	6,120	Negl	2,590	2,250	1,900	690	13,550
1958	6,140	Negl	2,550	3,570	780	700	13,740
1962	5,290	40	2,570	3,650	640	770	12,960
1967	3,560	n.a.	2,640	3,710	920	840	11,670

* 1 kwh equals 3,413 Btu.

Source: Table 64.

(3) Decreased use of waste paper from 0.28 pounds per pound of paper and paperboard production in 1958 to 0.21 pounds per pound of paper and paperboard production in 1967 and a resulting increase in wood pulp use from 0.73 pounds per pound to 0.78 pounds per pound. Since pulp made from recycled waste. paper uses only about one-fourth of the steam energy and less than one-tenth of the electric energy than that made from wood, declining use of waste paper results in increased energy consumption per unit of finished product.

(4) Pulp yields increased from 96% in 1958 to 98% in 1967, resulting in decreased energy consumption per unit of finished product.

(5) Increasing use of chips from the lumber and wood products industry. These chips are a by-product, particularly of plywood production, and if used as raw material for the production of pulp, they substitute for chips produced by the pulp industry by debarking and chipping whole logs. Debarking and chipping operations in pulp and paper mills account for significant amounts of electric energy consumed.

(6) The trend toward more refined products, with larger per unit energy consumption, increased the average energy consumed. For example, bleached and semibleached sulphate and sulphite pulps increased their share from 44% in 1958 to 49% of all sulphate and sulphite pulps in 1967.

(7) Increased emphasis on pollutant removal from water and air released from pulp and paper mills tends to increase energy consumption. The installation of electrostatic precipitators and wet scrubbers and devices for oxidation and indirect evaporation of black liquor particularly result in increased energy consumption.

The decline in the unit consumption of energy from 1958 to 1967 is less significant if the increased quantity of purchased electricity is considered. Converting purchased electricity at average heat input rates, the decline amounts to only 12% compared with 15% at a conversion rate of 3,413 Btu/kwh.

Manufacture of Paper and Paperboard

Paper and paperboard are manufactured in two distinct steps: production of pulp, which is essentially a chemical process, and refining of pulp into paper or paperboard, which is essentially a mechanical process.

Some 85% of all pulping is done by chemical or semichemical means, and of the chemical processes, the alkaline sulphate or kraft process is the most commonly used and the most rapidly growing. The relative importance of the different pulping processes is shown below (in thousands of short tons of pulp production).

	1958	1967
Sulphate		
Bleached and semibleached	4,669	10,318
Unbleached	7,647	12,452
Sulphite		
Bleached	1,849	2,256
Unbleached	532	413
Dissolving and special alpha grades	929	1,447
Soda	429	201
Total chemical	16,055	27,087

	1958	1967
Groundwood	2,890	4,074
Semichemical	1,622	3,273
Defibrated/exploded	1,133	1,254
Screenings/off-quality	95	266
Total wood pulp	21,795	35,954

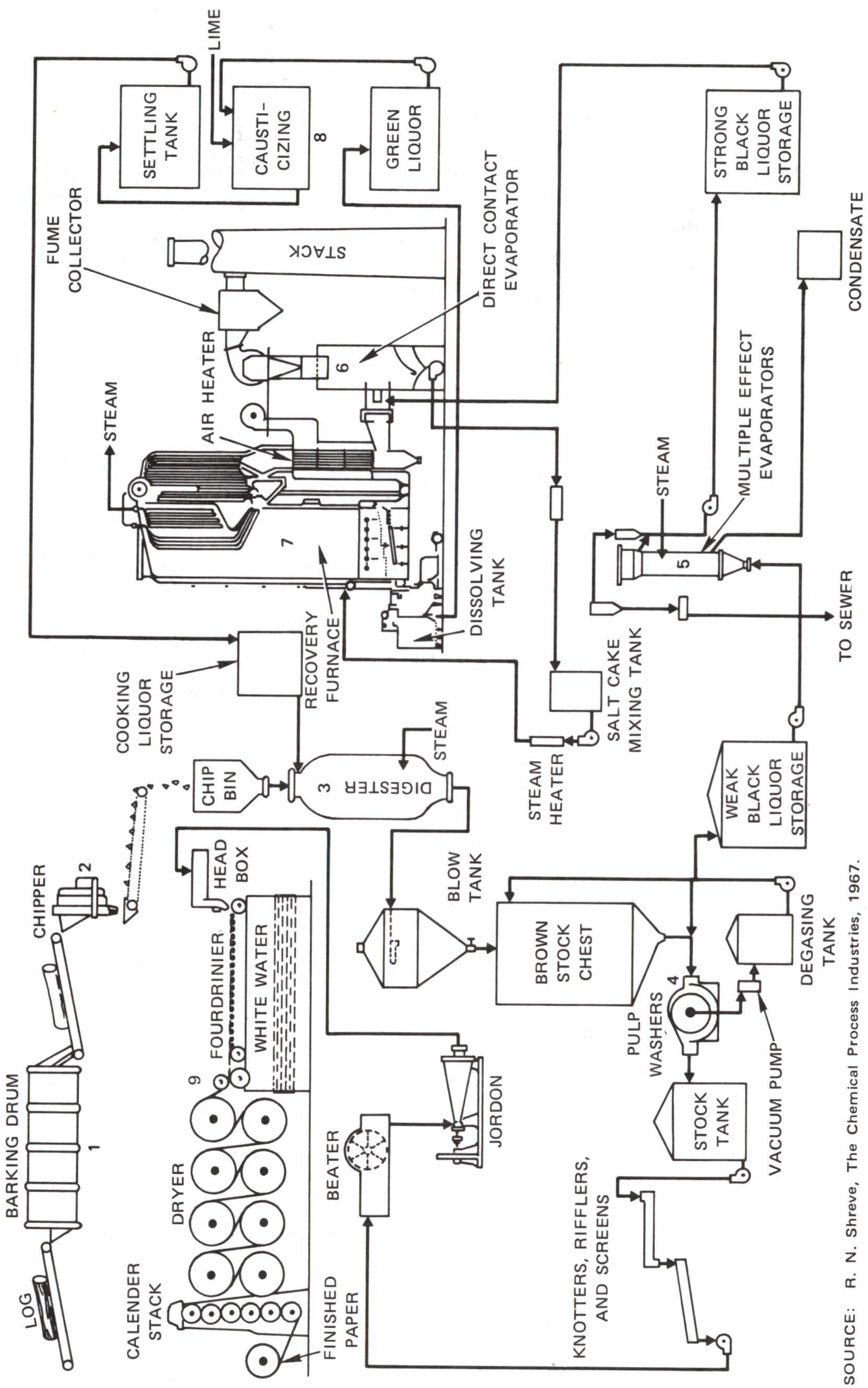
Pulp is then refined into paper or paperboard to generate opacity and to improve strength and feel. A flow chart for the kraft process is given in Figure 14, which shows the pulping and papermaking processes and recovery of inorganic chemicals and reuse and organic matter as fuel for steam production.

The pulp and paper industry generates two by-products that are used as fuel for the production of steam: bark and black liquor. Bark must be removed from the logs because of its low fiber value, and it is usually burned in bark boilers. Black liquor is the spent cooking liquor from the digester, a solution of inorganic chemicals (essentially sodium sulfide and caustic soda) and organic matter (lignin). The chemicals are recovered by evaporation, and the organic matter is burned in the recovery furnace producing thereby a substantial share of the mill's steam requirements.

Energy Consumption in Paper and Paperboard Manufacture

Energy in a pulp and paper mill is typically consumed in two forms--steam and electric power. The major energy consuming centers are numbered in Figure 14 and primarily consume energy in these forms and for these purposes:

(1)	Barking	Electricity	Mechanical drive
(2)	Chipping	Electricity	Mechanical drive
(3)	Digester	Steam	Heat
(4)	Washing	Steam	Heat
(5) (6)	Evaporators	Steam	Heat
(7)	Recovery plant	Steam	Heat
(8)	Recausticizing	Steam	Heat
(9)	Paper machine	Steam	Heat
		Gas	Heat
		Electricity	Mechanical drive



SOURCE: R. N. Shreve, The Chemical Process Industries, 1967.

FIGURE 14 KRAFT PAPER MANUFACTURING PROCESSES

Steam and electric power flow diagrams are shown in Figure 15. The steam and electric power consumption in individual mills can vary significantly depending on the pulping process, mill equipment, raw materials, product mix, and outside temperature and humidity, but typical consumption of steam is as tabulated below (in pounds per pound of pulp).

	Typical	Range
Kamyr Digester	2.0*	1.5 - 2.0
Washers	0.8	0.2 - 1.2
Bleaching	1.0	0.25 - 1.5
Recausticizing	0.25	--
Recovery plant	0.75	--
Liquor evaporators	1.4	1.25 - 1.5
Steam plant†	0.6	--
Heating‡	0.2	--
Total	7.0	5.0 - 8.0
Mill auxiliary uses (10%)	0.7	0.5 - 0.8
	7.7	5.5 - 8.8

Depending on whether the desired finished product is air-dried pulp or paper or paperboard, the following quantities of steam would alternatively be required.

	Typical	Range
Pulp drying	1.25	1.0 - 1.5
Newsprint machine§	3.25	2.75 - 3.75
Tissue machine	3.0**	--
Paperboard machine	3.25	3.0 - 3.5

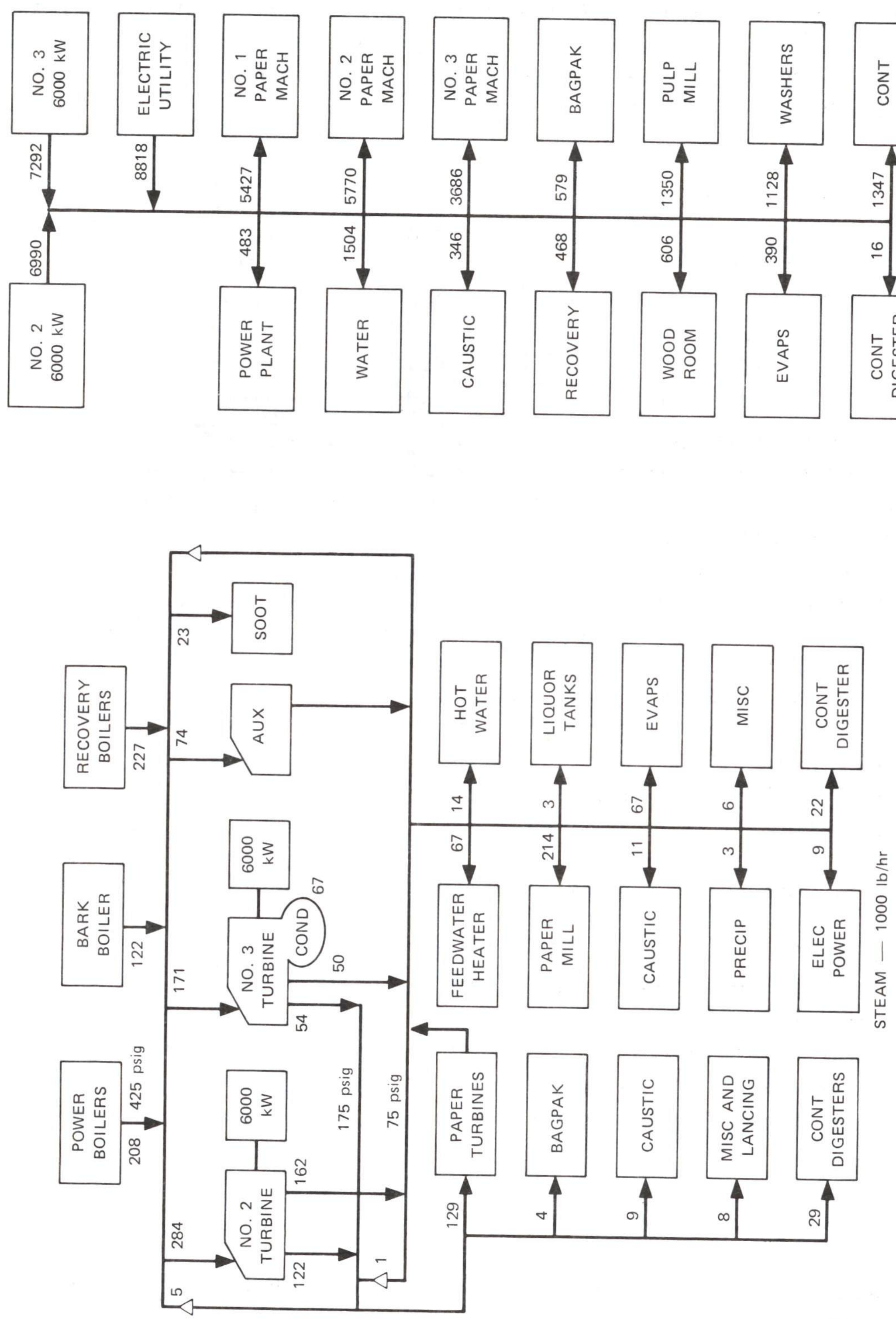
* Alternately batch digester 2.25 pounds per pound (sawdust 2.5 pounds per pound).

† Combustion air and feedwater heating.

‡ Offices, warehouses, and so forth.

§ For machine dryers and air systems only.

** Possibly 2 pounds steam and Btu equivalent of 1 pound steam in natural gas.



ELECTRIC POWER — kW

SOURCE: Watson, J.H., "Continuous Digesters: Their Effect on a Steam Power System," Tappi, May 1968, Vol. 51, No. 5.

FIGURE 15 STEAM AND ELECTRIC POWER FLOW DIAGRAM IN INTEGRATED PAPER MILL

Considering the current mix of processes and products, the average steam consumption per pound of paper or paperboard approximates 9.5 pounds. Some 5.5 to 6.0 pounds of steam per pound of product are produced in recovery boilers, leaving a net requirement of 3.5 to 4.0 pounds per pound.

Electric power requirements are estimated to average 0.5 kwh per pound of product as follows.

Wood mill and chip handling	0.25
Kraft mill (including bleach plant)	0.10
Paper mill	0.10
Power plant and pumping	0.05
	0.50

The average consumption of electric power per pound of paper varies widely, depending particularly on the type of pulping process used, but also on the type of paper produced. The Standard Handbook for Electrical Engineers,* mentions 0.25 to 0.55 kwh for kraft paper and 0.65 to 1.0 kwh for newsprint. A survey of Technical Association of the Pulp & Paper Industry (TAPPI) member companies by Mower & Peterson† shows an average consumption for 21 integrated mills of 0.52 kwh ranging from 0.285 kwh to 0.94 kwh and an average consumption of 8 paper mills of 0.507 kwh ranging from 0.294 kwh to 0.955 kwh.

Results of the 1962 and 1967 Census of Manufactures confirm the above averages; the total electric power consumed (purchased plus self-generated, less sold) in SICs 2611 (pulp mills), 2621 (paper mills), and 2631 (paperboard mills) amounted to 0.488 kwh per pound of paper and paperboard production in 1962 and to 0.492 kwh per pound in 1967.

Total "net" energy requirements of paper manufacturing can therefore be defined as 3.5 to 4.0 pounds of steam and 0.5 kwh of electric power per pound of paper or paperboard produced. Assuming that one-half of the electric power is purchased (in 1967, 53% was actually purchased) and that the remainder is generated in mill facilities, the "net" Btu requirements in paper manufacturing may be summarized as follows.

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* Standard Handbook for Electrical Engineers, A. E. Knowlton, Editor, McGraw Hill, 1957

† L. D. Mower, and A. W. Peterson, "Power Consumption Values for Pulp and Paper Mills," Tappi, March 1966, Vol 49, No. 3.

	Btu per Pound of Paper
Steam (at 1,350 Btu per pound)	4,720 - 5,400
Purchased electricity (at 3,413 Btu per kwh)	850
Self-generated electricity* (at 4,000 Btu/kwh)	1,000
Total	6,570 - 7,250

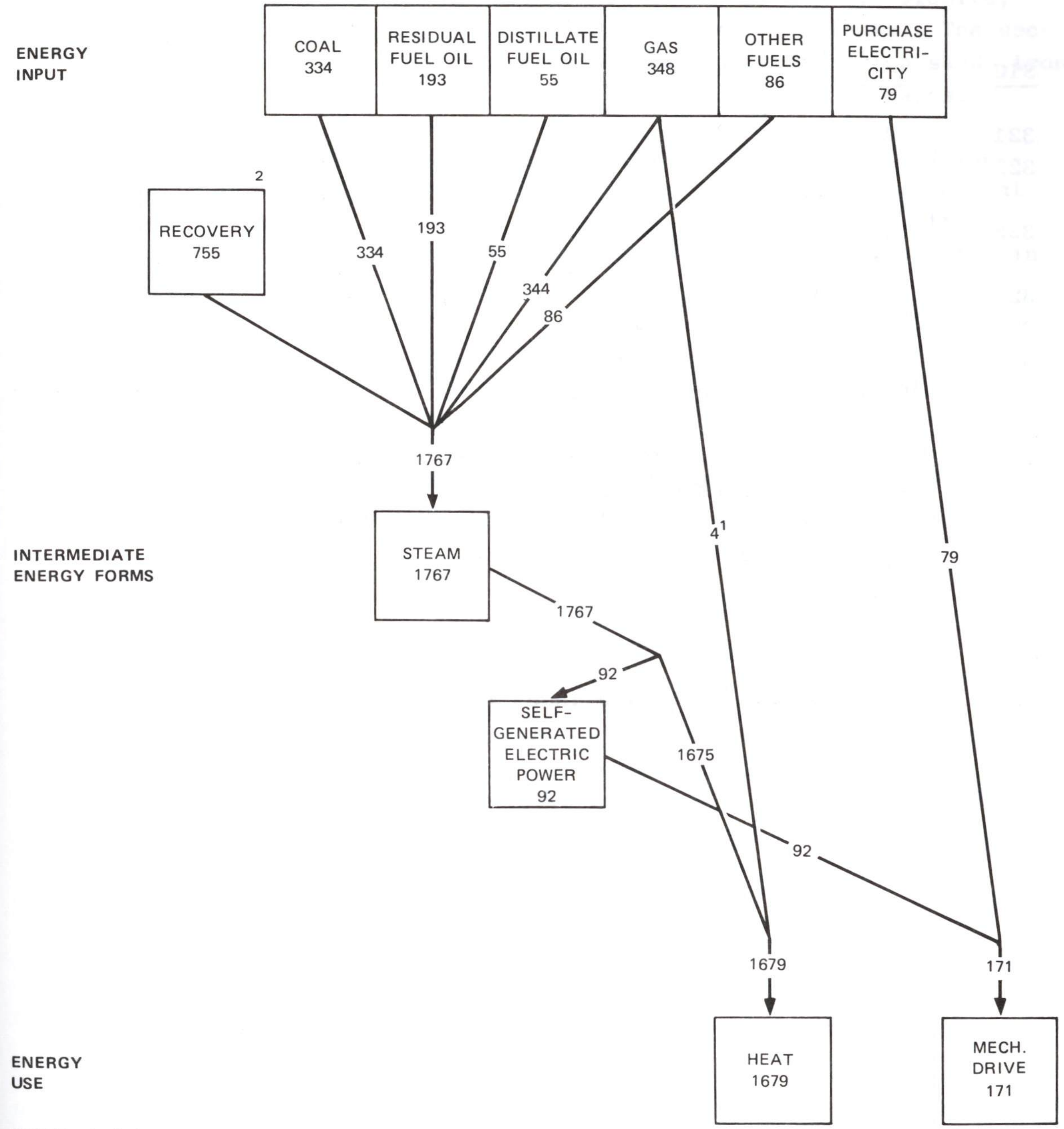
This compares with the average 1967 fuel input of 11,670 Btu per pound (see Table 66) and indicates an average fuel conversion efficiency of 56% to 62%.

Figure 16 details SRI's estimate of the 1967 energy flow in the pulp and paper industry. Essentially all electric power is used for mechanical drive; small amounts used for paper drying are relatively immeasurable. Also insignificant amounts of steam may be used for mechanical drives, but essentially all steam is used for heat. As the diagram shows, the final energy use in the pulp and paper industry is estimated as 90% for heat and 10% for mechanical drive.

Stone, Clay, Glass, and Concrete Products

Total energy consumption in stone, clay, glass, and concrete products amounts to about 9.4% of that used in the total industrial sector. Industries included are listed below.

* A heat rate of 4,000 Btu per kwh has been used because losses such as condensor losses are charged to process steam production. The reason for this is that steam is required in the papermaking process and electric energy generation takes place only because process steam is required.



NOTES: 1. Estimated as 15 percent of total energy consumption of tissue paper machines (0.15 x 6.0 x 1.35 x 3.23)

2. At 6 lb of steam per lb of paper and paperboard produced and 1350 Btu/lb.

FIGURE 16 ESTIMATED ENERGY FLOW IN MANUFACTURING PAPER AND ALLIED PRODUCTS—1967 (Trillions of Btu)

SIC	Industry	Trillions of Btu	Share of Industrial Sector Energy Consumption (percent)
321	Flat glass	41.3	0.4%
322	Glass and glassware, pressed or blown	170.8	1.5
323	Glass products made of purchased glass	6.1	0.1
324	Hydraulic cement	454.7	4.0
325	Structural clay products	152.4	1.3
326	Pottery and related products	5.9	0.1
327	Concrete, gypsum, and plastic products	157.7	1.4
328	Cut stone and stone products	--	--
329	Abrasive, asbestos, and miscellaneous nonmetallic mineral products	73.1	0.6
	Total	1,062.0	9.4%

Principal energy consuming industries in this group are:

	Approximate Energy Consumption
Cement	43%
Glass	16
Concrete	15
Clay	14
Other	12
	100%

Cement

Manufacture--Cement manufacture basically consists of surface mining operations followed by appropriately controlled crushing, grinding, heating, and blending operations.

In general, two types of raw materials are mined--those primarily containing calcium and those containing silica, alumina, and iron. The calcium containing material can be obtained from limestone, dolomite, marble, marl, oyster shells, or waste sludge from lime plants. The second material can be obtained from clay, shale, bauxite, silica sand, iron ore, waste from aluminum plants, or slag from iron blast furnaces.

Because of the nature of the raw materials and the required manufacturing processes, the predominant uses of energy are for mechanical operations of crushing, grinding, and blending and for direct fired heating operations to achieve chemical changes. This is illustrated in Figure 17, a simplified flow chart of Portland Cement manufacture.

Preparation of the raw material before kiln processing uses essentially all mechanical energy in the form of electric drives for the crushing equipment, for the conveyors and cranes used in blending, and for the ball and tube mill grinding equipment. A typical value for the total amount of electrical energy used is 110 kwh per barrel. Most of this is used in preparing the material for the kiln.

The kiln operation accounts for nearly all of the direct heat used in cement manufacture. It amounts to about 600 pounds of coal, 45 gallons of fuel oil, or 7,500 standard cubic feet (scf) of gas to produce 1 ton of cement.

The last step of cement manufacture uses mechanical energy in the form of electric drives. In this step, the clinker is blended with a small amount of gypsum and the mixture is ground to a very fine powder in tube mills and shipped either in bags or in bulk.

Glass

Manufacture--In the manufacture of glass products, melting of the raw material to a molten glass state consumes a major portion of the fuel used. Mechanical drives account for most of the electrical energy consumption.

Because of the wide variety of types of glass products and the variations in formation processes required, the fuel energy required to produce finished glass products can vary from about 14 to 18 million Btu per ton of mechanically formed plate, sheet, and hollow glassware; about 54 million Btu per ton for technical glassware; and about 80 million Btu per ton for hand-made glassware.

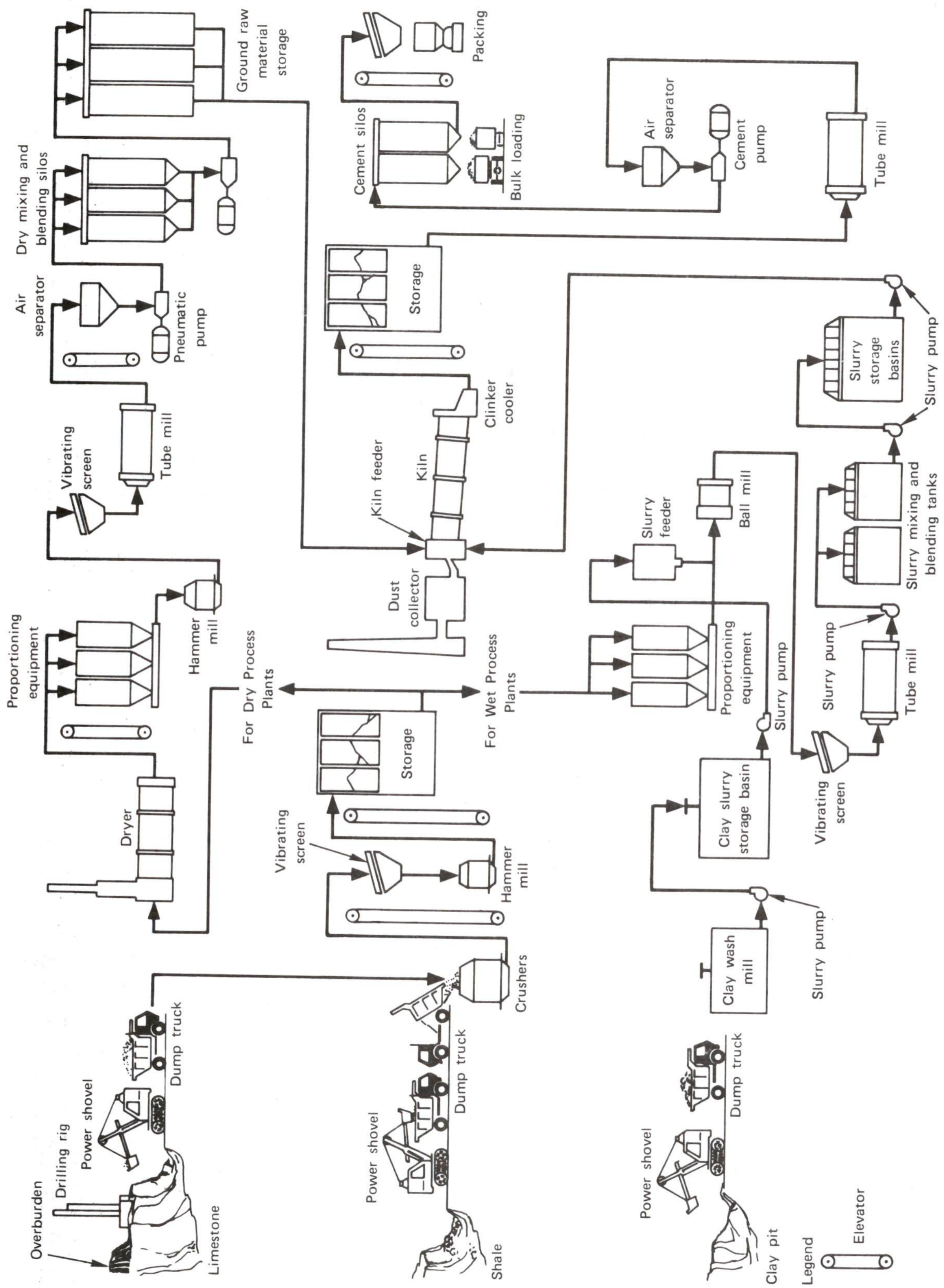


FIGURE 17 SIMPLIFIED FLOW CHART FOR THE MANUFACTURE OF PORTLAND CEMENT

The energy used in melting raw materials accomplishes three general types of reactions:

- Decomposition. The unstable materials decompose to yield metal oxides and bubbles of gases. This occurs through a temperature range of 500°C to 1200°C.

- Solid reactions. The various metal oxides combine at temperatures ranging from about 600°C to 1200°C.

- Liquid formation. The various metal oxides in combination melt to form a liquid glass.

The energy consumed will vary with the raw material used, time required during the melting process, the temperatures required, and the type of kiln or pot that is used.

At the temperatures required for glass manufacture, the refractory material needed to line the furnace becomes reactive with glass materials. To minimize this reaction and the resultant furnace repair and lowered glass product quality, the melting is accomplished by heating only the top or free surface of the glass. While this allows less reaction between the glass and the refractory, it results in large temperature gradients in the mass of glass which tends to product inhomogeneity and it necessarily results in some heat being wasted. Some heat is recovered from the kiln operations by using a dual flue system that alternates between intake air preheating and flue gas cooling.

Clay Products

Manufacture--The basic operations in the manufacture of structural clay products are similar to those of the cement industry. After mining, the raw materials must be crushed, ground, and powdered to the appropriate particle size and blended. However, at this stage the raw materials for clay products are formed to the desired shape and heated to chemically change the materials, resulting in a hardened and durable product. In this process nearly all of the mechanical energy is consumed in electric drives for the grinders, conveyors, and blenders. Similarly, nearly all of the fuel is consumed in direct process heat in the firing of the kiln. There are three types of kilns--the periodic (least efficient), chamber, and tunnel.

Fuel energy required per pound of finished product covers a wide range, depending on the material being fired, its maturing temperature, and the type of kiln used. This is illustrated in Figure 18.

In general, in the manufacturing of bricks the tunnel type and chamber type kilns use about the same amount of fuel for a given temperature, while the periodic type kiln uses about twice that amount of fuel.

Consumption of energy in the kiln operations relates only to process heat and electrical energy for mechanical drives for the required blowers, conveyors, and other material handling equipment. Energy for space heating or air conditioning is negligible in comparison to the other uses.

Food and Kindred Products Industry

Introduction

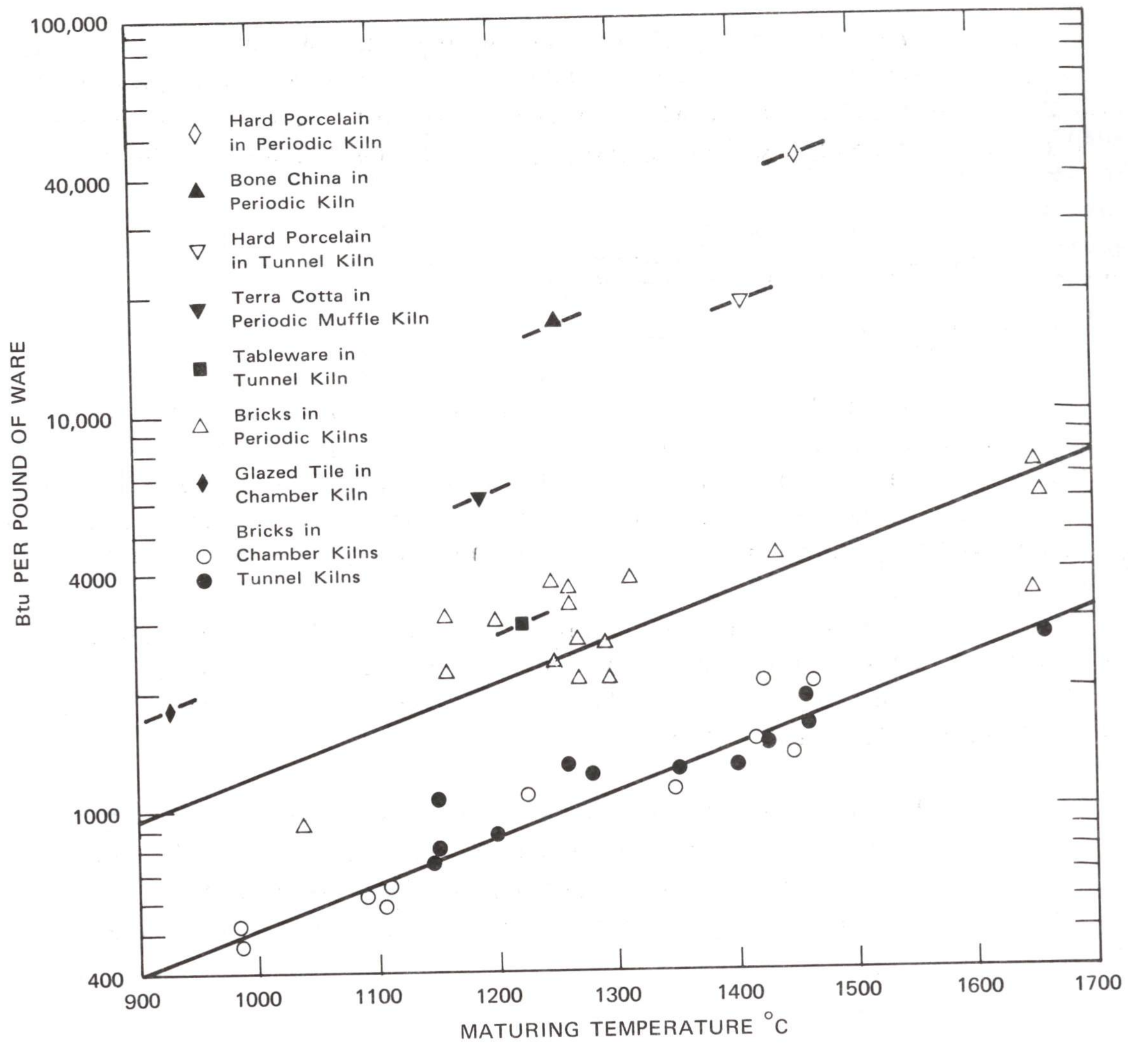
Despite steadily increasing demand for its products--reflecting increases in population and personal income--the food and kindred products industry is declining in terms of its relative share of total energy consumption. Also the proportion of disposable income spent on food and kindred products decreased from 24% in 1958 to about 21% in 1966.

During the 1962-67 period, energy use in the food and kindred product industries decreased by 5% if electricity is converted at 3,413 Btu/kwh; however, when converted at heat input rates as in Table 66, the decline amounted to less than 1%.

During this period, the use of coal decreased 28%, the use of oil decreased 19%, the use of gas increased 9% and the use of electricity increased 29%. In general, this decline may be attributed to a greater efficiency in operation; i.e., closing of inefficient plants and consolidation.

Meat Products

Meat products showed a 3% increase in energy consumption during the 1962-67 period, and concurrently had a 1% decline in total number of employees and a 21% increase in value of shipments. This increase in the value of shipments is based largely on a 12.5% increase in red meat production and a 26% increase in poultry products production. Poultry prices during this period were stabilized by greater efficiency in growing and processing. Red meat wholesale prices showed a slight decline.



SOURCE: "Elements of Ceramics" by F. H. Norton.

FIGURE 18 HEAT UNITS REQUIRED FOR FIRING IN THE CERAMIC INDUSTRY

Table 66

CONSUMPTION OF ENERGY IN THE FOOD AND KINDRED PRODUCT INDUSTRIES
(Trillions of Btu)

Category	Coal		Oil		Gas		Electric		Total		1967/
	1962	1967	1962	1967	1962	1967	1962	1967	1962	1967	1962
Meat	21.1	15.7	11.9	11.9	43.8	48.0	27.8	37.2	104.6	112.8	1.08
Dairy products	33.6	12.2	24.3	13.8	51.1	45.1	28.3	31.8	137.3	102.9	0.75
Canned and frozen foods	16.2	8.4	16.1	9.6	31.2	39.1	14.0	24.5	77.5	81.6	1.05
Grain mills	46.7	45.6	6.6	4.3	27.4	38.6	31.3	38.6	112.0	127.1	1.13
Bakery products	1.3	0.3	11.6	8.7	31.5	27.7	13.7	17.1	58.1	53.8	0.93
Sugar	34.2	26.5	13.9	11.5	50.6	58.4	10.0	11.4	108.7	107.8	0.99
Candy	5.6	1.5	4.0	3.3	4.2	4.8	6.5	9.0	20.3	18.6	0.92
Beverages	33.5	25.7	10.8	13.0	29.2	34.7	17.0	20.4	90.5	93.8	1.04
Miscellaneous	31.6	25.9	13.5	15.0	48.4	49.6	17.8	25.3	111.3	115.8	1.04
	223.8	161.8	112.7	91.1	317.4	346.0	166.4	215.3	820.3	814.2	0.99
1967 to 1962 ratio		.72		.81		1.09		1.29			

Note: Factors used are: 26.2 million Btu per short ton of coal
6.0 million Btu per barrel (42 gallons) of oil
1,035 Btu per cubic foot of gas
9,250 Btu per kwh

The increase in output was associated with a less than proportionate increase in energy consumption and an actual decline in the number of employees required. The industry has made great strides in modernizing its operations with increased production per worker. Generally, larger meat packers have discontinued operating their large old inefficient facilities (stockyards--Chicago and Omaha) in favor of more modern efficient operations.

Dairy Products

The dairy products industry showed a 31% decrease in energy consumption, a 13% decline in total employment, and an 8% increase in value of shipments during the 1962-66 period. The increase in value of shipments may be explained by a general decrease in production with a 13% increase in prices. The large drop in energy consumption can only be explained by use of more efficient processing systems that allow for conservation of energy.

Canned and Frozen Foods

Considering only canned specialties, canned fruits, and canned vegetables, frozen fruits, juices, vegetables, and specialties, there was a 4% drop in energy consumption, a 5% decline in employment, and a 28% increase in the value of shipments during the 1962-66 period. Since the average production in the above classification did not change significantly from 1962 to 1966 and the average price increased approximately 12%, the remaining 16% in increased value of shipments can be attributed to the use of more efficient processes that require less labor and power.

Grain Mills

Grain mills in this report include flour mills, prepared animal feeds, and wet corn milling. During the 1962-66 period, energy consumption increased 11%, total employment decreased 11%, and the value of shipments increased 14%.

Generally, since the increase in the value of shipments exceeded (by 4%) the increase in the cost of foods and there was an actual increase of approximately 15% in production, the actual cost per pound of product decreased. This decrease can be attributed to closing down outmoded processing plants, improvement of existing operating plants, and greater use of wheat and corn for nonhuman food uses. The greater productivity can also be attributed to better and increased use of fuel and electrical energy in place of human energy. Improved varieties of wheat and corn contributed to increased production at lower cost without markedly increasing energy uses.

Bakery Products

The power consumed in the production of bakery products decreased 13% with a concurrent drop of 7% in total employment and an increase of 14% in the value of shipments during the 1962-66 period. The trend in this industry is for lower per capita consumption. The industry has consolidated and improved its manufacturing operations, resulting in increased production per man-hour and lower energy consumption. Bakeries now generally operate at peak capacity.

Sugar

Energy consumption in the sugar industry declined by 2% from 1962 to 1966, while total employment remained the same and the value of shipments increased 16%. There was a decrease in production, but an increase in prices above the inflationary values, which was reflected in the increase in the value of shipments.

Products such as artificial sweeteners and sweeter corn syrups are making inroads into this industry. Generally the sugar plants are old and use inefficient processes.

Candy

The candy industry showed a 20% decline in energy use from 1962 to 1966. The total employment increased 2% with an increase in the value of shipments of 18%. Basically, there was no appreciable increase in production but development of high speed processing and wrapping machines allowed for greater production with decreased energy consumption.

Beverages

The beverage industry (wines, brandies, and flavors excluded) showed increases of 1% in energy consumption, 4% in total employment, and 28% in the value of shipments, reflecting an increase in production. Improved high speed bottling systems, improved fermentation techniques, and better choice of ingredients helped keep energy consumption down.

Miscellaneous

Only part of the miscellaneous food preparations and kindred products group is included in this analysis. The consumption of energy remained the same with a 7% increase in total employment and a 3% increase in value of shipments.

VI THE TRANSPORTATION SECTOR

In 1968, the transportation sector accounted for 15,184 trillion Btu or 25.1% of the U.S. energy consumption. In 1960, the transportation sector accounted for 11,014 trillion Btu or 25.6% of the U.S. total. Summaries of the 1960 and 1968 energy consumption in transportation are given in Figures 19 and 20. In these summaries, electric power consumption is measured in terms of fuel input.

Over the eight-year period, energy consumption in transportation increased by 4.1% annually on the average, a growth rate slightly lower than that of total U.S. energy consumption. Table 67 shows this growth by type of fuel. The relative importance of individual fuels for the transportation sector is tabulated below:

	1960	1968
Coal	1%	Nil%
Natural gas	3	4
Liquefied petroleum gas	1	1
Jet fuels	7	13
Gasoline	71	68
Distillate fuel	8	8
Residual fuel	8	5
Lubes and waxes	1	1
Electricity	Nil	Nil
Total	100%	100%

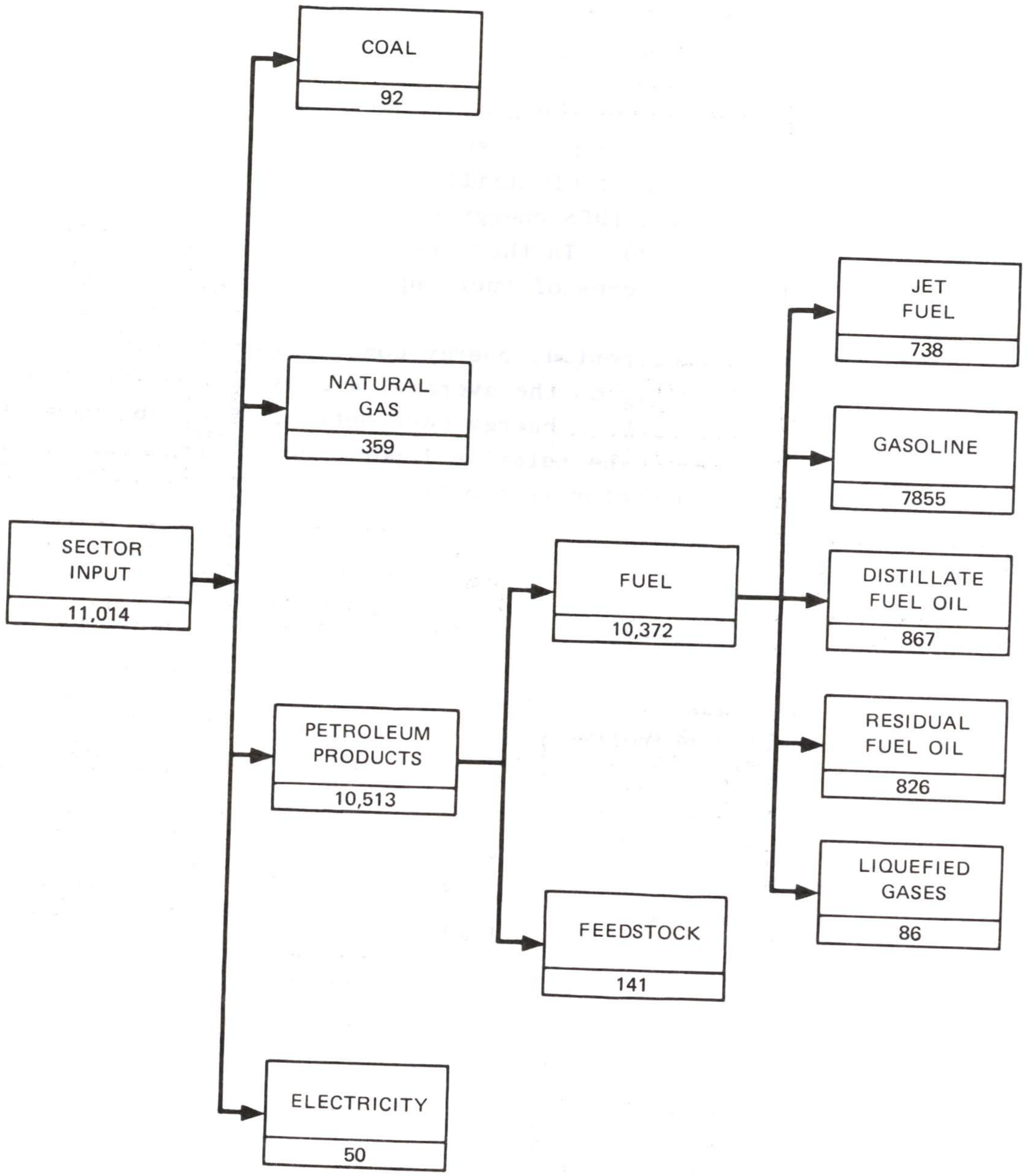


FIGURE 19 1960 TRANSPORTATION CONSUMPTION OF ENERGY (Trillions of Btu)

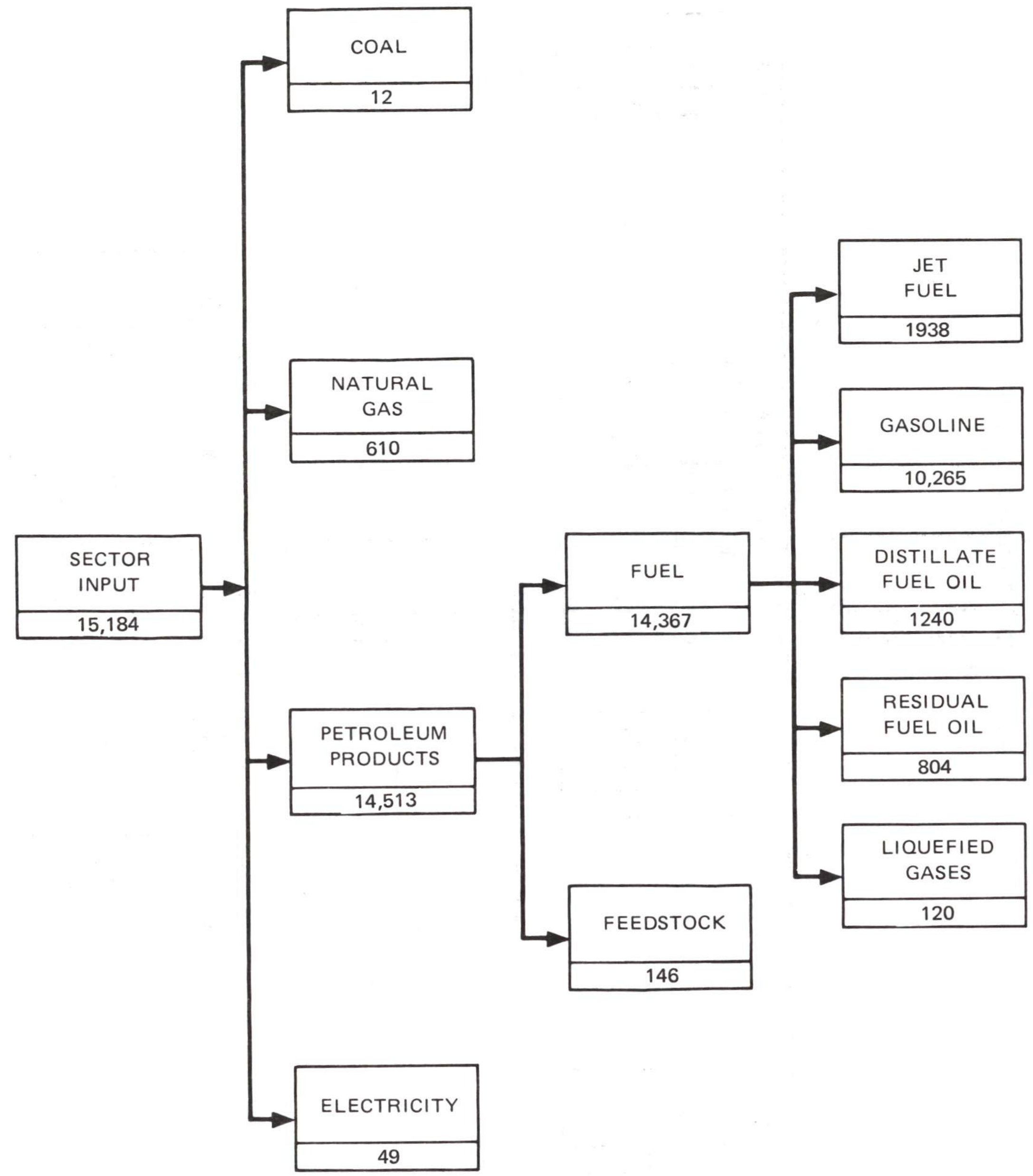


FIGURE 20 1968 TRANSPORTATION CONSUMPTION OF ENERGY (Trillions of Btu)

Table 67

CONSUMPTION BY END USE IN THE TRANSPORTATION SECTOR
(Trillions of Btu and Percent)

	1960			1968			Average Annual Rates of Growth 1960-68		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Coal	92	29	121	12	29	41	-22.0%	--%	-12.7%
Dry natural gas	359	13	372	610	10	620	6.8	-3.2	6.6
Petroleum products	10,513	4	10,517	14,513	5	14,518	4.1	2.8	4.1
Hydro	--	4	4	--	4	4	--	n.a.	n.a.
Nuclear	--	Nil	Nil	--	1	1	--	n.a.	n.a.
All fuels	10,964	50	11,014	15,135	49	15,184	4.1	-0.2	4.1

* n.a. = Not available.

VII EFFICIENCY OF FUEL UTILIZATION

The efficiency with which fuel and energy are utilized is basically unknown for the nation as a whole, or for any single sector except power generation. No data on efficiency are regularly collected by any government agency or other organization, nor does any individual or company maintain such information, so far as can be ascertained.

Defining efficiency is difficult; in fact, a number of definitions could be used. There is always the question of whether the lower heating value or the higher heating value of the fuel should be used as the total energy available, against which actual use is measured. However other questions influence results far more, for example:

- Measuring the efficiency of the fuel--or electricity--using equipment by itself, for example, the boiler efficiency in generating process steam, the furnace efficiency in a residential space heating unit, the efficiency of a water heater in heating water, or the efficiency of an internal combustion engine in an automobile.

- Measuring the efficiency at a later stage, including the total system entailed. In the process steam example, the total system would be the energy finally delivered and used at each consuming point of the steam, divided by the thermal content of the fuel. In residential space heating, the definition could be in terms of the heat actually delivered to rooms, or the definition could even be derived indirectly from the heat loss from the structure. For the automobile, the system definition might be in terms of the energy at the tire-road interface or some adjustment can be made for the heating and air-conditioning benefits.

- Defining the efficiency to include some allowance for quality temperature gradients and air freshness in a space heating system or the quality (or labor input required) for an industrial product.

- Defining the efficiency (for industrial uses) in terms of the energy required per unit of output, measured (if possible) against some theoretical limit.

There may be other possibilities, but the above list is sufficient to indicate the difficulty in dealing with this subject. Moreover, as stated earlier, no data are available on the subject, and for some of the definitions (particularly any definition approaching total system efficiency) the efficiency will vary greatly from one establishment to another.

The most useful measure would probably be some form of total system efficiency, because this measure would provide the best indication of the portion of the total energy provided that is actually utilized. All that is actually known is that total system efficiency is quite low--in the broad range of 15% to 50%. This applies to automobiles, space heating, air conditioning, refrigeration, process steam, generation of electrical energy, and many other applications (for any use of electricity, if the system is defined to include the efficiency of generating the electricity, the total system efficiency is always less than 40%, often much less). It is possible that the only system efficiency that exceeds 50% is in some industrial processes that use direct heat.

The principal factor influencing system efficiency is considered to be the investment in the energy system. For example, space heating efficiency can be improved by insulation, design of the structure, and characteristics of the heat distribution system. The variety of actual installations, the degree to which improvements could be made, the extent to which new installations could incorporate efficiency-maximizing materials and equipment, the economic feasibility of potential changes, and the effect on average system efficiency in each application are even more difficult to estimate than system efficiencies existing at the present time. A major research effort would be required to prepare these estimates.

For the industrial sector, the energy required per unit of industrial output was developed, as well as the change over time. The results are given in Table 68 by SIC classification. For all industry, the value added by manufacture (in constant dollars) increased 38% between 1962 and 1967, while the total energy consumed increased by 24%. The use of energy increased about two-thirds as rapidly as the real increase in value added. However there was a wide spread by sector, with energy use growing more rapidly than value added in some sectors and energy growing hardly at all in one sector.

Caution should be used in extrapolating these results, which are based on only five years of experience. For example, later data, when they become available, are likely to show that the industrial use of energy between 1967 and 1970 (or 1971) has increased at least as rapidly as value added by manufacture (in constant dollars). In addition, there is the usual question regarding the appropriateness of the deflator used to translate current dollars into constant dollars (the value added deflator developed by the Department of Commerce), so that the magnitude of "real" increase in value added should be considered an approximation.

Table 68

COMPARISON OF VALUE ADDED IN MANUFACTURING WITH POWER AND FUEL CONSUMPTION IN THE INDUSTRIAL SECTOR
(Feedstocks not Included)

Standard Industrial Classification	Ratio of Value Added in 1967 to Value Added in 1962*	Ratio of Energy Used in 1967 to Energy Used in 1962	Ratio of Increase in Energy Used to Increase in Value Added	Rate of Growth in Value Added--1962 to 1967 (percent per year)	Rate of Growth of Energy Used--1962 to 1967 (percent per year)	Ratio of Rate of Growth in Energy Used to Rate of Growth in Value Added
20	1.20	1.13	0.942	3.7%	2.5%	0.676
21	1.19	2.00	1.681	3.5	14.9	4.257
22	1.26	1.28	1.016	4.7	5.1	1.085
23	1.32	1.67	1.265	5.7	10.8	1.895
24	1.31	1.58	1.206	5.5	9.6	1.746
25	1.39	1.25	0.899	6.8	4.6	0.677
26	1.30	1.25	0.962	5.4	4.6	0.852
27	1.35	1.40	1.037	6.2	7.0	1.129
28	1.39	1.31	0.942	6.8	5.5	0.809
29	1.50	1.22	0.813	8.5	4.1	0.482
30	1.49	1.29	0.866	8.3	5.2	0.627
31	1.19	1.00	0.840	3.5	0.1	0.029
32	1.21	1.16	0.959	3.9	3.0	0.767
33	1.37	1.20	0.876	6.5	3.7	0.569
34	1.52	1.43	0.941	8.7	7.4	0.851
35	1.63	1.29	0.791	10.3	5.2	0.505
36	1.50	1.41	0.940	8.5	7.1	0.835
37	1.27	1.23	0.969	4.9	4.2	0.857
38	1.37	1.25	0.912	6.5	4.6	0.708
39	1.70	1.29	0.759	11.2	5.2	0.464
Sector total	1.38	1.24	0.899	6.7	4.4	0.657

* Constant dollars.

Sources: 1963 Census of Manufactures.
1967 Census of Manufactures.
Stanford Research Institute.

Another measure similar to the above is the energy required to produce various products--see Table 69. However the drawback with both measures is that they do not actually give a measure of efficiency; they do not relate actual energy consumption to the amount that would be required if there were no losses. Efficiency is actually concerned with that amount in relation to the theoretical requirement, with no losses. There is a variation in the latter, depending on a number of factors including the type of process, the type of fuel, and the moisture content.

Table 69

ENERGY REQUIRED FOR ONE TON OF MATERIAL

Material	Millions of Btu to Produce a Ton of Product
Magnesium	92.6
Aluminum	60.8
Zinc	45.9
Manganese	45.8
Tin	20.0
Steel	26.0
Copper	27.8
Glass	17.5
Ferroalloys	17.3
Lead	11.2
Paper	27.0
Nickel	6.4
Lime	5.6

Sources: A Study of Process Energy Requirements for U.S. Industries--AGA. Stanford Research Institute.

Using the production of cement as an example, for one situation--wet process, rotary kiln, coal as fuel, and 36% moisture content--the energy in the coal is distributed as follows:

28.1%	Form to clinker
1.9	Loss in CO_2 from mill
2.2	Clinker waste heat
35.2	Water evaporation--slurry
4.9	Superheat water vapor
16.1	Radiation loss
11.5	Combustion gas heat loss
99.9%	

Thus, the efficiency is about 28%, but this is measured only against the energy in the coal fed to the kiln. There are other uses of energy in the cement plant to be measured against the output of the cement, thus, total efficiency drops well below 28%. Such a measure, if it could be developed for each use of energy, would be of great interest and could be valuable, but the use of energy per unit of output does not provide a real measure of efficiency.

Thus, the only efficiency data that can be readily estimated relate to the energy conversion only--generally the first step in a total system. The discussion below for each sector covers those data that can be estimated.

Residential and Commercial

Space Heating

Differences in space heating efficiencies (for the furnace units alone) can be attributed to the type of fuel used. These estimates are as follows:

	Residential	Commercial
Coal	55%	70%
Natural gas	75	77
Petroleum products	63	76
Electricity	95	95

The above estimates are intended to reflect average experience rather than maximum achievable. Thus, coal efficiency is much higher in commercial establishments than in residences because better maintenance is possible and greater care is exercised in obtaining as complete combustion as possible.

Natural gas is easy to burn with little maintenance, and sophistication of the equipment adds little to the efficiency; i.e., 77% for the larger installations in commercial establishments compared with 75% for residential.

Petroleum products (distillate fuel oil) have lower efficiency than natural gas in the residential sector. The nozzles tend to clog, and home installations are generally not too well maintained. Oil efficiency in commercial installations approaches that of natural gas.

Electric heating is considered to have a 95% efficiency. This does not take into account the conversion of fuel to electricity, but applies solely to the conversion of electricity to heat.

Water heating

The efficiency in heating water varies as follows.

	Residential	Commercial
Coal	15%	70%
Natural gas	64	64
Petroleum products	50	50
Electricity	92	92

Cooking

Natural gas and LPG both have about a 37% efficiency in cooking, while electricity has 75% efficiency.

Clothes Drying

Natural gas and LPG have a 47% efficiency in drying clothes, while the efficiency of electricity is 57%.

Refrigeration

Electricity is essentially the only source of energy used in refrigeration, and the efficiency is about 50%.

Air Conditioning

Electricity also meets most of the air-conditioning requirements, with an efficiency compared to refrigeration (cooling cycle) and about half the efficiency of electric heating. The cooling (refrigeration) cycle is inherently much less efficient than heating.

Industrial

Process Steam Production and Generation of Electricity

The efficiencies of different fuels are about the same for process steam production and generation of electricity. The basic difference stems from the water produced in the combustion, which absorbs energy in vaporization, but is not condensed to prevent corrosion. The efficiencies are as follows.

	Coal	Gas	Oil
Process steam	70%	64%	68%
Electricity generation (combined with process steam production)	88	88	88

Electric Drives

Efficiency can vary to some extent in electric drives, but 90% is a reasonably average efficiency.

Electrolytic Process

The efficiency of electrolytic processes depends heavily on the material being reduced, but in general the efficiency is much lower than might be expected in an electrical process. Losses are incurred in a number of ways; e.g., in the circuitry, in the electrodes, in the heating of the containers and heat loss from the containers, in the consumption of electrodes, and in chemical reactions to contaminants. Thus, in the conversion of alumina to aluminum (i.e., Al_2O_3 to Al), the theoretical energy required for that conversion is 35% to 40% of the electrical power input and 10% to 15% of the energy in the fuel consumed to generate the electricity.

Appendix A

END-USE CONSUMPTION WITH ELECTRICITY CONVERSION AT 3413 Btu PER kwh

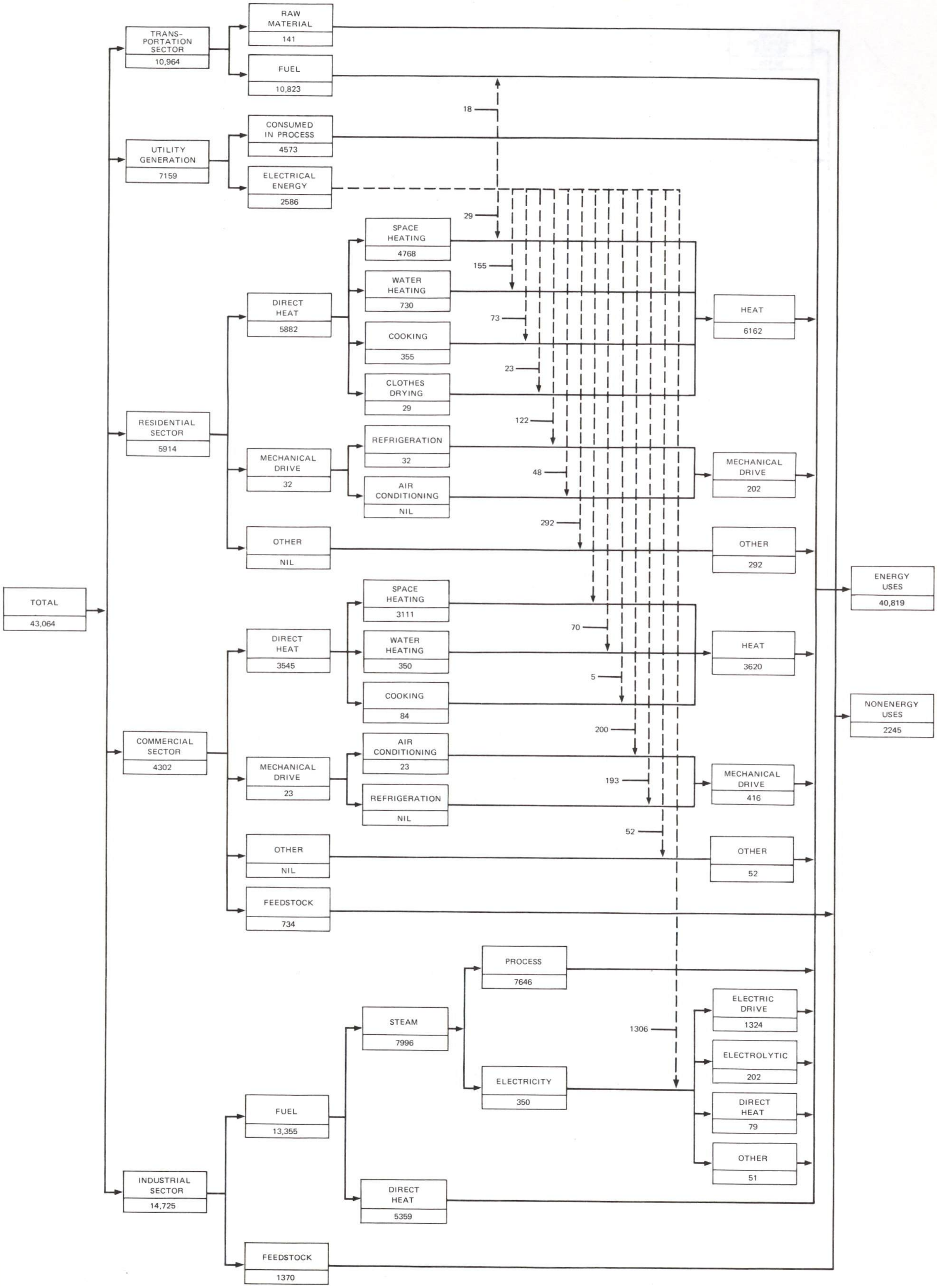


FIGURE 21 1960 ENERGY CONSUMPTION—ALL FUELS (Trillions of Btu)

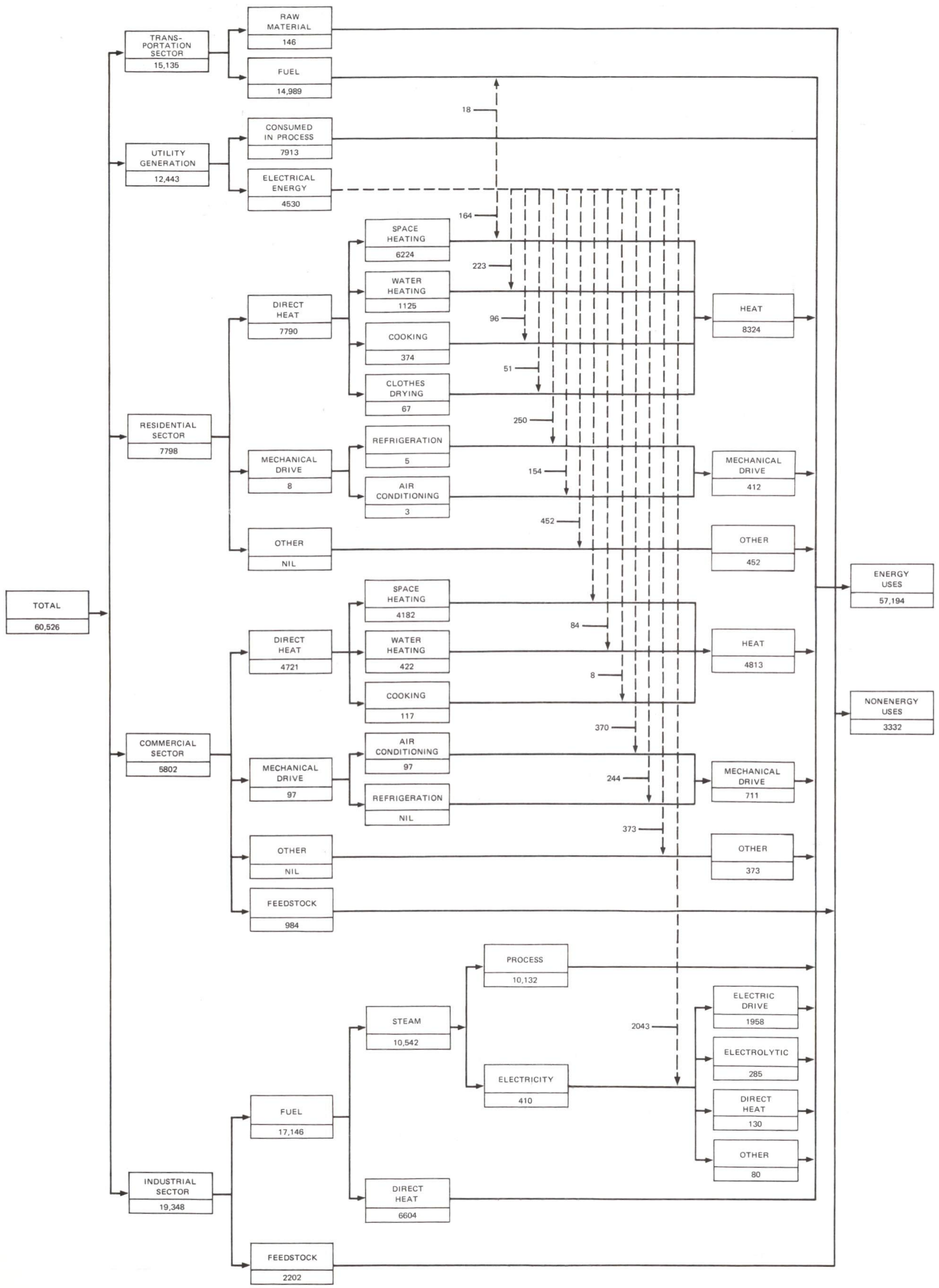


FIGURE 22 1968 ENERGY CONSUMPTION—ALL FUELS (Trillions of Btu)

Table 70

CONSUMPTION OF ALL FUELS
AS A PERCENTAGE OF NATIONAL CONSUMPTION
1960 and 1968

	1960			1968		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential						
Space heating	11.1%	0.1%	11.2%	10.3%	0.3%	10.6%
Water heating	1.7	0.3	2.0	1.9	0.4	2.3
Cooking	0.8	0.2	1.0	0.6	0.1	0.7
Clothes drying	nil	nil	nil	0.1	0.1	0.2
Refrigeration	0.1	0.3	0.4	nil	0.4	0.4
Air conditioning	nil	0.1	0.1	nil	0.3	0.3
Other	nil	0.7	0.7	nil	0.7	0.7
Total	13.7%	1.7%	15.4%	12.9%	2.3%	15.2%
Commercial						
Space heating	7.2	nil	7.2	6.9	nil	6.9
Water heating	0.8	0.2	1.0	0.7	0.1	0.8
Cooking	0.2	nil	0.2	0.2	nil	0.2
Refrigeration	--	0.4	0.4	--	0.4	0.4
Air conditioning	0.1	0.5	0.6	0.2	0.6	0.8
Feedstock	1.7	--	1.7	1.6	--	1.6
Other	nil	0.1	0.1	nil	0.6	0.6
Total	10.0%	1.2%	11.2%	9.6%	1.7%	11.3%
Industrial						
Process steam	17.8	--	17.8	16.8	--	16.8
Electricity generation	0.8	-0.8	--	0.7	-0.7	--
Electric drive	--	3.1	3.1	--	3.2	3.2
Electrolytic process	--	0.4	0.4	--	0.5	0.5
Direct heat	12.4	0.2	12.6	10.9	0.2	11.1
Feedstock	3.2	--	3.2	3.6	--	3.6
Other	--	0.1	0.1	--	0.2	0.2
Total	34.2%	3.0%	37.2%	32.0%	3.4%	35.4%
Electric utility	16.6	-5.9	10.7	20.5	-7.4	13.1
Transportation						
Fuel	25.2	nil	25.2	24.8	nil	24.8
Raw material	0.3	--	0.3	0.2	--	0.2
Total	25.5%	nil%	25.5%	25.0%	nil%	25.0%
Total	100.0%	--	100.0%	100.0%	--	100.0%

Sources: Bureau of Mines. Stanford Research Institute.

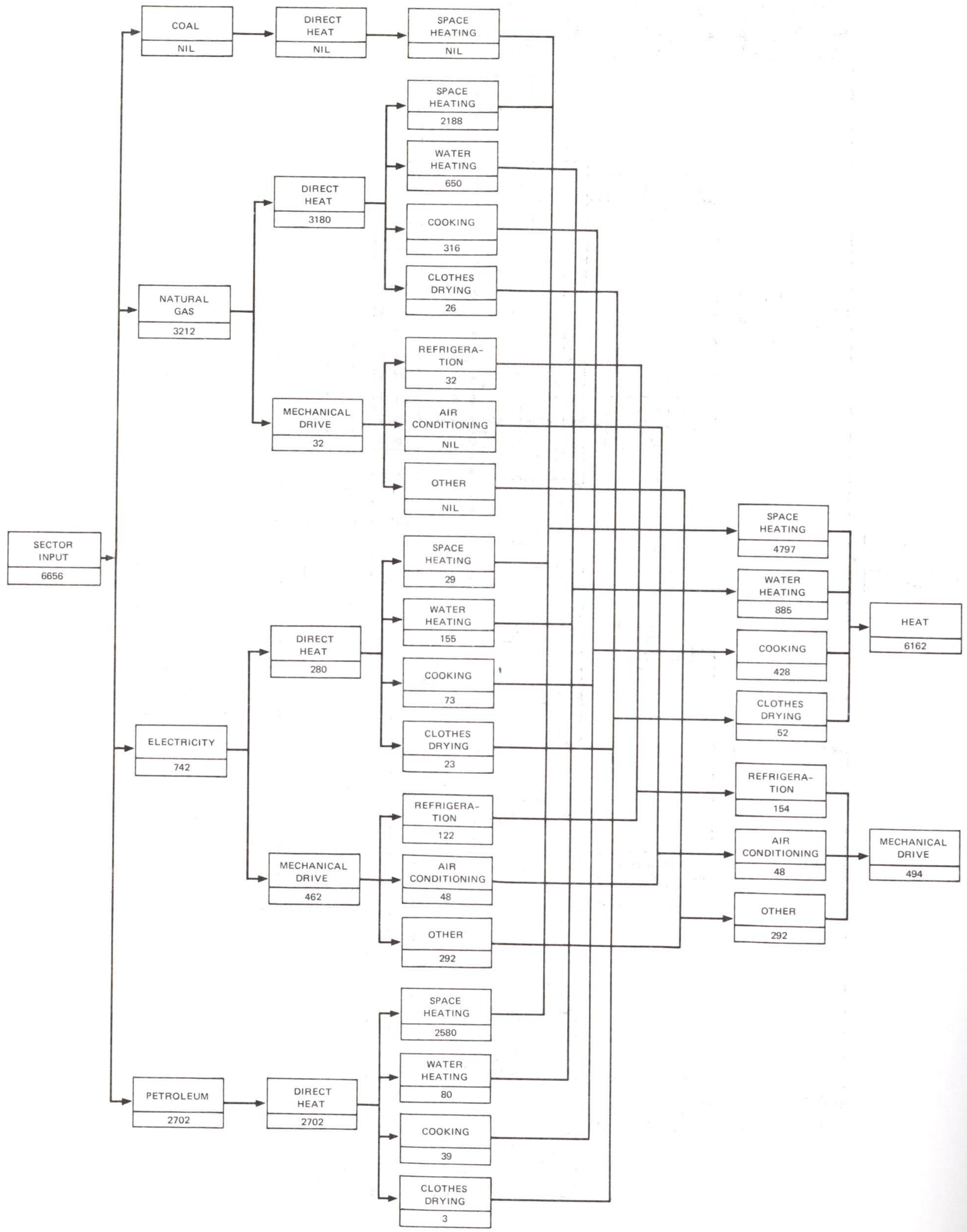


FIGURE 23 1960 RESIDENTIAL CONSUMPTION OF ENERGY (Trillions of Btu)

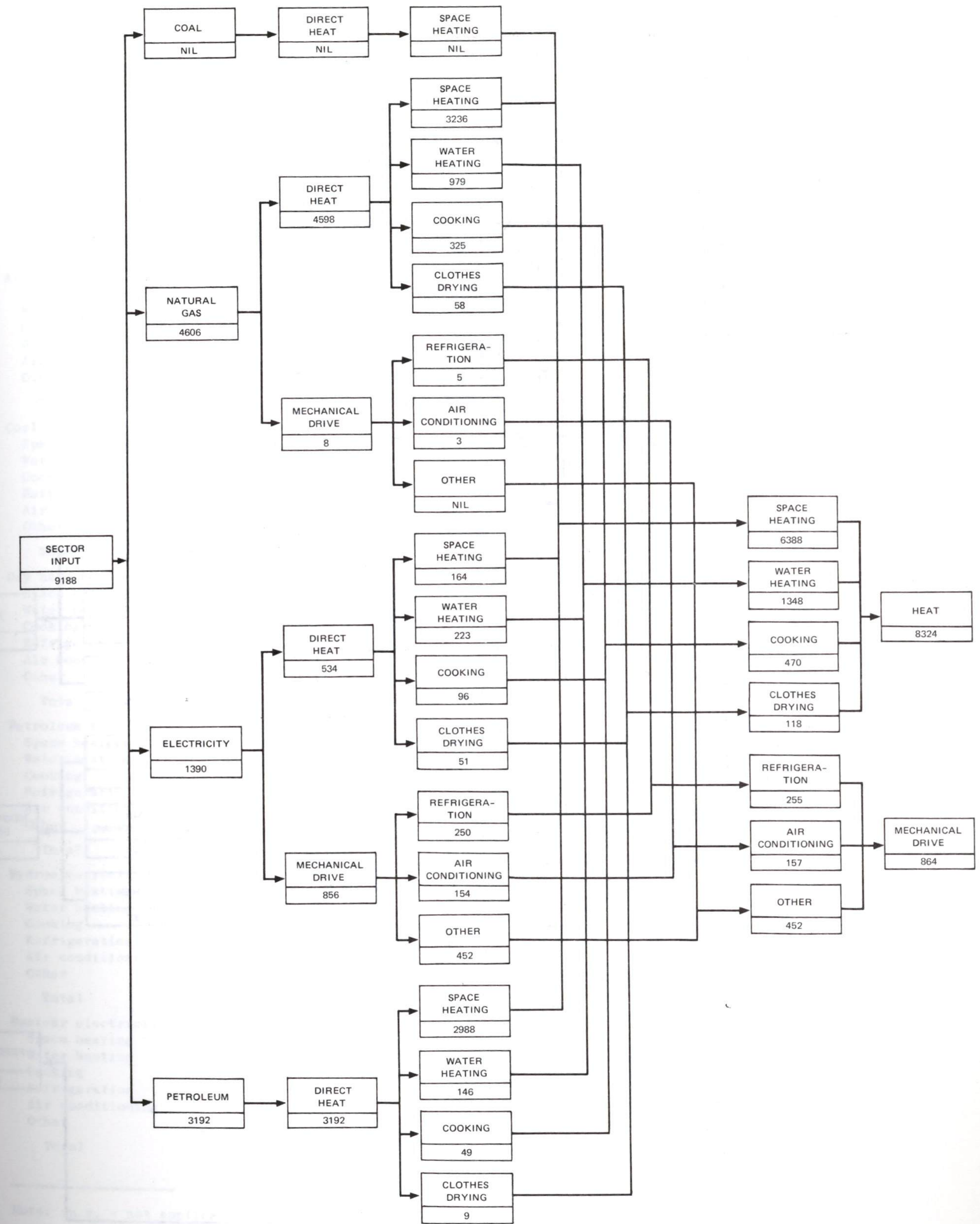


FIGURE 24 1968 RESIDENTIAL CONSUMPTION OF ENERGY (Trillions of Btu)

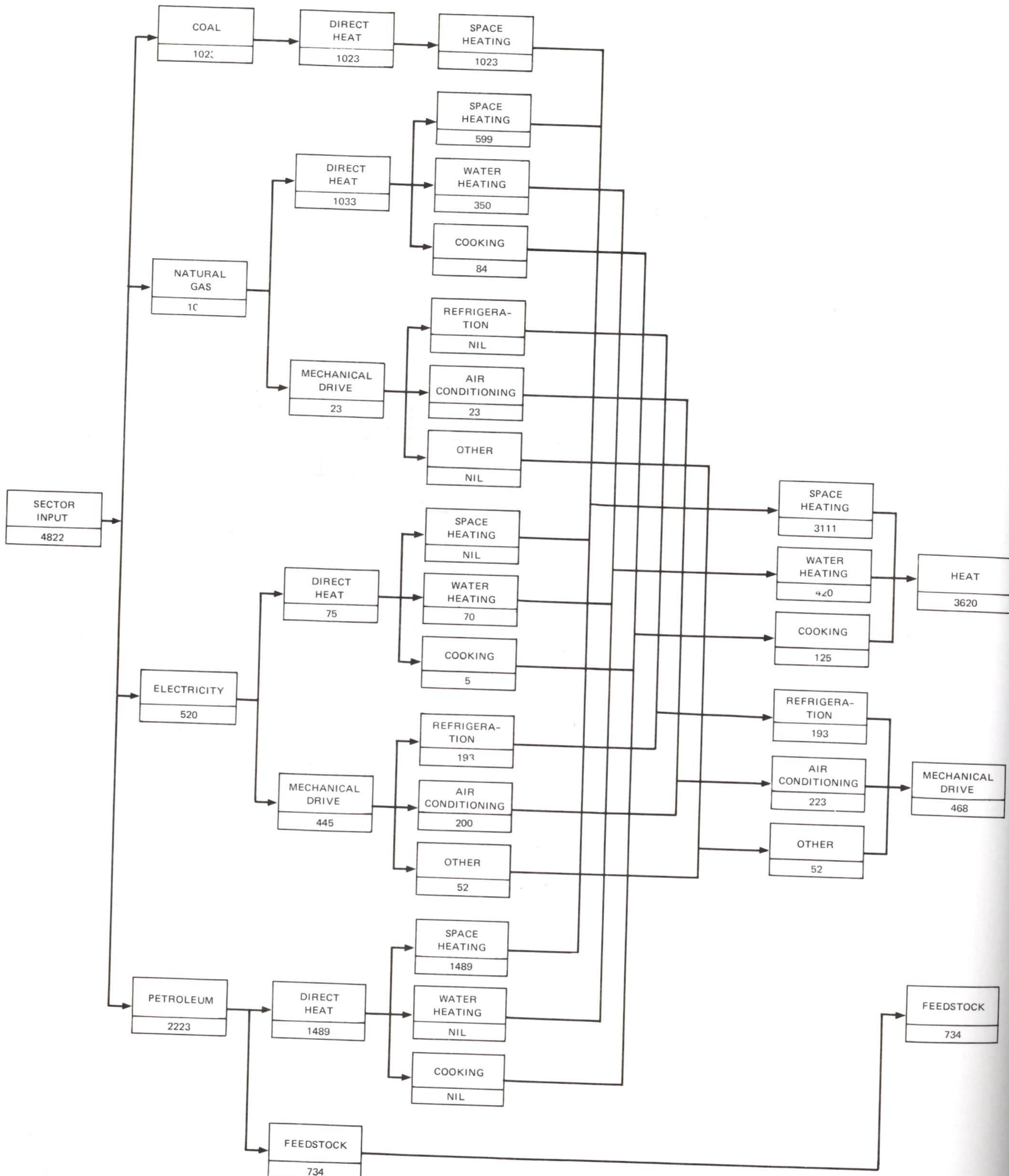


FIGURE 25 1960 COMMERCIAL CONSUMPTION OF ENERGY (Trillions of Btu)

Table 71

RATE OF GROWTH OF FUEL CONSUMPTION BY END USE IN THE COMMERCIAL SECTOR
1960-1968
(Trillions of Btu)

	1960			1968			Average Annual Rate of Growth 1960-68 (percent)		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
All fuels									
Space heating	3,111	--	3,111	4,182	--	4,182	3.8%	--%	3.8%
Water heating	350	70	420	422	84	506	2.4	2.3	2.4
Cooking	84	5	89	117	8	125	4.2	6.0	4.3
Refrigeration	--	193	193	--	244	244	--	3.0	3.0
Air conditioning	23	200	223	97	370	467	19.7	8.0	9.7
Other	734	52	786	984	373	1,357	3.7	27.7	7.0
Total	4,302	520	4,822	5,802	1,079	6,881	3.8	9.5	4.5
Coal									
Space heating	1,023	--	1,023	568	--	568	-7.1	--	-7.1
Water heating	--	35	35	--	43	43	--	2.6	2.6
Cooking	--	3	3	--	4	4	--	3.7	3.7
Refrigeration	--	98	98	--	124	124	--	3.0	3.0
Air conditioning	--	102	102	--	188	188	--	7.9	7.9
Other	--	26	26	--	189	189	--	28.2	28.2
Total	1,023	264	1,287	568	548	1,116	-7.1	9.5	-1.8
Dry natural gas									
Space heating	599	--	599	1,209	--	1,209	9.1	--	9.1
Water heating	350	15	365	422	19	441	2.4	3.0	2.4
Cooking	84	1	85	117	2	119	4.2	9.1	4.3
Refrigeration	--	41	41	--	56	56	--	4.0	4.0
Air conditioning	23	43	66	97	85	182	19.7	8.9	13.5
Other	--	11	11	--	87	87	--	29.4	29.4
Total	1,056	111	1,167	1,845	249	2,094	7.2	10.6	7.6
Petroleum products									
Space heating	1,489	--	1,489	2,405	--	2,405	6.2	--	6.2
Water heating	--	5	5	--	7	7	--	4.3	4.3
Cooking	--	nil	nil	--	1	1	--	n.a.	n.a.
Refrigeration	--	13	13	--	21	21	--	6.2	6.2
Air conditioning	--	13	13	--	31	31	--	11.4	11.4
Other	734	4	738	984	31	1,015	3.7	29.2	4.1
Total	2,223	35	2,258	3,389	91	3,480	5.4	12.6	5.6
Hydroelectricity									
Space heating		--	--		--	--		--	--
Water heating		15	15		14	14		-0.9	-0.9
Cooking		1	1		1	1		n.a.	n.a.
Refrigeration		41	41		41	41		n.a.	n.a.
Air conditioning		42	42		62	62		5.0	5.0
Other		11	11		62	62		24.3	24.3
Total	--	110	110	--	180	180		6.3	6.3
Nuclear electricity									
Space heating		--	--		--	--		--	--
Water heating		nil	nil		1	1		n.a.	n.a.
Cooking		nil	nil		nil	nil		n.a.	n.a.
Refrigeration		nil	nil		2	2		n.a.	n.a.
Air conditioning		nil	nil		4	4		n.a.	n.a.
Other		nil	nil		4	4		n.a.	n.a.
Total	--	nil	nil	--	11	11		n.a.	n.a.

Note: n.a. = not applicable.

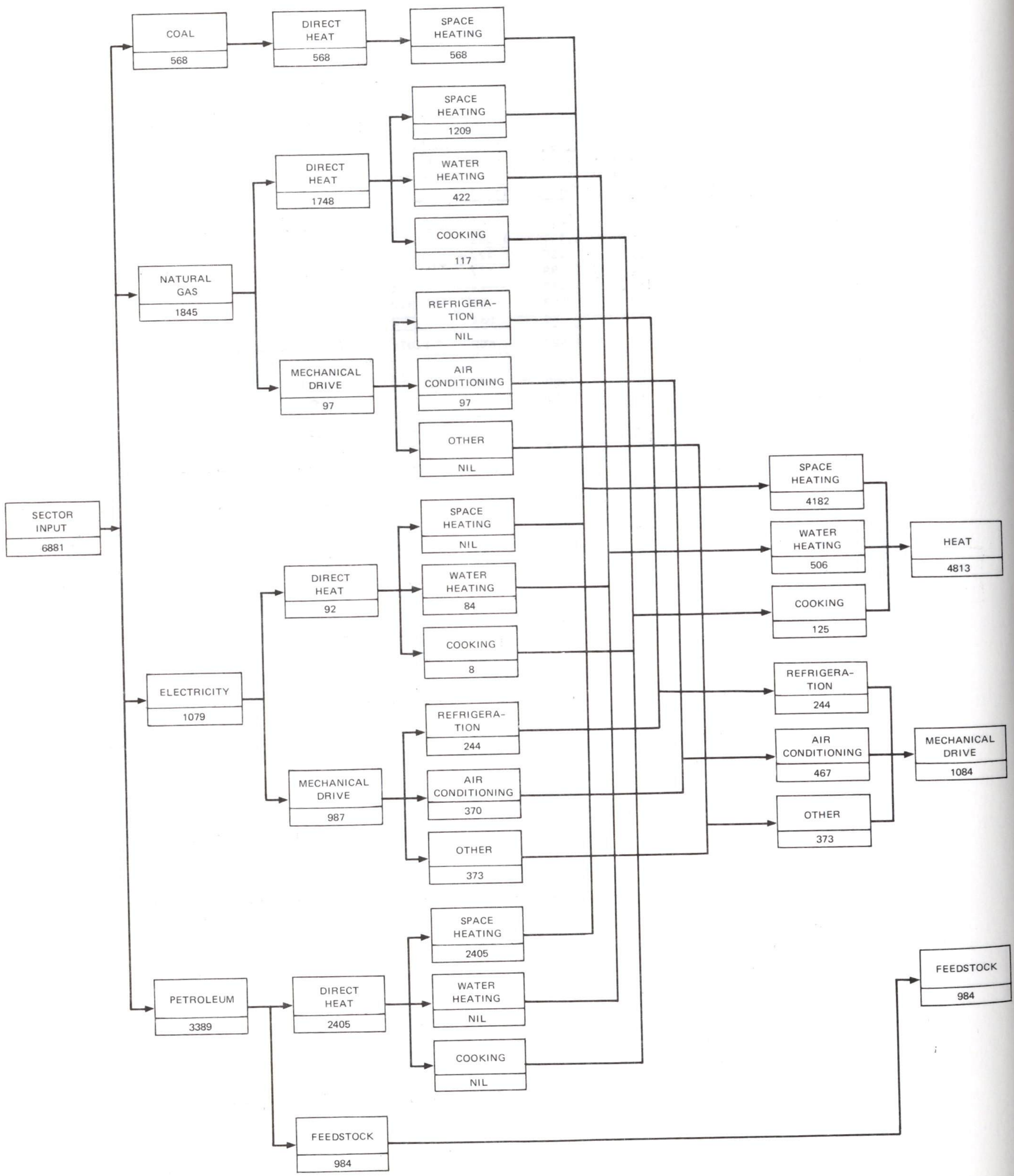


FIGURE 26 1968 COMMERCIAL CONSUMPTION OF ENERGY (Trillions of Btu)

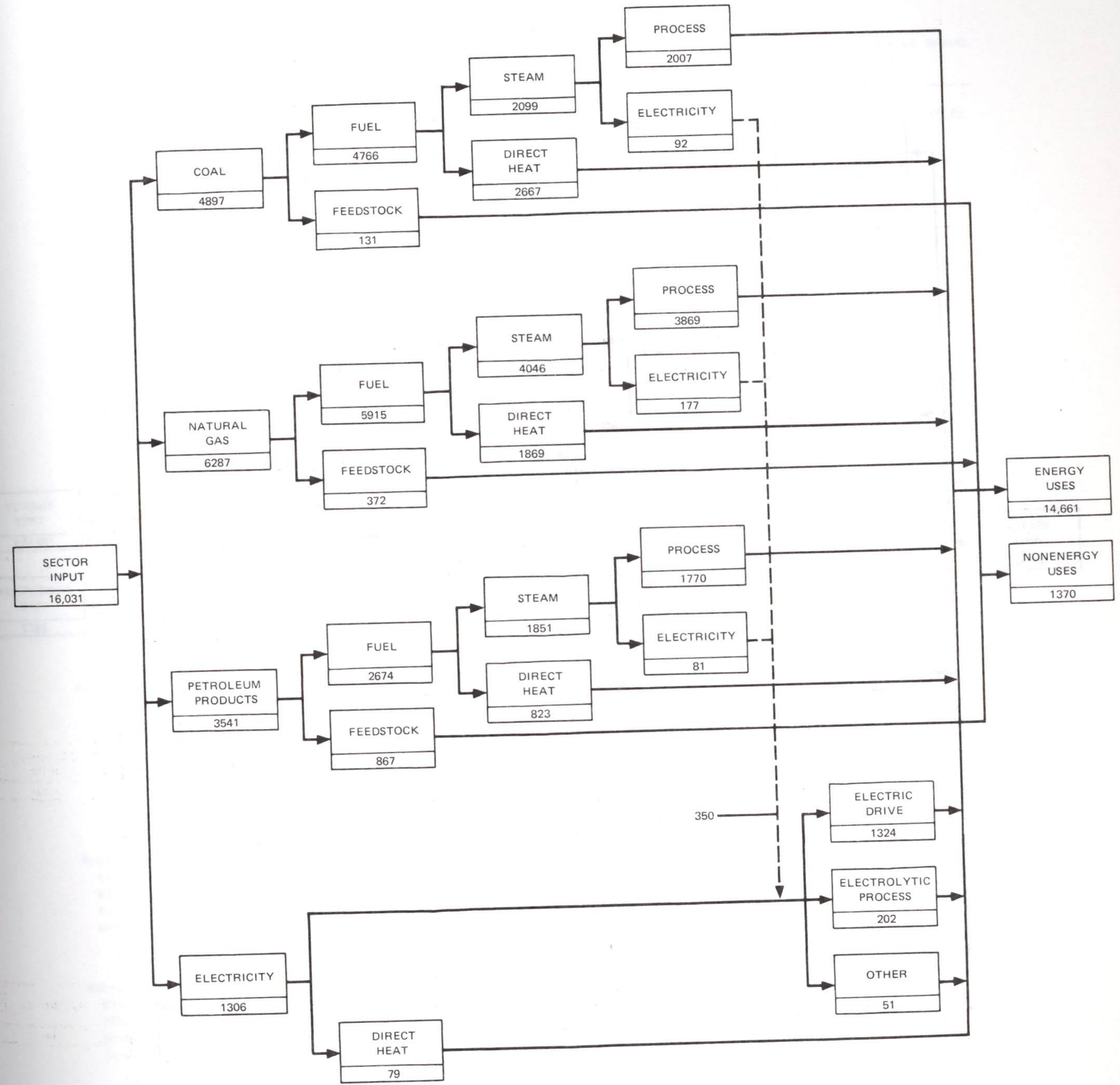


FIGURE 27 1960 INDUSTRIAL CONSUMPTION OF ENERGY (Trillions of Btu)

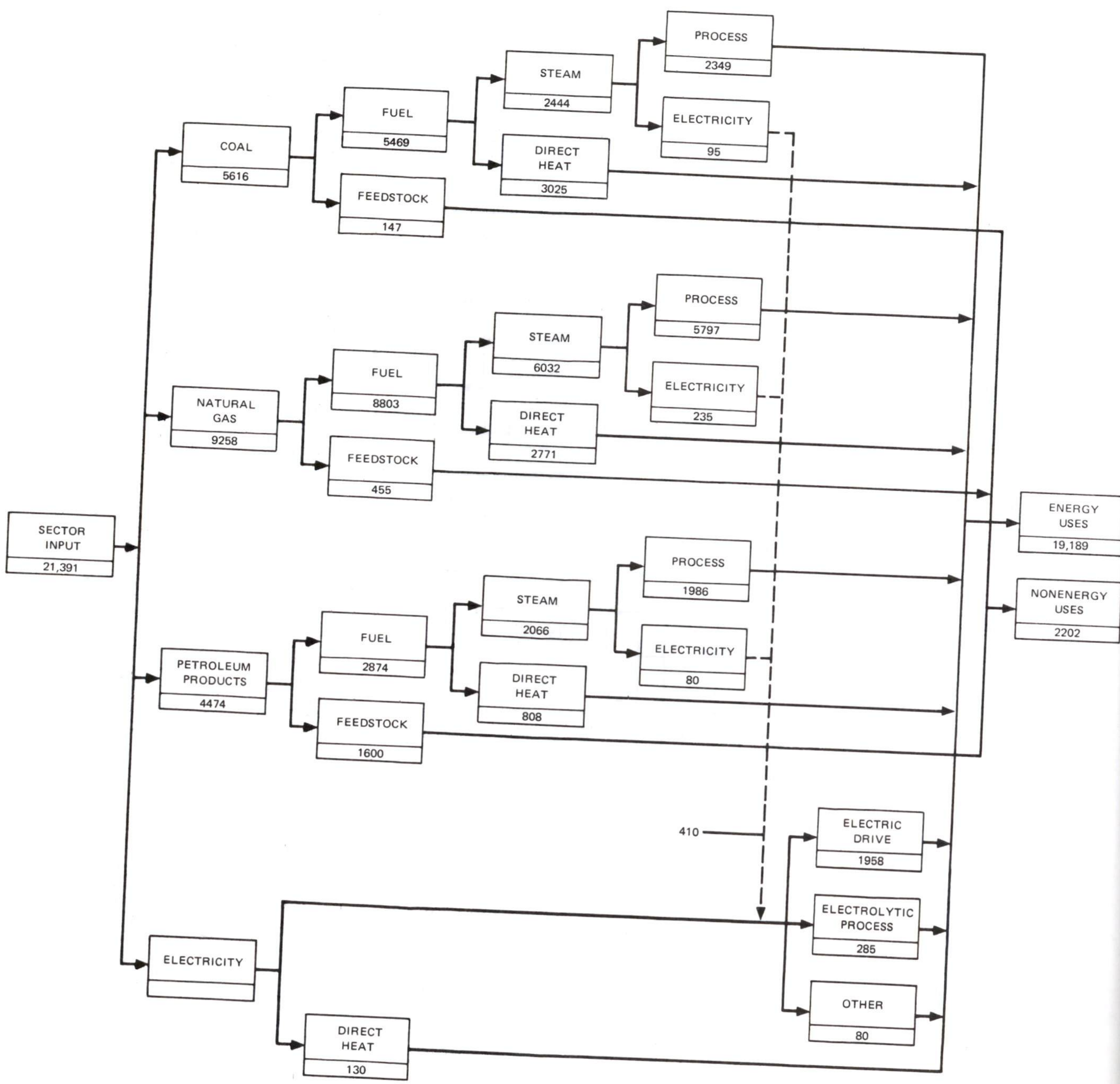


FIGURE 28 1968 INDUSTRIAL CONSUMPTION OF ENERGY (Trillions of Btu)

Table 72

RATE OF GROWTH OF FUEL CONSUMPTION BY END USE
IN THE INDUSTRIAL SECTOR
1960-1968
(Trillions of Btu)

	1960			1968			Average Annual Rate of Growth 1960-1968 (percent)		
	Direct	Electrical Energy	Total	Direct	Electrical Energy	Total	Direct	Electrical Energy	Total
All fuels									
Process steam	7,646	--	7,646	10,132	--	10,132	3.6%	--%	3.6%
Electricity generation	350	-350	--	410	-410	--	2.0	-2.0	n.a.
Electric drive	--	1,324	1,324	--	1,958	1,958	--	5.0	5.0
Electrolytic process	--	202	202	--	285	285	--	4.4	4.4
Direct heat	5,359	79	5,438	6,604	130	5,734	2.7	6.4	2.7
Feed stock	1,370	--	1,370	2,202	--	2,202	6.1	--	6.1
Other	--	51	51	--	80	80	--	5.8	5.8
Total all fuels	14,725	1,306	16,031	19,348	2,043	21,391	3.5	5.8	3.7
Coal									
Process steam	2,007	--	2,007	2,349	--	2,349	2.0	--	2.0
Electricity generation	92	-92	--	95	-95	--	nil	nil	n.a.
Electric drive	--	604	604	--	902	902	--	5.1	5.1
Electrolytic process	--	92	92	--	132	132	--	4.6	4.6
Direct heat	2,667	36	2,703	3,025	61	3,086	1.6	6.8	1.7
Feed stock	131	--	131	147	--	147	1.5	--	1.5
Other	--	23	23	--	37	37	--	6.1	6.1
Total coal	4,897	663	5,560	5,616	1,037	6,653	1.7	5.8	2.2
Dry natural gas									
Process steam	3,869	--	3,869	5,797	--	5,797	5.2	--	5.2
Electricity generation	177	-177	--	235	-235	--	3.6	-3.6	--
Electric drive	--	364	364	--	565	565	--	5.7	5.7
Electrolytic process	--	55	55	--	82	82	--	5.2	5.2
Direct heat	1,869	22	1,891	2,771	37	2,808	5.1	6.7	5.1
Feed stock	372	--	372	455	--	455	2.6	--	2.6
Other	--	14	14	--	23	23	--	6.4	6.4
Total natural gas	6,287	278	6,565	9,258	472	9,730	5.0	6.8	5.1
Petroleum products									
Process steam	1,770	--	1,770	1,986	--	1,986	1.5	--	1.5
Electricity generation	81	-81	--	80	-80	--	-0.2	0.2	n.a.
Electric drive	--	135	135	--	202	202	--	5.2	5.2
Electrolytic process	--	21	21	--	29	29	--	4.1	4.1
Direct heat	823	8	831	808	13	821	-0.2	6.2	-0.2
Feed stock	867	--	867	1,600	--	1,600	8.0	--	8.0
Other	--	5	5	--	8	8	--	6.1	6.1
Total petroleum products	3,541	88	3,629	4,474	172	4,646	3.0	8.7	3.2
Hydroelectricity									
Electric drive	--	221	221	--	273	273	--	2.7	2.7
Electrolytic process	--	34	34	--	40	40	--	2.0	2.0
Direct heat	--	13	13	--	18	18	--	4.1	4.1
Other	--	9	9	--	11	11	--	2.6	2.6
Total hydroelectricity	--	277	277	--	342	342	--	2.7	2.7
Nuclear electricity									
Electric drive	--	nil	nil	--	16	16	--	n.a.	n.a.
Electrolytic process	--	nil	nil	--	2	2	--	n.a.	n.a.
Direct heat	--	nil	nil	--	1	1	--	n.a.	n.a.
Other	--	nil	nil	--	1	1	--	n.a.	n.a.
Total nuclear electricity	--	nil	nil	--	20	20	--	n.a.	n.a.

Note: n.a. = not applicable.

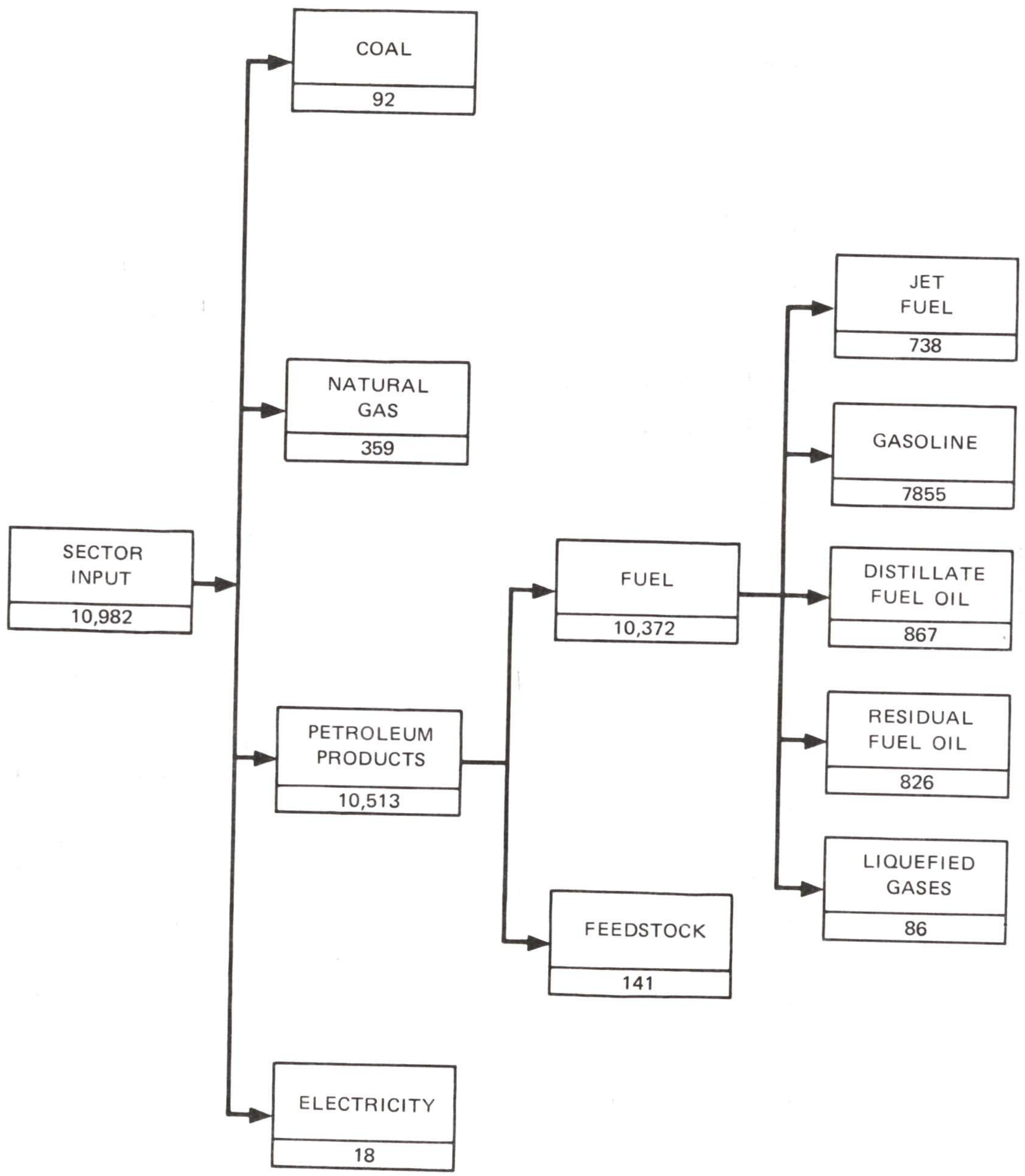


FIGURE 29 1960 TRANSPORTATION CONSUMPTION OF ENERGY (Trillions of Btu)

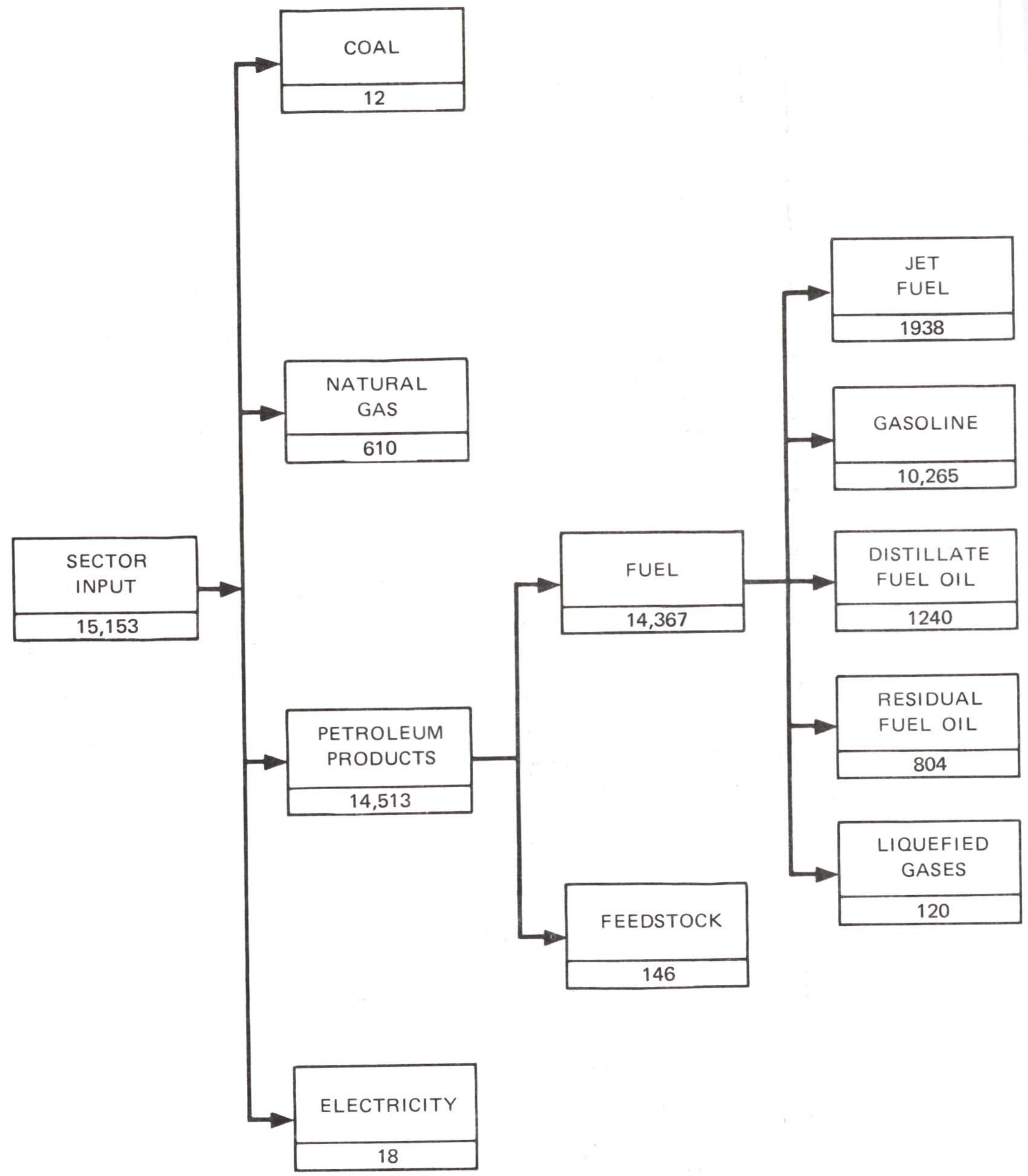


FIGURE 30 1968 TRANSPORTATION CONSUMPTION OF ENERGY (Trillions of Btu)

Table 73

RATES OF GROWTH OF FUEL CONSUMPTION BY END USE IN THE TRANSPORTATION SECTOR

(Trillions of Btu and Percent)

	1960			1968			Average Annual Growth Rate 1960-68 (percent)		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Coal	92	9	101	12	9	21	-22.0%	--%	-17.9%
Dry natural gas	359	4	363	610	4	614	6.8	--	6.8
Petroleum products	10,372	1	10,373	14,514	2	14,516	4.2	9.1	4.3
Hydro	--	4	4	--	3	3	na	-3.6	-3.6
Nuclear	--	nil	nil	--	nil	nil	na	na	na
All fuels	10,823	18	10,841	15,136	18	15,154	4.3	--	4.3

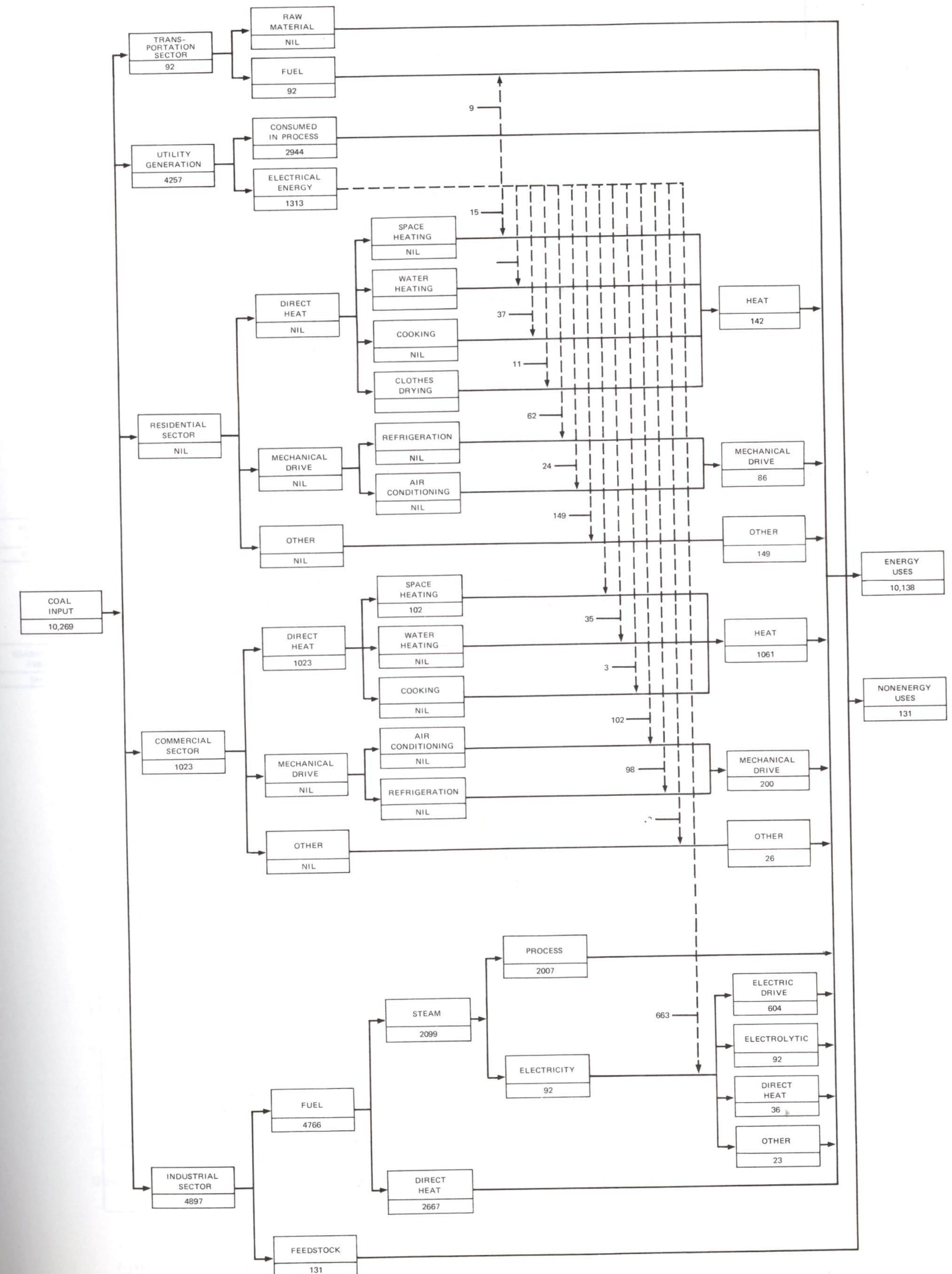


FIGURE 31 1960 CONSUMPTION OF ALL TYPES OF COAL (Trillions of Btu)

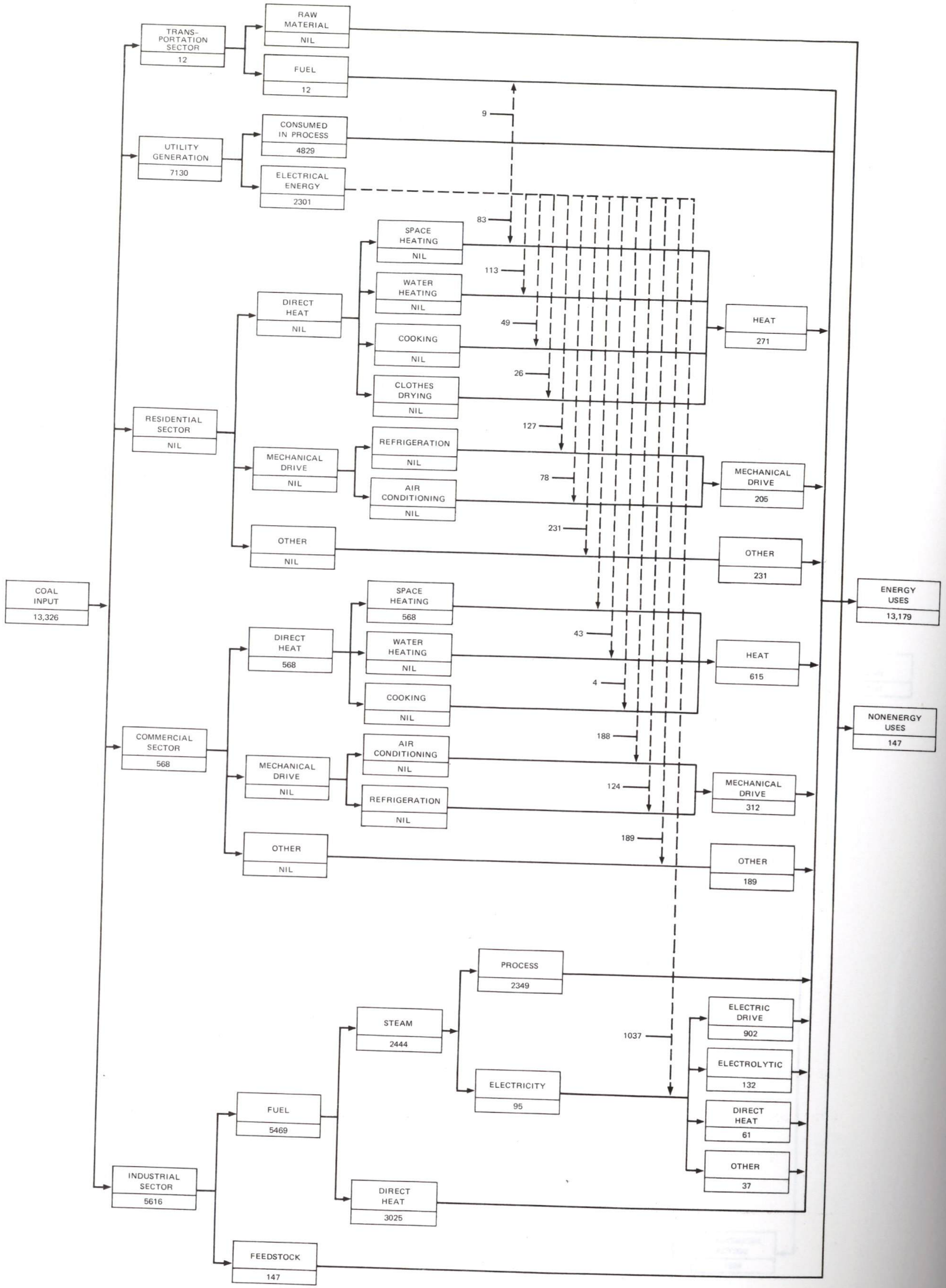


FIGURE 32 1968 CONSUMPTION OF ALL TYPES OF COAL (Trillions of Btu)

Table 74

CONSUMPTION OF ALL TYPES OF COAL
AS A PERCENTAGE OF NATIONAL CONSUMPTION
1960 and 1968

	1960			1968		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential						
Space heating	nil%	nil%	nil%	nil%	0.1%	0.1%
Water heating	nil	0.2	0.2	nil	0.2	0.2
Cooking	nil	0.1	0.1	nil	0.1	0.1
Clothes drying	nil	nil	nil	nil	nil	nil
Refrigeration	nil	0.1	0.1	nil	0.2	0.2
Air conditioning	nil	0.1	0.1	nil	0.2	0.2
Other	nil	0.4	0.4	nil	0.4	0.4
Total	nil	0.9%	0.9%	nil	1.2%	1.2%
Commercial						
Space heating	2.4	nil	2.4	0.9	nil	0.9
Water heating	nil	0.1	0.1	nil	0.1	0.1
Cooking	nil	nil	nil	nil	nil	nil
Air conditioning	nil	0.2	0.2	nil	0.3	0.3
Refrigeration	nil	0.2	0.2	nil	0.2	0.2
Other	nil	0.1	0.1	nil	0.3	0.3
Total	2.4%	0.6%	3.0%	0.9%	0.9%	1.8%
Industrial						
Process steam	4.8	--	4.8	3.9	--	3.9
Electricity generation	0.2	-0.2	--	0.2	-0.2	--
Electric drive	--	1.4	1.4	--	1.5	1.5
Electrolytic process	--	0.2	0.2	--	0.2	0.2
Direct heat	6.1	0.1	6.2	5.0	0.1	5.1
Feedstock	0.2	--	0.2	0.2	--	0.2
Other	--	nil	nil	--	0.1	0.1
Total	11.3%	1.5%	12.8%	9.3%	1.7%	11.0%
Electric utility	9.9	(3.0)	6.9	11.8	(3.8)	8.0
Transportation	0.2	nil	0.2	nil	nil	nil
Total	23.8%	--	23.8%	22.0%	--	22.0%

Sources: Bureau of Mines. Stanford Research Institute.

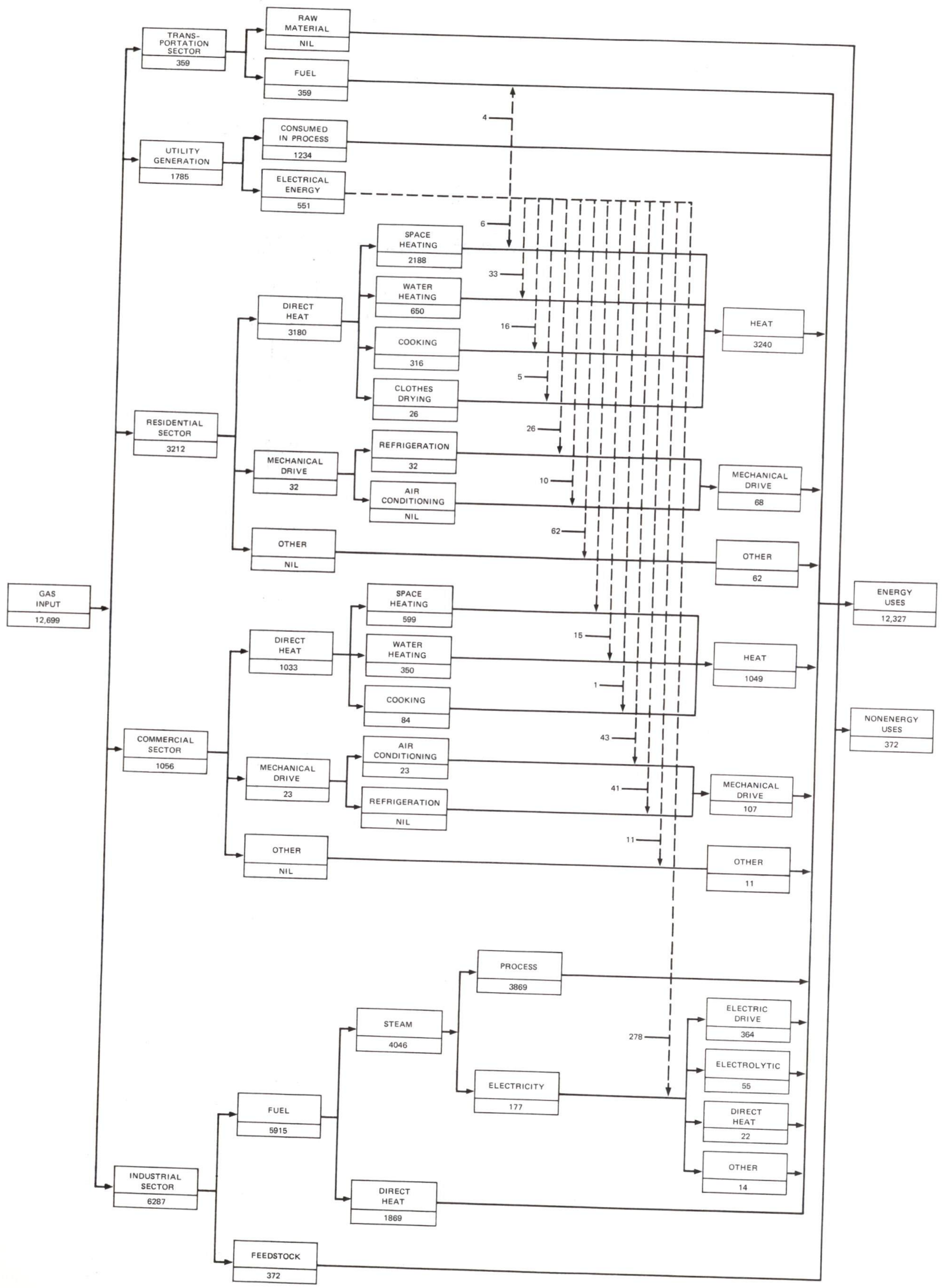


FIGURE 33 1960 CONSUMPTION OF DRY NATURAL GAS (Trillions of Btu)

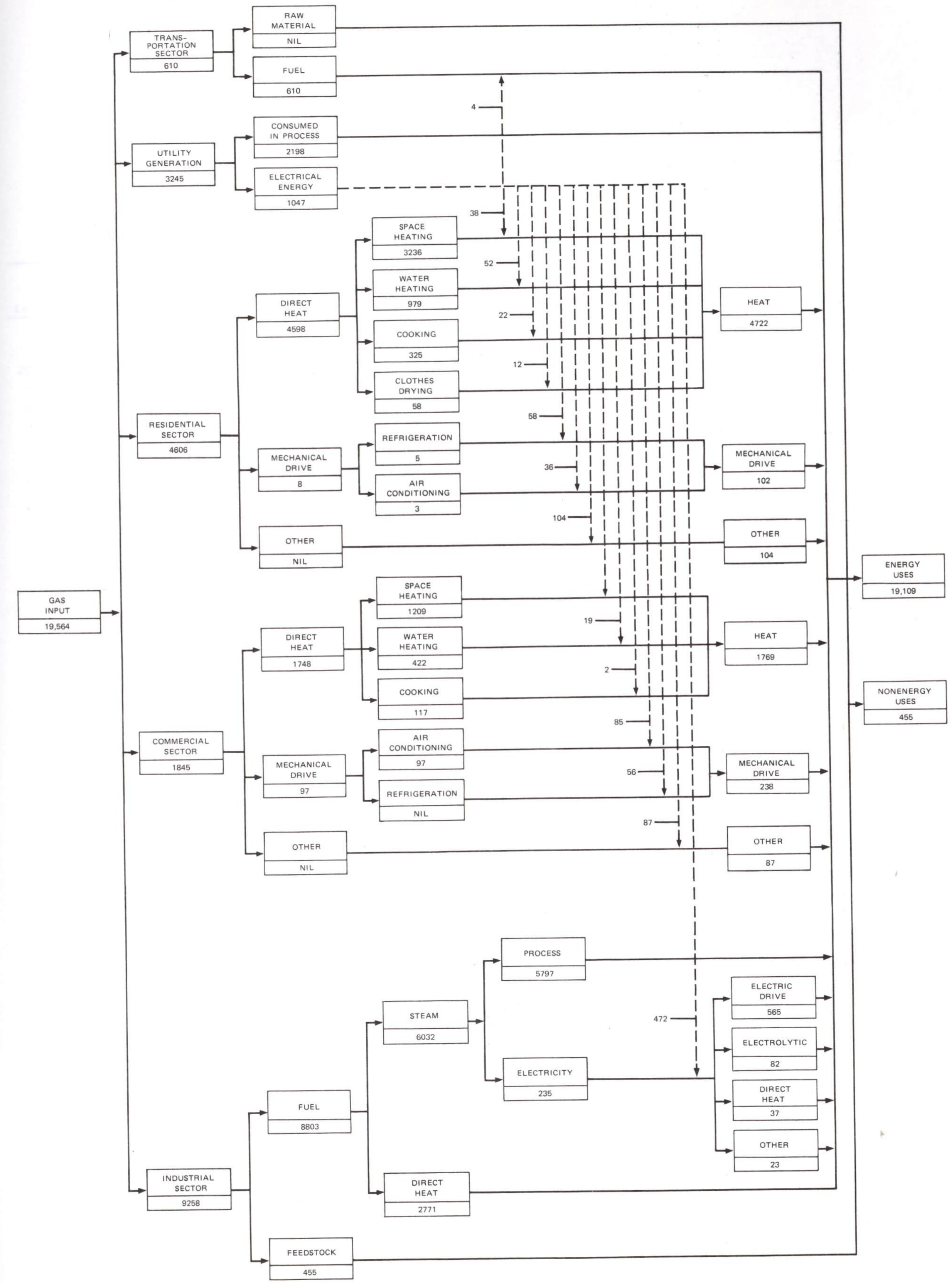


FIGURE 34 1968 CONSUMPTION OF DRY NATURAL GAS (Trillions of Btu)

Table 75

GROWTH IN CONSUMPTION OF DRY NATURAL GAS
1960 and 1968
(Trillions of Btu)

	1960			1968			Average Annual Rate of Growth 1960-68 (percent)		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential									
Space heating	2,188	6	2,194	3,236	38	3,274	5.0%	26.0%	5.2%
Water heating	650	33	683	979	52	1,031	5.2	5.8	5.3
Cooking	316	16	332	325	22	347	0.3	4.1	0.6
Clothes drying	26	5	31	58	12	70	10.5	11.5	10.6
Refrigeration	32	26	58	5	58	63	-21.2	10.5	1.0
Air conditioning	nil	10	10	3	36	39	n.a.	17.3	18.5
Other	nil	62	62	nil	104	104	n.a.	6.6	6.6
Total	3,212	158	3,370	4,606	322	4,928	4.6	9.3	4.9
Commercial									
Space heating	599	nil	599	1,209	nil	1,209	9.1	n.a.	9.1
Water heating	350	15	365	422	19	441	2.4	3.0	2.4
Cooking	84	1	85	117	2	119	4.2	9.1	4.3
Air conditioning	23	43	66	97	85	182	19.7	8.9	13.5
Refrigeration	nil	41	41	nil	56	56	n.a.	4.0	4.0
Other	nil	11	11	nil	87	87	n.a.	29.4	29.4
Total	1,056	111	1,167	1,845	249	2,094	7.2	10.6	7.6
Industrial									
Process steam	3,869	--	3,869	5,797	--	5,797	5.2	n.a.	5.2
Electricity generation	177	-177	--	235	-235	--	3.6	-3.6	n.a.
Electric drive	--	364	364	--	565	565	n.a.	5.7	5.7
Electrolytic process	--	55	55	--	82	82	n.a.	5.2	5.2
Direct heat	1,869	22	1,891	2,771	37	2,808	5.1	6.7	5.1
Feedstock	372	--	372	455	--	455	2.6	n.a.	2.6
Other	--	14	14	--	23	23	nil	6.4	6.4
Total	6,287	278	6,565	9,258	472	9,730	5.0	6.8	5.1
Electric utility	1,785	(551)	1,234	3,245	(1,047)	2,198	7.7	8.4	7.5
Transportation	359	4	363	610	4	614	6.8	--	6.8
Total	12,699	--	12,699	19,564	--	19,564	5.6	--	5.6

Note: n.a. = not applicable.

Sources: Bureau of Mines. Stanford Research Institute.

Table 76

CONSUMPTION OF DRY NATURAL GAS
AS A PERCENTAGE OF NATIONAL CONSUMPTION
1960 and 1968

	1960			1968		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential						
Space heating	5.1%	nil%	5.1%	5.4%	0.1%	5.5%
Water heating	1.5	0.1	1.6	1.6	0.1	1.7
Cooking	0.7	nil	0.7	0.5	nil	0.5
Clothes drying	0.1	nil	0.1	0.1	nil	0.1
Refrigeration	0.1	0.1	0.2	nil	0.1	0.1
Air conditioning	nil	nil	nil	nil	nil	nil
Other	nil	0.2	0.2	nil	0.2	0.2
Total	7.5%	0.4%	7.9%	7.6%	0.5%	8.1%
Commercial						
Space heating	1.4	nil	1.4	2.0	nil	2.0
Water heating	0.8	nil	0.8	0.7	nil	0.7
Cooking	0.2	nil	0.2	0.2	nil	0.2
Air conditioning	0.1	0.1	0.2	0.2	0.1	0.3
Refrigeration	nil	0.1	0.1	nil	0.1	0.1
Other	nil	nil	nil	nil	0.2	0.2
Total	2.5%	0.2%	2.7%	3.1%	0.4%	3.5%
Industrial						
Process steam	9.0	--	9.0	9.6	--	9.6
Electricity generation	0.4	-0.4	--	0.4	-0.4	--
Electric drive	--	0.9	0.9	--	1.0	1.0
Electrolytic process	--	0.1	0.1	--	0.1	0.1
Direct heat	4.3	0.1	4.4	4.6	0.1	4.7
Feedstock	0.9	--	0.9	0.7	--	0.7
Other	--	nil	nil	--	nil	nil
Total	14.6%	0.7%	15.3%	15.3%	0.8%	16.1%
Electric utility	4.1	(1.3)	2.8	5.3	(1.7)	3.6
Transportation	0.8	nil	0.8	1.0	nil	1.0
Total	29.5%	--	29.5%	32.3%	--	32.3%

Sources: Bureau of Mines. Stanford Research Institute.

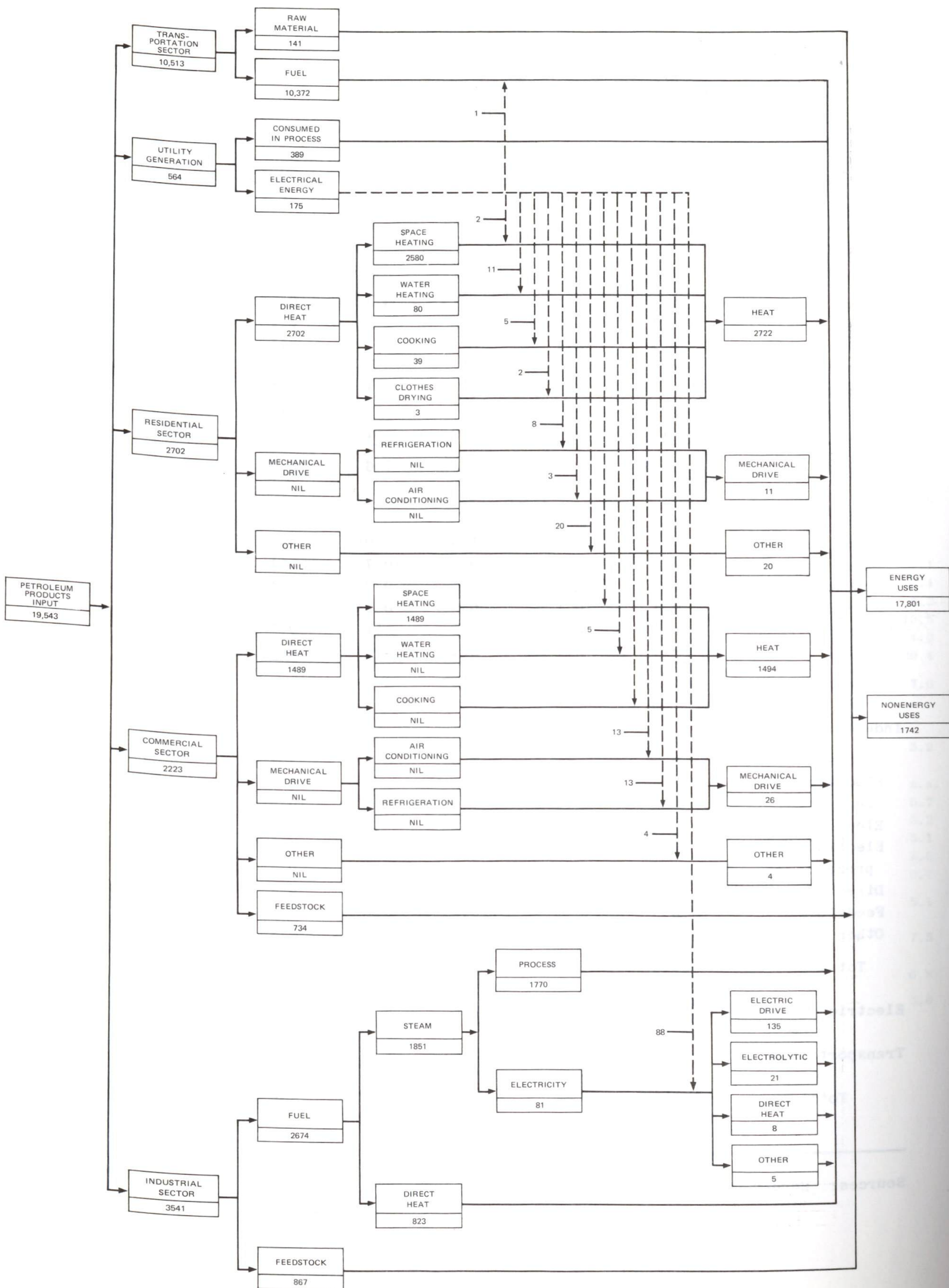


FIGURE 35 1960 CONSUMPTION OF PETROLEUM PRODUCTS (Trillions of Btu)

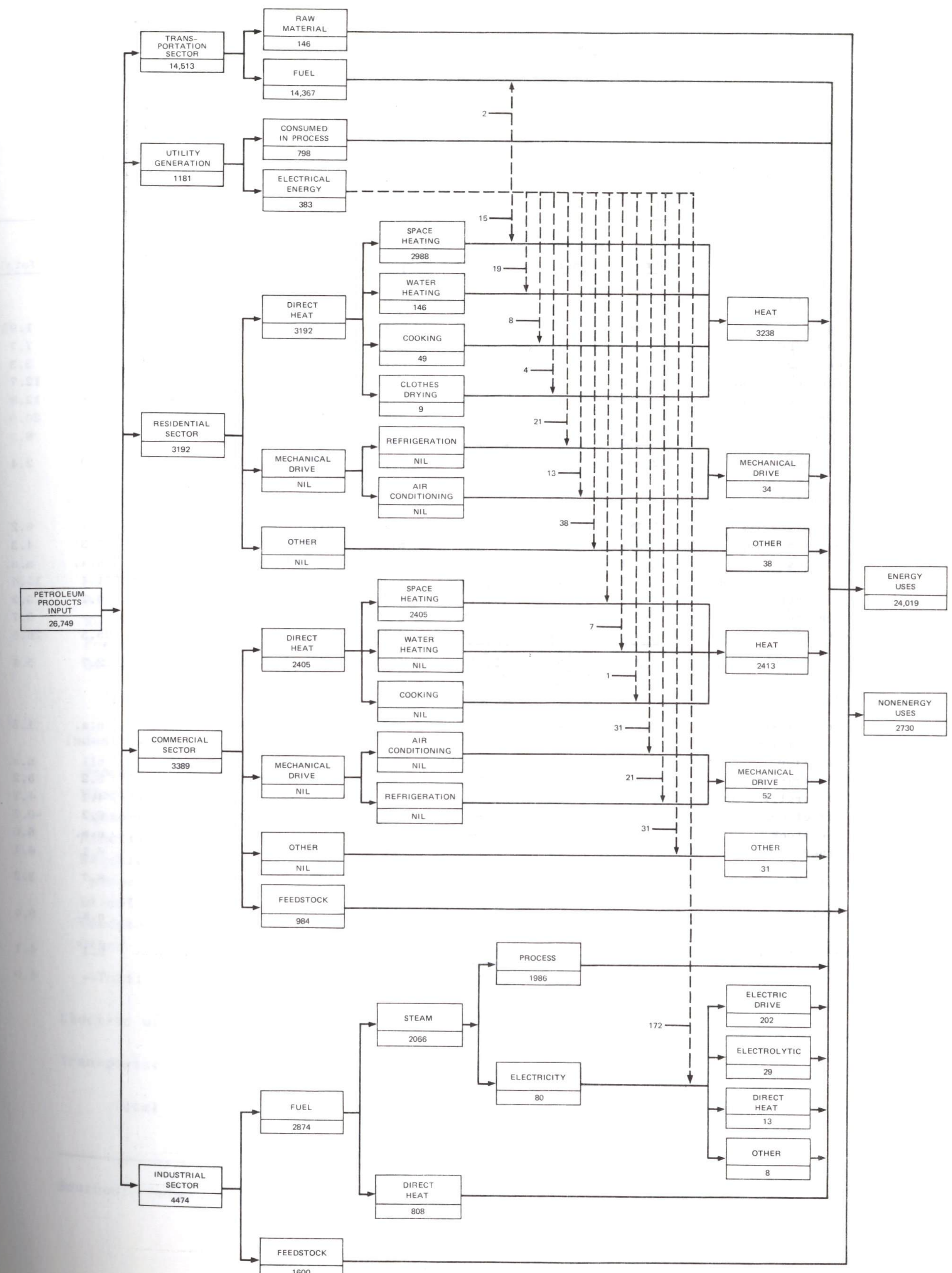


FIGURE 36 1968 CONSUMPTION OF PETROLEUM PRODUCTS (Trillions of Btu)

Table 77

GROWTH IN CONSUMPTION OF PETROLEUM PRODUCTS
1960 and 1968
(Trillions of Btu)

	1960			1968			Average Annual Rate of Growth 1960-68 (percent)		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential									
Space heating	2,580	2	2,582	2,988	15	3,003	1.8%	28.5%	1.9%
Water heating	80	11	91	146	19	165	7.8	7.0	7.7
Cooking	39	5	44	49	8	57	2.9	6.1	3.3
Clothes drying	3	2	5	9	4	13	14.8	9.1	12.7
Refrigeration	nil	8	8	nil	21	21	--	12.8	12.8
Air conditioning	nil	3	3	nil	13	13	--	20.0	20.0
Other	nil	20	20	nil	38	38	--	8.3	8.3
Total	2,702	51	2,753	3,192	118	3,310	2.1	11.0	2.4
Commercial									
Space heating	1,489	nil	1,489	2,405	nil	2,405	6.2	--	6.2
Water heating	nil	5	5	nil	7	7	--	4.3	4.3
Cooking	nil	nil	nil	nil	1	1	--	n.a.	n.a.
Air conditioning	nil	13	13	nil	31	31	--	11.4	11.4
Refrigeration	nil	13	13	nil	21	21	--	6.2	6.2
Feedstock	734	nil	734	984	nil	984	3.7	--	3.7
Other	nil	4	4	nil	31	31	--	25.5	25.5
Total	2,223	35	2,258	3,389	91	3,480	5.4	12.7	5.6
Industrial									
Process steam	1,770	--	1,770	1,986	--	1,986	1.5	n.a.	1.5
Electricity generation	81	-81	--	80	-80	--	nil	nil	n.a.
Electric drive	--	135	135	--	202	202	n.a.	5.2	5.2
Electrolytic process	--	21	21	--	29	29	n.a.	4.1	4.1
Direct heat	823	8	831	808	13	821	-0.2	6.2	-0.2
Feedstock	867	--	867	1,600	--	1,600	8.0	n.a.	8.0
Other	--	5	5	--	8	8	nil	6.1	6.1
Total	3,541	88	3,629	4,474	172	4,646	3.0	8.7	3.2
Electric utility	564	(175)	389	1,181	(383)	798	9.7	n.a.	9.4
Transportation	10,513	1	10,514	14,513	2	14,515	4.1	9.1	4.1
Total	19,543	--	19,543	26,749	--	26,749	4.0	--	4.0

Note: n.a. = not applicable.

Sources: Bureau of Mines. Stanford Research Institute.

Table 78

CONSUMPTION OF PETROLEUM PRODUCTS
AS A PERCENTAGE OF TOTAL NATIONAL ENERGY CONSUMPTION
1960 and 1968

	1960			1968		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential						
Space heating	6.0%	nil%	6.0%	4.9%	nil%	4.9%
Water heating	0.2	nil	0.2	0.2	nil	0.2
Cooking	0.1	nil	0.1	0.1	nil	0.1
Clothes drying	nil	nil	nil	nil	nil	nil
Refrigeration	nil	nil	nil	nil	0.1	0.1
Air conditioning	nil	nil	nil	nil	nil	nil
Other	nil	0.1	0.1	nil	0.1	0.1
Total	6.3%	0.1%	6.4%	5.2%	0.2%	5.4%
Commercial						
Space heating	3.5	nil	3.5	4.0	nil	4.0
Water heating	nil	nil	nil	nil	nil	nil
Cooking	nil	nil	nil	nil	nil	nil
Air conditioning	nil	0.1	0.1	nil	0.1	0.1
Refrigeration	nil	nil	nil	nil	nil	nil
Feedstock	1.7	nil	1.7	1.6	nil	1.6
Other	nil	nil	nil	nil	nil	nil
Total	5.2%	0.1%	5.3%	5.6%	0.1%	5.7%
Industrial						
Process steam	4.1	nil	4.1	3.3	nil	3.3
Electricity generation	0.2	-0.2	--	0.1	-0.1	--
Electric drive	--	0.3	0.3	--	0.2	0.2
Electrolytic process	--	0.1	0.1	--	0.1	0.1
Direct heat	1.9	nil	1.9	1.3	nil	1.3
Feedstock	2.0	--	2.0	2.7	--	2.7
Other	--	nil	nil	--	nil	nil
Total	8.2%	0.2%	8.4%	7.4%	0.2%	7.6%
Electric utility	1.3	(0.4)	0.9	2.0	(0.5)	1.5
Transportation	24.4	nil	24.4	24.0	nil	24.0
Total	45.4%	--	45.4%	44.2%	--	44.2%

Sources: Bureau of Mines. Stanford Research Institute.

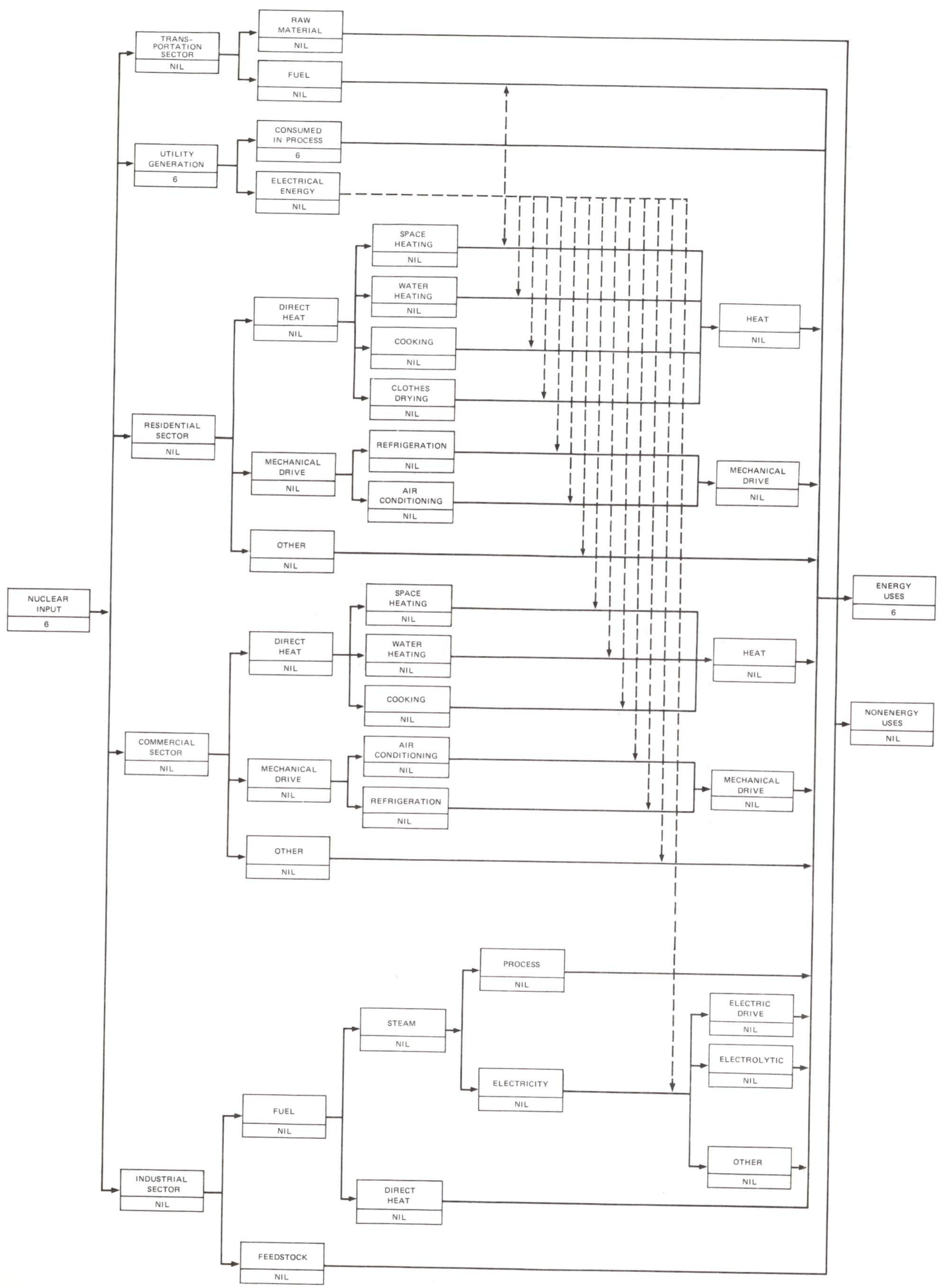


FIGURE 37 1960 CONSUMPTION OF NUCLEAR POWER (Trillions of Btu)

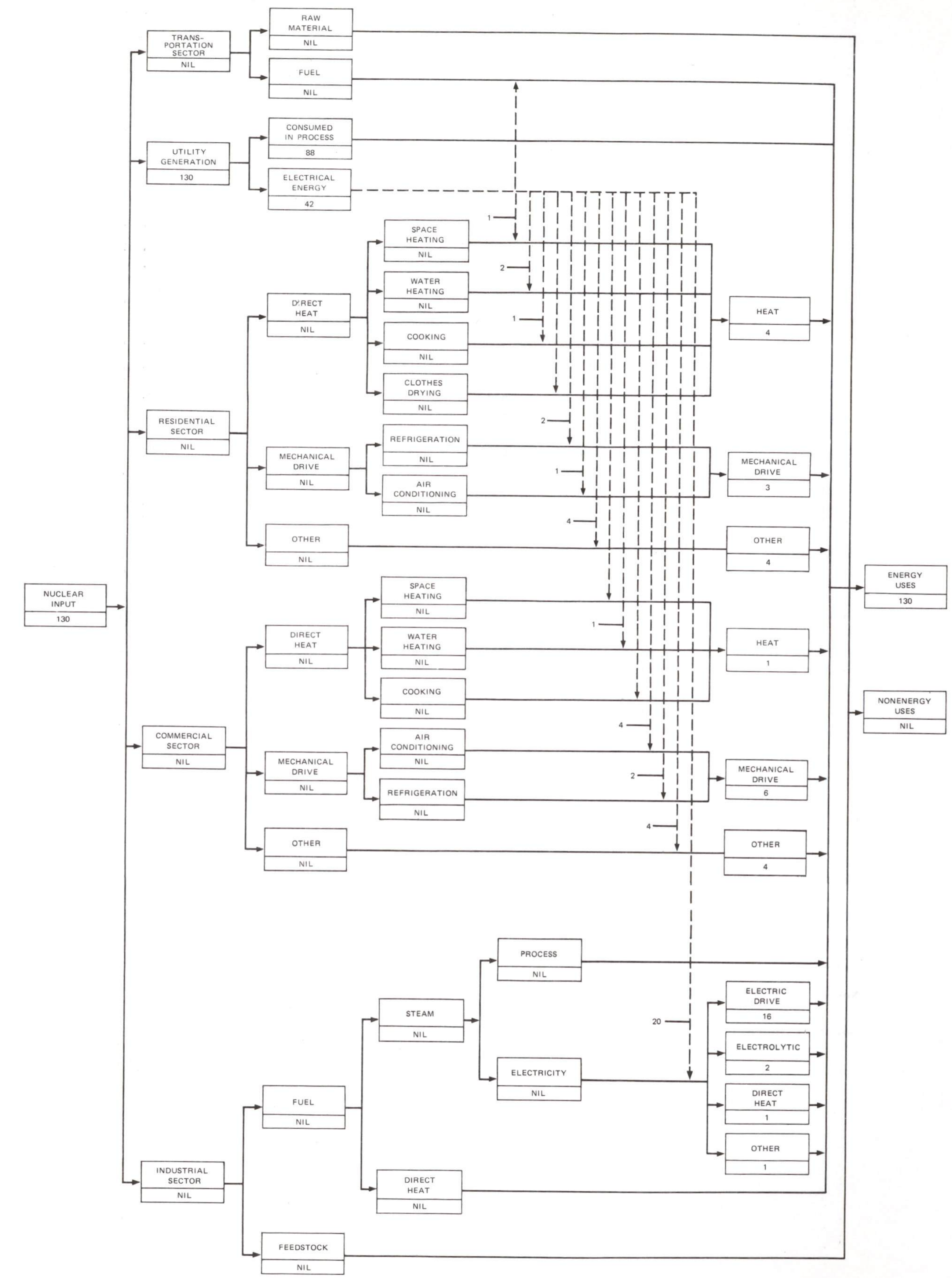


FIGURE 38 1968 CONSUMPTION OF NUCLEAR POWER (Trillions of Btu)

Table 79

GROWTH IN CONSUMPTION OF NUCLEAR ENERGY
1960 and 1968
(Trillions of Btu)

	1960			1968			Average Annual Rate of Growth 1960-68 (percent)		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential									
Space heating	--	nil	nil	--	1	1	--	n.a.%	n.a.%
Water heating	--	nil	nil	--	2	2	--	n.a.	n.a.
Cooking	--	nil	nil	--	1	1	--	n.a.	n.a.
Clothes drying	--	nil	nil	--	nil	nil	--	n.a.	n.a.
Refrigeration	--	nil	nil	--	2	2	--	n.a.	n.a.
Air conditioning	--	nil	nil	--	1	1	--	n.a.	n.a.
Other	--	nil	nil	--	4	4	--	n.a.	n.a.
Total	--	nil	nil	--	11	11	--	n.a.	n.a.
Commercial									
Space heating	--	nil	nil	--	nil	nil	--	n.a.	n.a.
Water heating	--	nil	nil	--	1	1	--	n.a.	n.a.
Cooking	--	nil	nil	--	nil	nil	--	n.a.	n.a.
Air conditioning	--	nil	nil	--	4	4	--	n.a.	n.a.
Refrigeration	--	nil	nil	--	2	2	--	n.a.	n.a.
Other	--	nil	nil	--	4	4	--	n.a.	n.a.
Total	--	nil	nil	--	11	11	--	n.a.	n.a.
Industrial									
Electric drive	--	nil	nil	--	16	16	--	n.a.	n.a.
Electrolytic process	--	nil	nil	--	2	2	--	n.a.	n.a.
Direct heat	--	nil	nil	--	1	1	--	n.a.	n.a.
Other	--	nil	nil	--	1	1	--	n.a.	n.a.
Total	--	nil	nil	--	20	20	--	n.a.	n.a.
Electric utility	--	6	6	--	88	88	--	40.0	40.0
Transportation	--	nil	nil	--	nil	nil	--	n.a.	n.a.
Total	--	6	6	--	130	130	--	47.0	47.0

Note: n.a. = not applicable.

Sources: Bureau of Mines. Stanford Research Institute.

Appendix B

DATA ON INDIVIDUAL FUELS

Appendix B

DATA ON INDIVIDUAL FUELS

Consumption of Coal

Coal consumption in the United States increased from 10.4 quadrillion Btu in 1960 to 13.3 quadrillion Btu in 1968 or by 3.1 percent annually on average--see Table 80. Industries and utilities traditionally accounted for some 90 percent of the coal consumption, but only utilities increased their share of the total domestic consumption of coal and accounted for more than half of the 1968 consumption, as shown below.

	1960	1968
Share of total coal consumption		
Residential and commercial	10%	4%
Industrial	47	42
Utilities	41	54
Other	2	nil
Total	100%	100%

Summaries of coal consumption by sector and end uses for 1960 and 1968 are given in Figures 38 and 39; electricity is shown in terms of work output (3,413 Btu per kwh). Table 81 shows the shares that end uses account for of the total U.S. energy consumption by sector.

Consumption of Natural Gas

Consumption of natural gas increased at a rate of 5.5 percent per year between 1960 and 1968. The consumption by sectors of the economy in trillions of Btu and the percentage of total U.S. consumption accounted for by each sector is shown below.

Table 80

CONSUMPTION OF ALL TYPES OF COAL
1960-1968
(Trillions of Btu)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	Average Annual Rate of Growth (percent)
Residential and commercial	1,023	912	920	774	751	714	718	625	568	-7.1%
Industrial										
Fuel	4,766	4,610	4,680	4,945	5,338	5,591	5,747	5,498	5,469	1.7
Feedstock	131	129	130	127	139	149	148	145	147	1.5
Total	4,897	4,739	4,810	5,072	5,477	5,740	5,894	5,643	5,616	1.7
Transportation	92	22	20	19	20	19	18	14	12	-22.5
Utility generation	4,257	4,375	4,638	5,072	5,410	5,880	6,396	6,578	7,130	6.6
Total accounted for										
Fuel	10,138	9,919	10,258	10,810	11,519	12,205	12,879	12,715	13,179	3.3
Feedstock	131	129	130	127	139	149	148	145	147	1.5
Total	10,269	10,048	10,388	10,937	11,658	12,354	13,027	12,860	13,326	3.3
Miscellaneous and unaccounted for	145	165	153	146	2	4	3	1	1	-50.5
Gross consumption	10,414	10,213	10,541	11,083	11,660	12,358	13,030	12,861	13,327	3.1

Sources: Bureau of Mines. Stanford Research Institute.

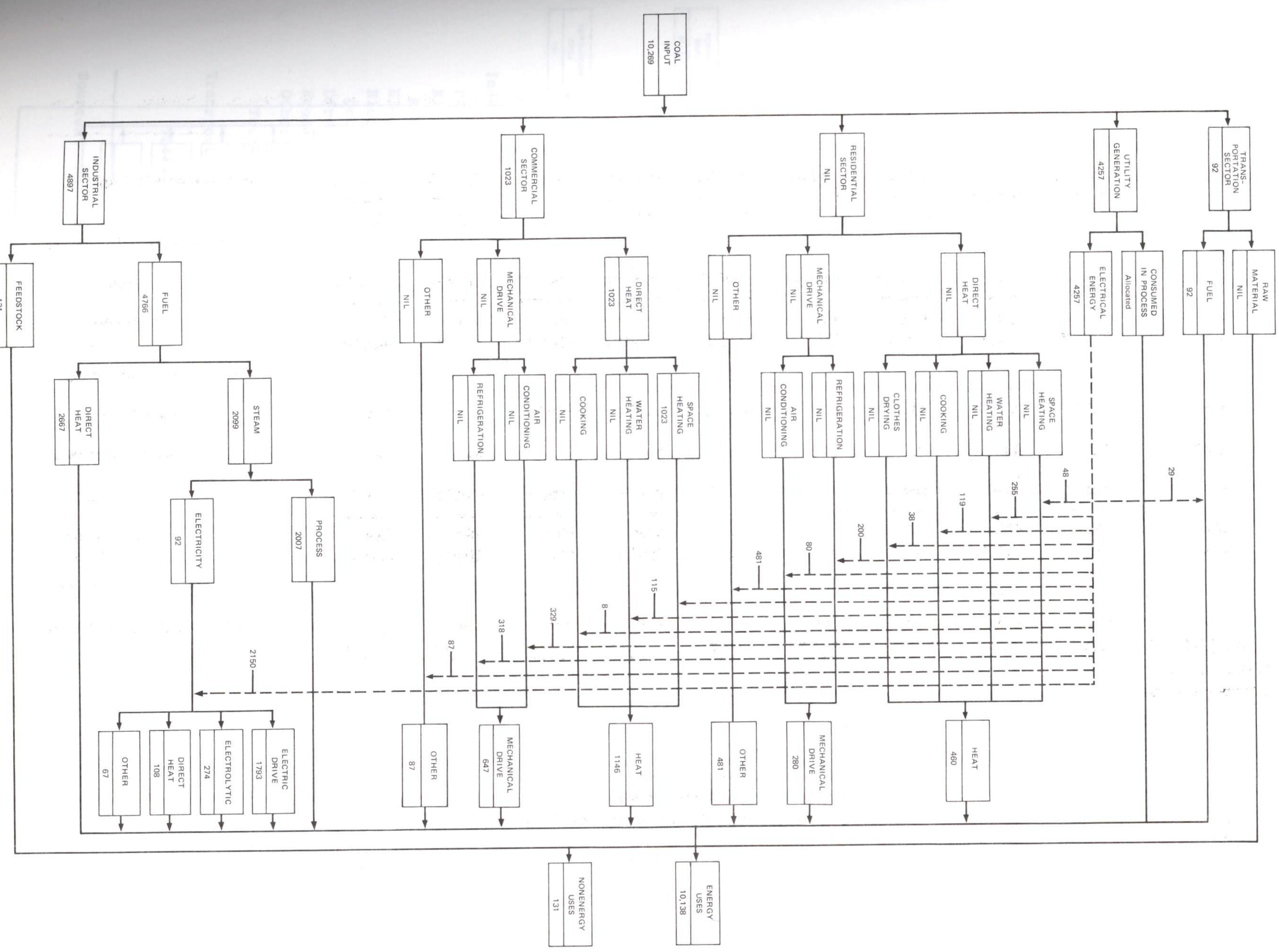


FIGURE 39 1960 CONSUMPTION OF ALL TYPES OF COAL (Trillions of Btu)

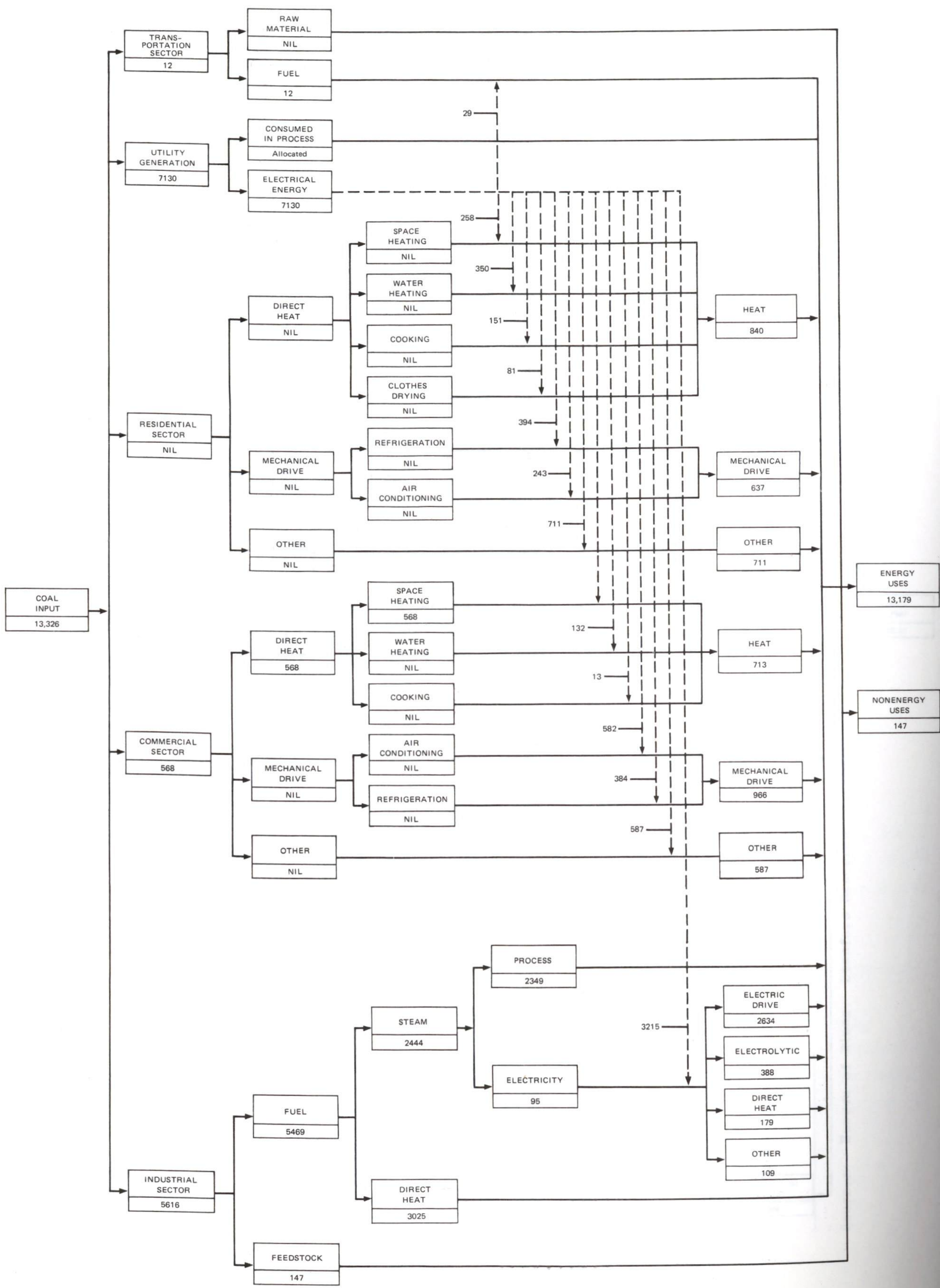


FIGURE 40 1968 CONSUMPTION OF ALL TYPES OF COAL (Trillions of Btu)

Table 81

CONSUMPTION OF ALL TYPES OF COAL AS A PERCENTAGE OF NATIONAL CONSUMPTION
1960 and 1968

	1960			1968		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential						
Space heating	nil%	0.1%	0.1%	nil%	0.4%	0.4%
Water heating	nil	0.6	0.6	nil	0.6	0.6
Cooking	nil	0.3	0.3	nil	0.2	0.2
Clothes drying	nil	0.1	0.1	nil	0.1	0.1
Refrigeration	nil	0.5	0.5	nil	0.7	0.7
Air conditioning	nil	0.2	0.2	nil	0.4	0.4
Other	nil	1.0	1.0	nil	1.2	1.2
Total	nil	2.8%	2.8%	nil	3.6%	3.6%
Commercial						
Space heating	2.4	nil	2.4	0.9	nil	0.9
Water heating	nil	0.3	0.3	nil	0.2	0.2
Cooking	nil	nil	nil	nil	nil	nil
Air conditioning	nil	0.8	0.8	nil	1.0	1.0
Refrigeration	nil	0.7	0.7	nil	0.6	0.6
Other	nil	0.2	0.2	nil	1.0	1.0
Total	2.4%	2.0%	4.4%	0.9%	2.8%	3.7%
Industrial						
Process steam	4.8	--	4.8	3.9	--	3.9
Electricity generation	0.2	-0.2	--	0.2	-0.2	--
Electric drive	--	4.2	4.2	--	4.3	4.3
Electrolytic process	--	0.6	0.6	--	0.7	0.7
Direct heat	6.1	0.2	6.3	5.0	0.3	5.3
Feedstock	0.2	--	0.2	0.2	--	0.2
Other	--	0.2	0.2	--	0.2	0.2
Total	11.3%	5.0%	16.3%	9.3%	5.3%	14.6%
Transportation	0.2	0.1	0.3	nil	nil	nil
Total	13.9%	9.9%	23.8%	10.2%	11.8%	22.0%

Sources: Bureau of Mines. Stanford Research Institute.

	Trillions of Btu	
	1960	1968
Residential	3,724	5,602
Commercial	1,415	2,619
Industrial	7,188	10,723
Transportation	372	620
Total	12,699	19,564

	Percentage of Total U.S. Gas Consumption	
	1960	1968
Residential	29.4%	28.6%
Commercial	11.1	13.4
Industrial	56.6	54.8
Transportation	2.9	3.2
Total	100.0%	100.0%

Table 82 shows the consumption of natural gas by years from 1960 through 1968. Figures 40 and 41 show the consumption of gas by end use for 1960 and 1968 with electric utility energy consumption allocated to end uses.

Table 83 shows the percentage of total national energy consumption represented by each end use when utility consumption is allocated to end use.

Consumption of Petroleum Products

Consumption of petroleum products increased from 20 quadrillion Btu in 1960 to 27 quadrillion Btu in 1968 or by an average 3.9 percent annually, as shown in Table 84. Transportation accounted for more than half of the demand for petroleum products, and its share is still increasing, as shown below.

Table 82

CONSUMPTION OF DRY NATURAL GAS
1960-1968
(Trillions of Btu)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	Average Annual Rate of Growth (percent)
Residential and commercial	4,268	4,477	4,849	5,027	5,343	5,518	5,945	6,223	6,451	5.3%
Industrial										
Fuel	5,915	6,133	6,531	6,862	7,154	7,379	7,907	8,138	8,803	5.1
Feedstock	372	338	310	298	297	292	295	461	455	2.6
Total	6,287	6,471	6,841	7,160	7,451	7,671	8,202	8,599	9,258	4.9
Transportation	359	391	396	439	451	517	553	594	610	6.8
Electric utility generation	1,785	1,889	2,034	2,218	2,403	2,392	2,692	2,834	3,245	7.7
Total accounted for										
Fuel	12,327	12,890	13,810	14,546	15,351	15,806	17,097	17,789	19,109	5.6
Feedstock	372	338	310	298	297	292	295	461	455	2.6
Total	12,699	13,228	14,120	14,844	15,648	16,098	17,392	18,250	19,564	5.5

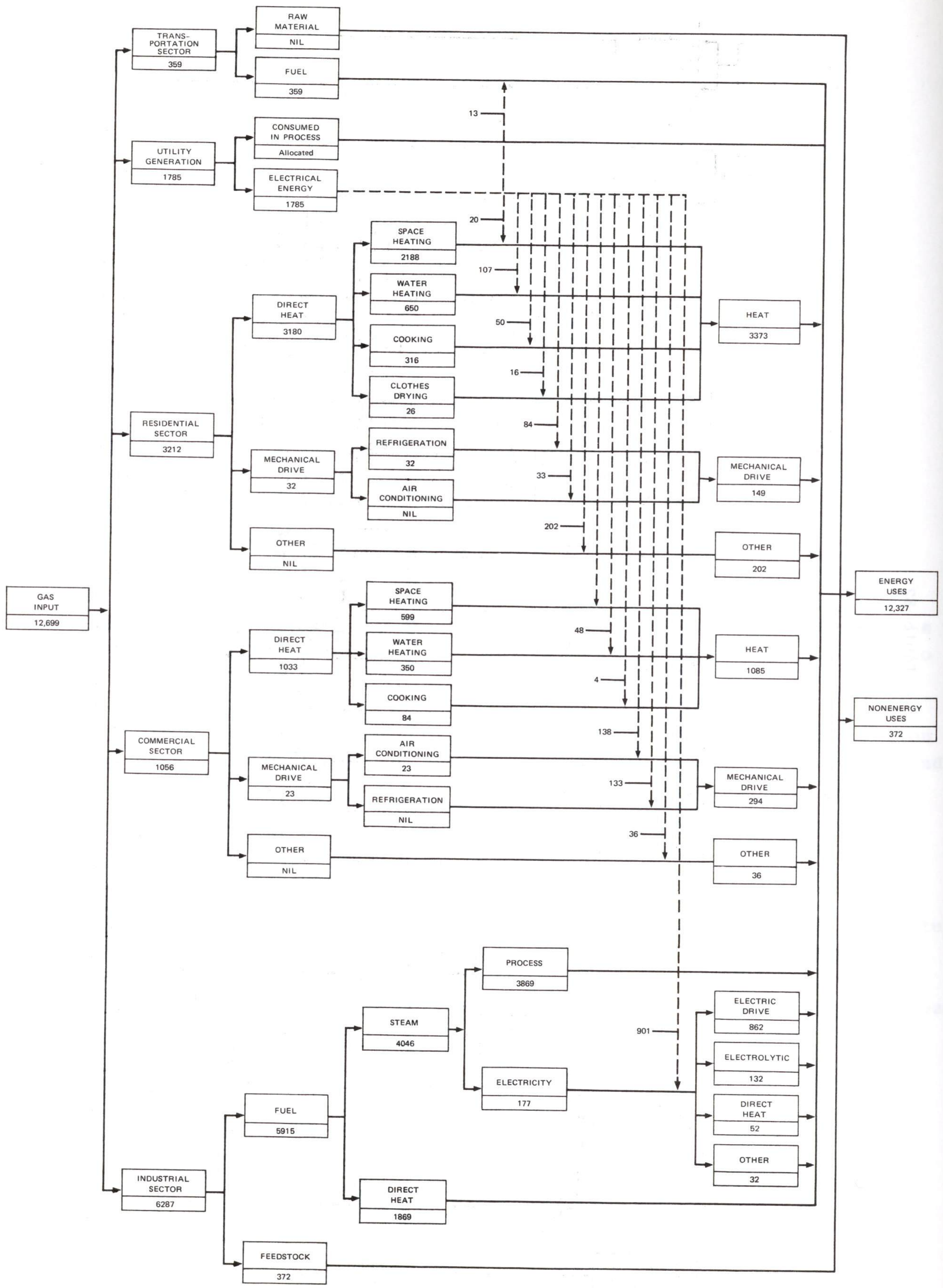


FIGURE 41 1960 CONSUMPTION OF DRY NATURAL GAS (Trillions of Btu)

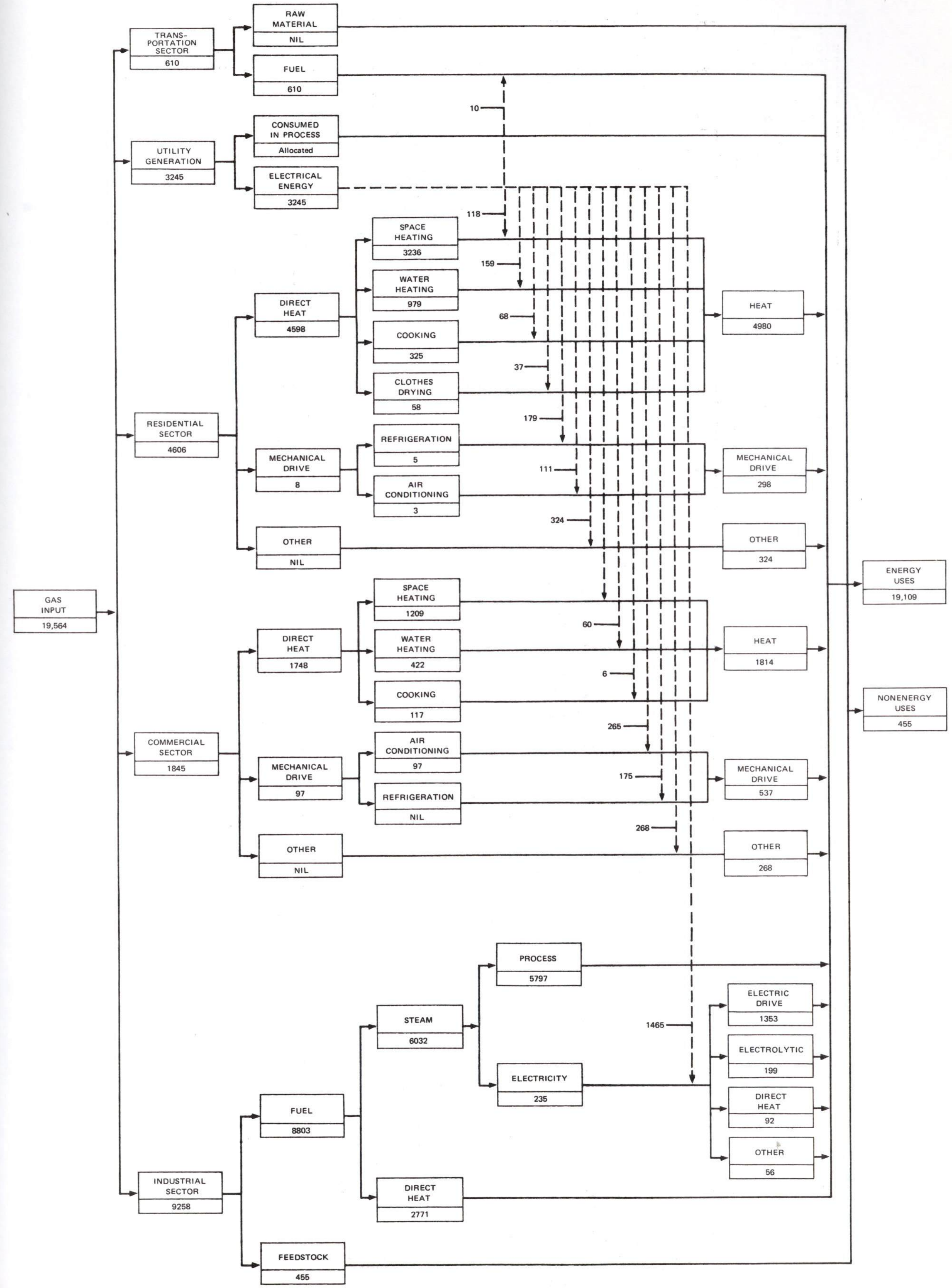


FIGURE 42 1968 CONSUMPTION OF DRY NATURAL GAS (Trillions of Btu)

Table 83

CONSUMPTION OF DRY NATURAL GAS AS A PERCENTAGE OF NATIONAL CONSUMPTION
1960 and 1968

	1960			1968		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential						
Space heating	5.1%	0.1%	5.2%	5.4%	0.2%	5.6%
Water heating	1.5	0.2	1.7	1.6	0.3	1.9
Cooking	0.7	0.1	0.8	0.5	0.1	0.6
Clothes drying	0.1	nil	0.1	0.1	0.1	0.2
Refrigeration	0.1	0.2	0.3	nil	0.3	0.3
Air conditioning	nil	0.1	0.1	nil	0.2	0.2
Other	nil	0.5	0.5	nil	0.5	0.5
Total	7.5%	1.2%	8.7%	7.6%	1.7%	9.3%
Commercial						
Space heating	1.4	nil	1.4	2.0	nil	2.0
Water heating	0.8	0.1	0.9	0.7	0.1	0.8
Cooking	0.2	nil	0.2	0.2	nil	0.2
Air conditioning	0.1	0.3	0.4	0.2	0.4	0.6
Refrigeration	nil	0.3	0.3	nil	0.3	0.3
Other	nil	0.1	0.1	nil	0.5	0.5
Total	2.5%	0.8%	3.3%	3.1%	1.3%	4.4%
Industrial						
Process steam	9.0	--	9.0	9.6	--	9.6
Electricity generation	0.4	-0.4	--	0.4	-0.4	--
Electric drive	--	2.0	2.0	--	2.1	2.1
Electrolytic process	--	0.3	0.3	--	0.3	0.3
Direct heat	4.3	0.1	4.4	4.6	0.2	4.8
Feedstock	0.9	--	0.9	0.7	--	0.7
Other	--	0.1	0.1	--	0.1	0.1
Total	14.6%	2.1%	16.7%	15.3%	2.3%	17.6%
Transportation	0.8	nil	0.8	1.0	nil	1.0
Total	25.4%	4.1%	29.5%	27.0%	5.3%	32.3%

Sources: Bureau of Mines. Stanford Research Institute.

Table 84

CONSUMPTION OF PETROLEUM PRODUCTS BY CONSUMING SECTOR
1960-1968
(Trillions of Btu)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	Average Annual Rate of Growth 1960-1968 (percent)
Household and commercial										
Fuel and power										
Liquefied gases	404	412	450	483	495	511	543	594	686	6.8%
Kerosene	448	445	469	453	404	449	433	388	446	-0.1
Distillate fuel	2,552	2 657	2,719	2,711	2,658	2,802	2,723	3,099	3,233	3.0
Residual fuel	787	762	787	788	795	983	1,132	1,208	1,232	5.8
Subtotal	4,191	4,276	4,425	4,435	4,352	4,745	4,831	5,289	5,597	3.7
Raw material										
Asphalt and road oil	734	753	804	824	841	891	936	917	984	3.8
Subtotal	734	753	804	824	841	891	936	917	984	3.8
Total	4,925	5,029	5,229	5,259	5,193	5,636	5,767	6,206	6,581	3.7
Industrial										
Fuel and power										
Liquefied gases	72	54	63	81	103	77	72	70	83	1.8
Kerosene	114	95	87	80	100	104	137	179	133	1.9
Distillate fuel	269	232	288	304	271	308	335	348	357	3.6
Residual fuel	1,272	1,246	1,271	1,234	1,259	1,100	1,108	1,068	1,075	-2.1
Still gas	745	732	751	777	787	812	813	840	899	2.4
Petroleum coke	202	275	290	263	257	268	258	315	327	6.2
Subtotal	2,674	2,634	2,750	2,739	2,777	2,669	2,723	2,820	2,874	0.9
Raw material										
Special naphthas*	148	174	191	101	144	156	159	132	142	-0.5
Lubes and waxes†	142	138	146	143	149	154	160	155	171	2.4
Petroleum coke	125	125	136	154	167	175	186	137	133	0.8
Petrochemical feedstock offtake	452	469	511	714	797	832	966	1,054	1,154	12.4
Subtotal	867	910	984	1,113	1,258	1,316	1,471	1,478	1,600	8.0
Total	3,541	3,544	3,734	3,852	4,035	3,985	4,194	4,298	4,474	3.0
Transportation										
Fuel and power										
Liquefied gases	86	84	89	95	112	114	116	111	120	4.3
Jet fuels	738	839	974	1,050	1,096	1,214	1,354	1,670	1,938	12.8
Gasoline	7,855	7,967	8,219	8,580	8,701	9,028	9,412	9,671	10,265	3.4
Distillate fuel	867	872	929	1,038	1,103	1,082	1,145	1,175	1,240	4.6
Residual fuel	826	813	790	743	779	742	750	781	804	-0.3
Subtotal	10,372	10,575	11,001	11,506	11,791	12,179	12,777	13,408	14,367	4.2
Raw material										
Lubes and waxes†	141	138	146	142	149	154	159	134	146	0.4
Subtotal	141	138	146	142	149	154	159	134	146	0.4
Total	10,513	10,713	11,147	11,648	11,940	12,333	12,936	13,542	14,513	4.1
Electricity generation - utilities										
Fuel and power										
Distillate fuel	27	24	24	24	22	22	21	17	18	-4.9
Residual fuel	537	553	555	576	614	722	884	996	1,163	10.1
Total	564	577	579	600	636	744	905	1,013	1,181	9.7
Miscellaneous and unaccounted for	526	625	580	592	585	545	594	276	295	-6.8
Total gross consumption	20,069	20,488	21,269	21,951	22,389	23,243	24,396	25,335	27,044	3.9

* For years 1960-1963 category designated as "other."

† Lubes and waxes before 1967 allocated 50% industrial, 50% transportation.

Sources: Bureau of Mines, Minerals Yearbook, 1964-1968. Bureau of Mines, "An Energy Model for the United States," Information Circular 8384 July 1968.

	1960	1968
Share of total petroleum products consumption		
Residential and commercial	25%	24%
Industrial	18	17
Transportation	52	54
Utilities	3	4
Miscellaneous and unaccounted for	2	1
Total	100%	100%

Consumption of petroleum products in the residential and commercial sectors is usually reported as a single item; the individual fuels were therefore allocated so that all liquefied gases and kerosene are assumed to be consumed in the residential sector and all residual fuels in the commercial sector. Distillate fuels were divided according to consumption estimates in both sectors, which were derived by taking into account the number of commercial and residential oil heating installations (as reported by the American Petroleum Institute in Petroleum Facts and Figures) and an estimate of the average annual consumption for both. Asphalt and road oils are used in commercial establishments exclusively.

Total consumption of petroleum products for 1960 and 1968 by sector and end use is summarized in Figures 42 and 43; electricity shown in terms of work output (3,413 Btu per kwh).

Table 85 shows the shares of total U.S. energy consumption accounted for by end uses in individual sectors.

The use of petroleum products as feedstocks increased at an average rate of 4.9% per year from 1960 through 1968.

Consumption of Electrical Energy

Consumption of electricity increased from 2.6 quadrillion Btu in 1960 to 4.5 quadrillion Btu in 1968 or by an average 7.3 percent annually. When electricity is measured in terms of fuel input, its consumption increased from 7.2 quadrillion Btu to 12.4 quadrillion Btu or by an average 7.1 percent annually as shown in Table 86. The growth rate of fuel input is slightly lower than that of work output because of increased conversion efficiencies of electric utilities.

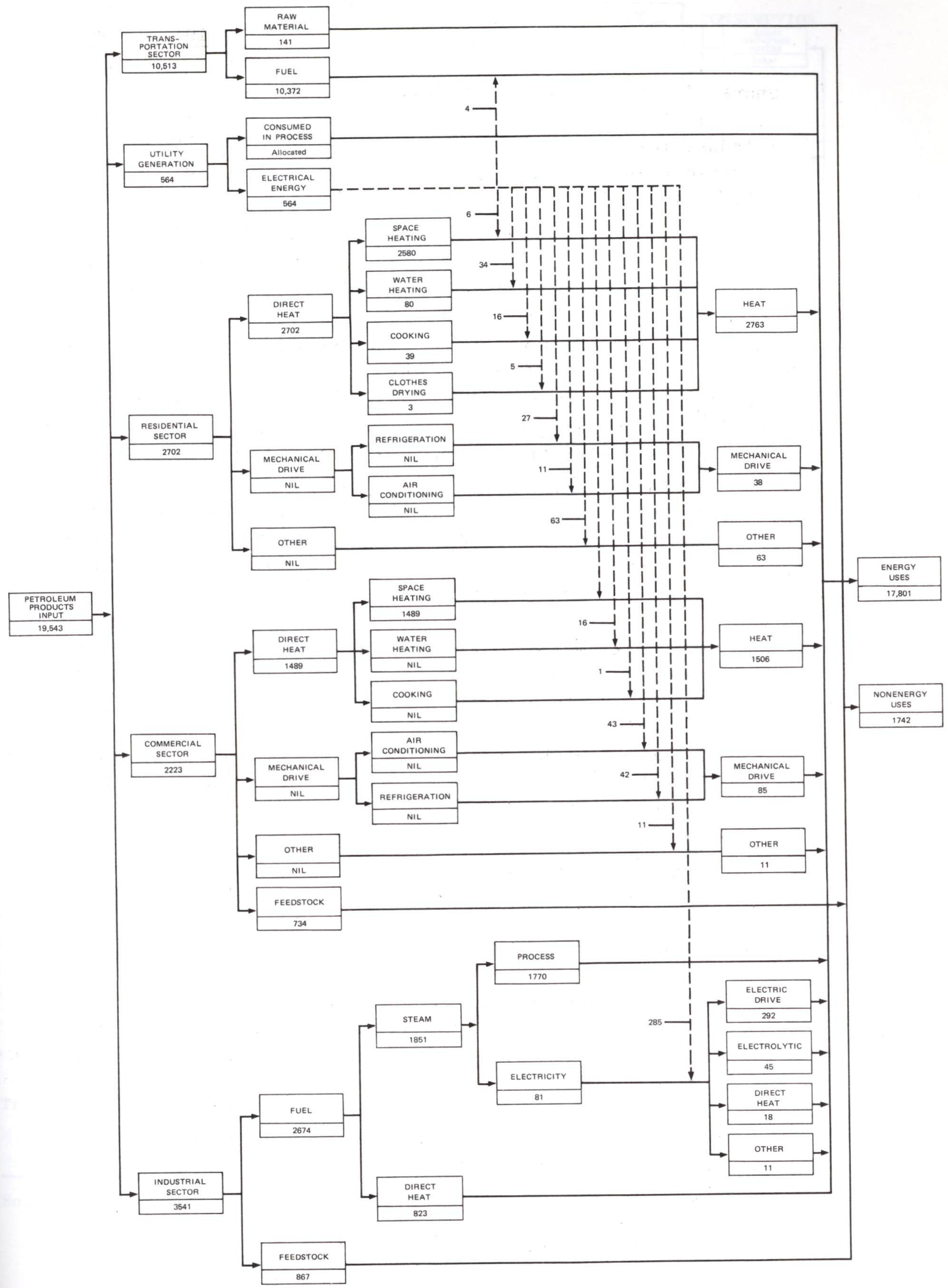


FIGURE 43 1960 CONSUMPTION OF PETROLEUM PRODUCTS (Trillions of Btu)

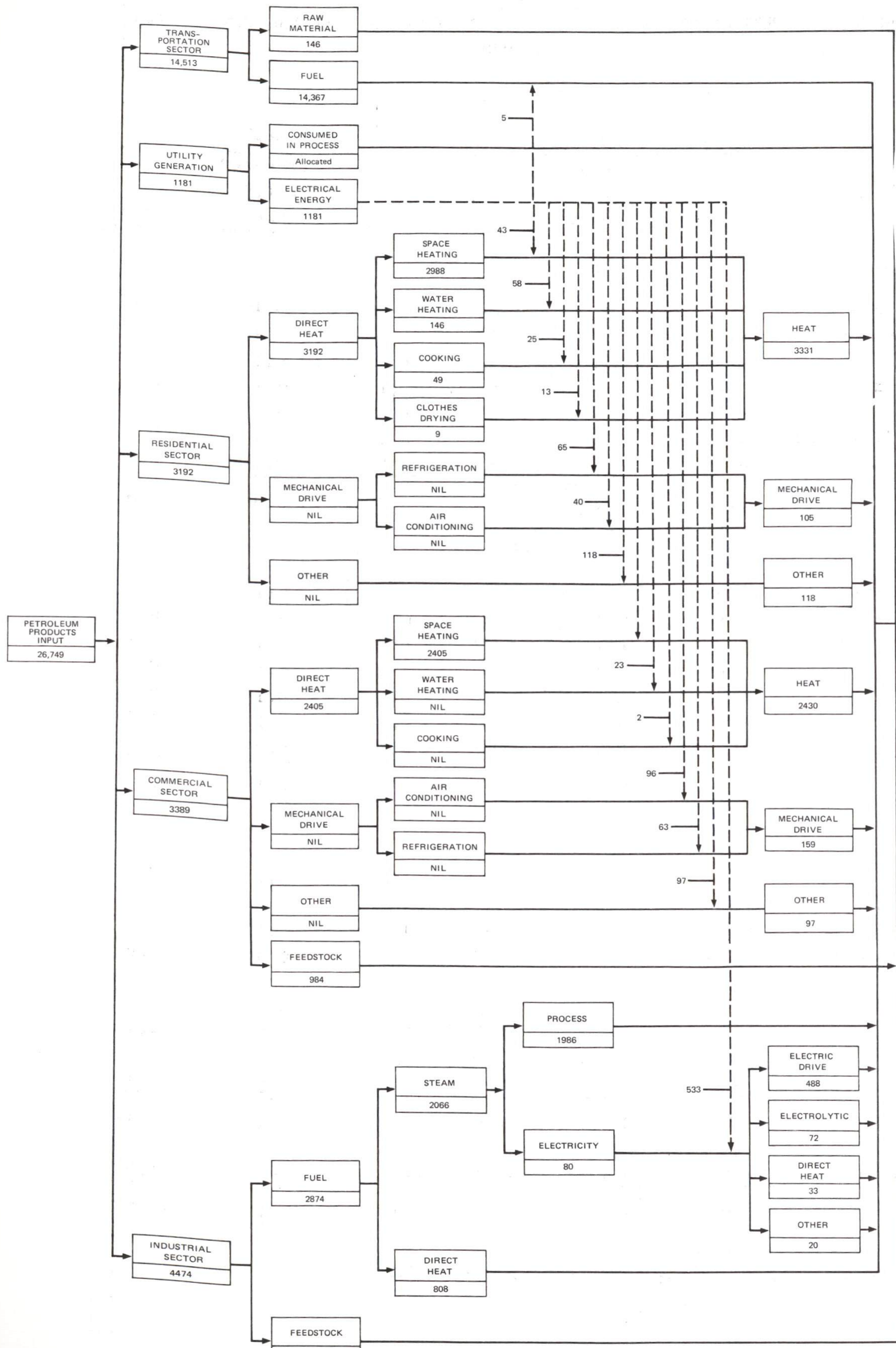


FIGURE 44 1968 CONSUMPTION OF PETROLEUM PRODUCTS (Trillions of Btu)

Table 85

CONSUMPTION OF PETROLEUM PRODUCTS AS A PERCENTAGE OF NATIONAL CONSUMPTION
1960 and 1968

	1960			1968		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential						
Space heating	6.0%	nil	6.0%	4.9%	0.1%	5.0%
Water heating	0.2	0.1%	0.3	0.2	0.1	0.3
Cooking	0.1	nil	0.1	0.1	nil	0.1
Clothes drying	nil	nil	nil	nil	nil	nil
Refrigeration	nil	0.1	0.1	nil	0.1	0.1
Air conditioning	nil	nil	nil	nil	0.1	0.1
Other	nil	0.1	0.1	nil	0.2	0.2
Total	6.3%	0.3%	6.6%	5.2%	0.6%	5.8%
Commercial						
Space heating	3.5	nil	3.5	4.0	nil	4.0
Water heating	nil	nil	nil	nil	nil	nil
Cooking	nil	nil	nil	nil	nil	nil
Air conditioning	nil	0.1	0.1	nil	0.1	0.1
Refrigeration	nil	0.1	0.1	nil	0.1	0.1
Feedstock	1.7	nil	1.7	1.6	nil	1.6
Other	nil	0.1	0.1	nil	0.2	0.2
Total	5.2%	0.3%	5.5%	5.6%	0.4%	6.0%
Industrial						
Process steam	4.1	nil	4.1	3.3	nil	3.3
Electricity generation	0.2	-0.2	--	0.1	-0.1	--
Electric drive	--	0.7	0.7	--	0.9	0.9
Electrolytic process	--	0.1	0.1	--	0.1	0.1
Direct heat	1.9	0.1	2.0	1.3	0.1	1.4
Feedstock	2.0	--	2.0	2.7	--	2.7
Other	--	nil	nil	--	nil	nil
Total	8.2%	0.7%	8.9%	7.4%	1.0%	8.4%
Transportation	24.4	nil	24.4	24.0	nil	24.0
Total	44.1%	1.3%	45.4%	42.2%	2.0%	44.2%

Sources: Bureau of Mines. Stanford Research Institute.

Table 86

CONSUMPTION OF ELECTRICAL ENERGY AND SOURCES OF SUPPLY
1960-1968
(Trillions of Btu)

	1960	1961	1962	1963	1964	1965	1966	1967	1968	Average Annual Rate of Growth (percent)
Consumption										
Residential	742	785	847	910	988	1,062	1,155	1,274	1,390	8.2%
Commercial	520	600	643	735	807	886	946	983	1,079	9.6
Industrial	1,306	1,306	1,402	1,464	1,544	1,634	1,788	1,868	2,043	5.8
Transportation	18	19	18	19	17	18	16	17	18	--
Total	2,586	2,710	2,910	3,129	3,356	3,600	3,905	4,142	4,530	7.3
Supply										
Coal	4,257	4,375	4,638	5,072	5,410	5,880	6,396	6,578	7,130	6.6
Natural gas	1,785	1,889	2,034	2,218	2,403	2,392	2,692	2,834	3,245	7.7
Petroleum products	564	577	579	600	636	744	905	1,013	1,181	9.7
Hydroelectric energy	547	520	572	563	609	664	668	755	757	4.1
Nuclear energy	6	17	23	33	34	38	58	81	130	47.0
Total	7,159	7,378	7,846	8,486	9,092	9,718	10,719	11,261	12,443	7.1

Sources: Bureau of Mines. Edison Electric Institute. SRI estimate.

The residential and commercial sectors increased their share of the total electric power consumption as follows.

	1960	1968
Share of total electric power consumption		
Residential	29%	31%
Commercial	20	24
Industrial	50	45
Transportation	1	nil
Total	100%	100%

Coal and hydroelectric electricity accounted for declining shares of the electric power supply, as tabulated below.

	1960	1968
Share of total electric power supply		
Coal	59%	57%
Natural gas	25	26
Petroleum products	8	10
Hydroelectric energy	8	6
Nuclear energy	nil	1
Total	100%	100%

Production of electricity from coal, natural gas, and petroleum products is the result of converting one form of energy into another. Electric energy generated in hydroelectric and nuclear plants is also the result of converting one form of energy into another, but in contrast to the conversion of fossil fuels, it consists of the conversion of otherwise nonusable energy (for all practical purposes) into usable energy--electricity.

A simple allocation procedure was used to determine the consumption, by end use, of each of the primary energy sources in the form of electrical energy. The quantity of energy represented by hydro can be presented in two ways.

In one of them, each kwh of hydro output is taken to be equal to the number of Btu that would have been required to produce each kwh if it had been generated in a steam electric station.

In the other, each kwh of hydro output is taken to be equal to 3,413 Btu--the theoretical equivalent to a kwh in terms of Btu. This latter method was used in SRI's analysis.

Consumption of hydroelectric energy by sector and end use for 1960 and 1968 is summarized in Figures 44 and 45. Table 87 shows the consumption of hydroelectric energy as a percentage of total U.S. energy consumption.

Consumption of nuclear energy for 1960 and 1968 is summarized in Figures 46 and 47; these summaries show the electric energy produced by nuclear fuel at 3,413 Btu per kwh.

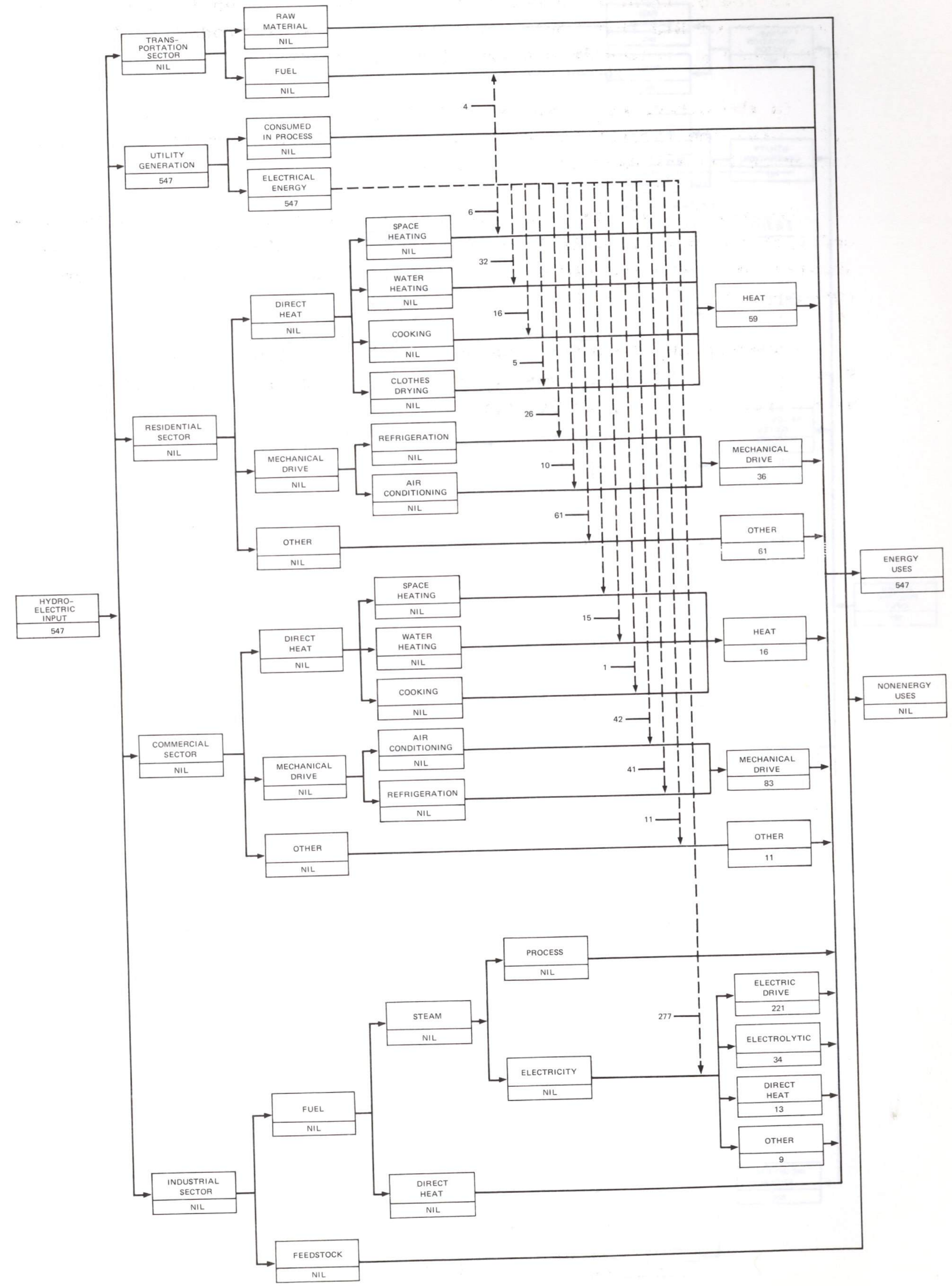


FIGURE 45 1960 CONSUMPTION OF HYDROPOWER (Trillions of Btu)

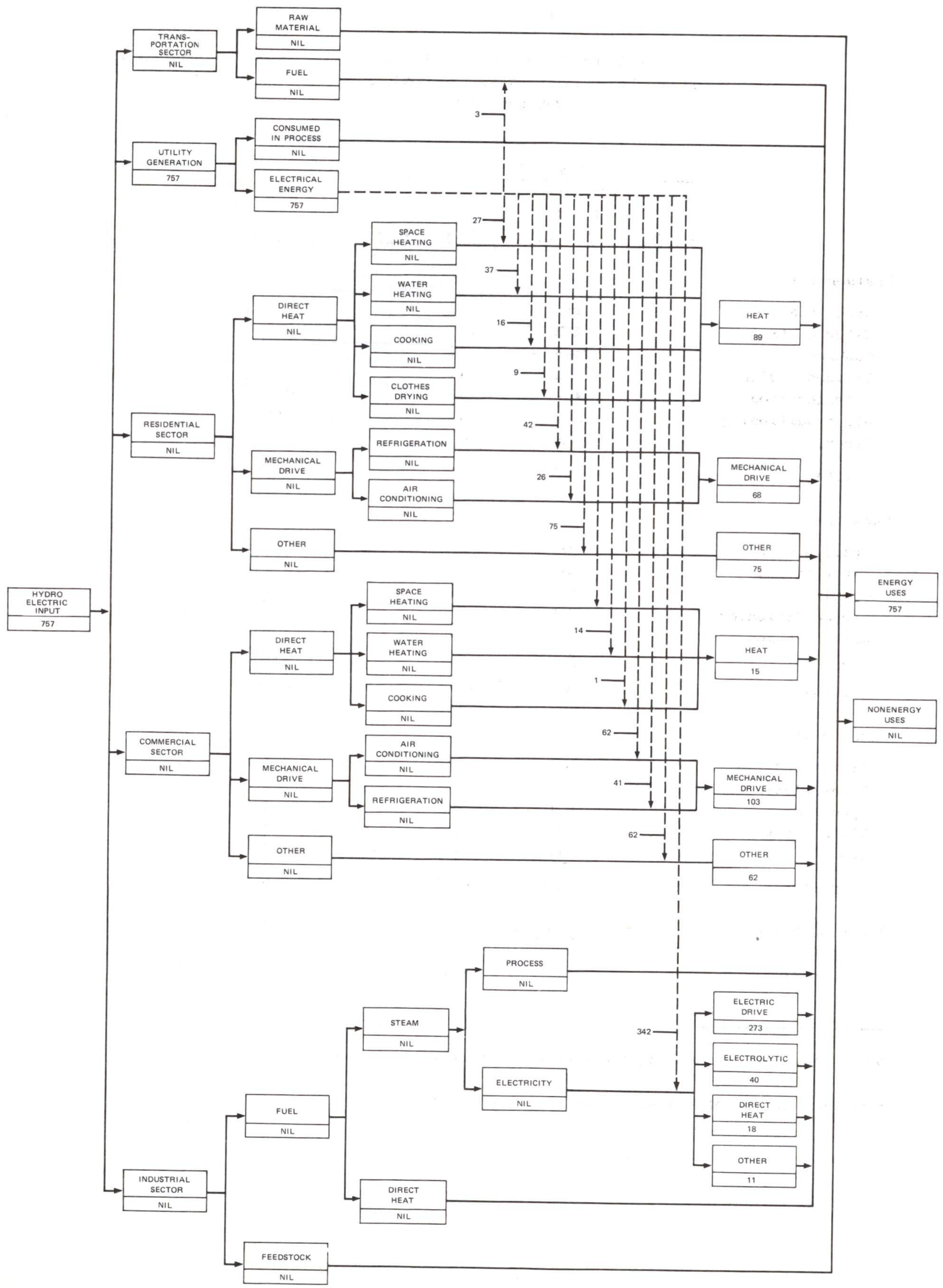


FIGURE 46 1968 CONSUMPTION OF HYDROPOWER (Trillions of Btu)

Table 87

CONSUMPTION OF HYDROELECTRIC ENERGY AS A PERCENTAGE OF NATIONAL CONSUMPTION 1960 and 1968

	1960			1968		
	Direct	Purchased Electrical Energy	Total	Direct	Purchased Electrical Energy	Total
Residential						
Space heating		nil%	nil%		nil%	nil%
Water heating		0.1	0.1		0.1	0.1
Cooking		nil	nil		nil	nil
Clothes drying		nil	nil		nil	nil
Refrigeration		0.1	0.1		0.1	0.1
Air conditioning		nil	nil		nil	nil
Other		0.1	0.1		0.2	0.2
Total		0.3%	0.3%		0.4%	0.4%
Commercial						
Space heating		nil	nil		nil	nil
Water heating		nil	nil		nil	nil
Cooking		nil	nil		nil	nil
Air conditioning		0.1	0.1		0.1	0.1
Refrigeration		0.1	0.1		0.1	0.1
Other		nil	nil		0.1	0.1
Total		0.2%	0.2%		0.3%	0.3%
Industrial						
Electric drive		0.5	0.5		0.5	0.5
Electrolytic process		0.1	0.1		0.1	0.1
Direct heat		nil	nil		nil	nil
Other		nil	nil		nil	nil
Total		0.6%	0.6%		0.6%	0.6%
Transportation		nil	nil		nil	nil
Total		1.2%	1.2%		1.3%	1.3%

Note: Because of rounding the figures in this table may not total exactly.

Sources: Bureau of Mines. Stanford Research Institute.

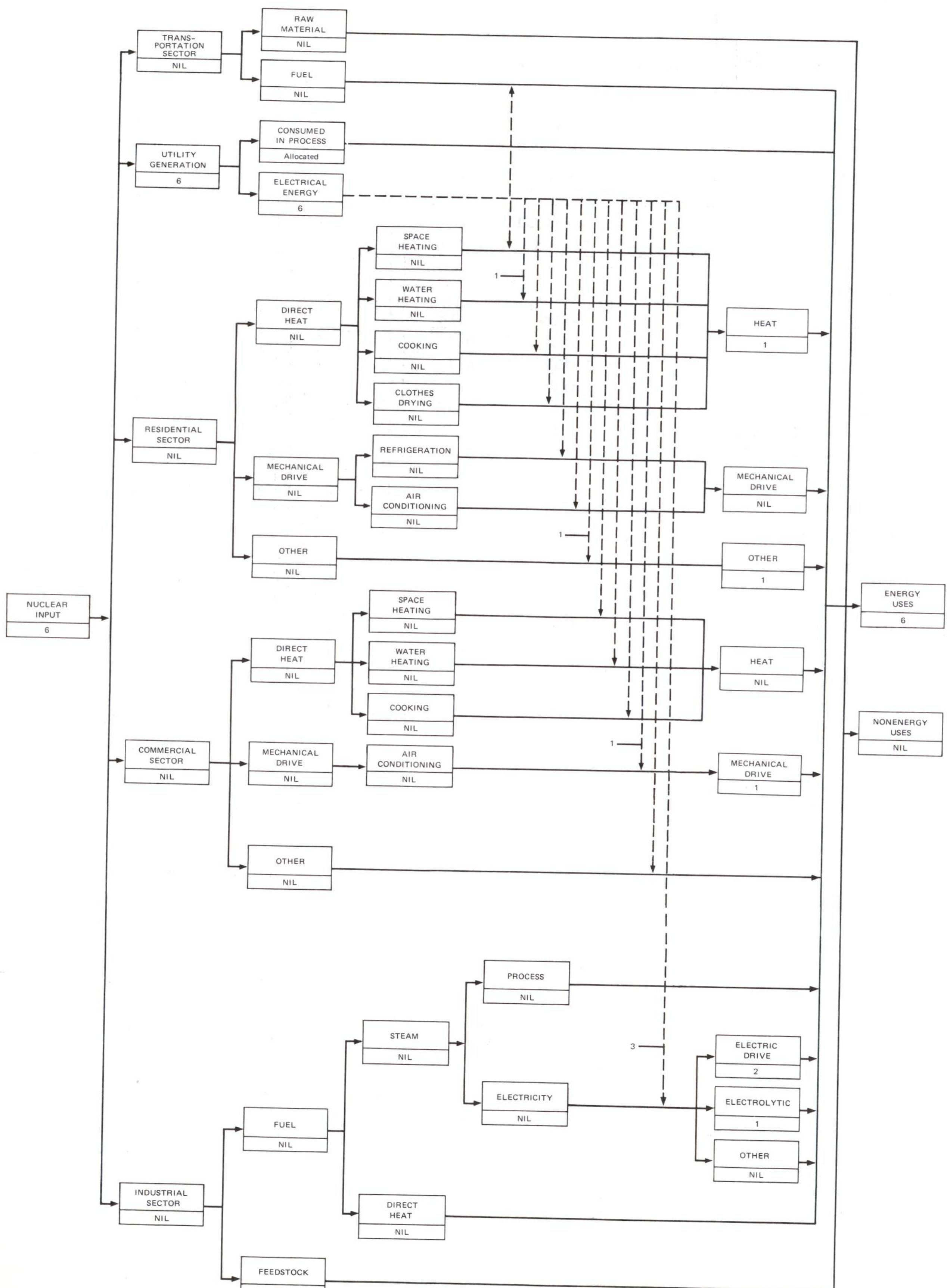


FIGURE 47 1960 CONSUMPTION OF NUCLEAR POWER (Trillions of Btu)

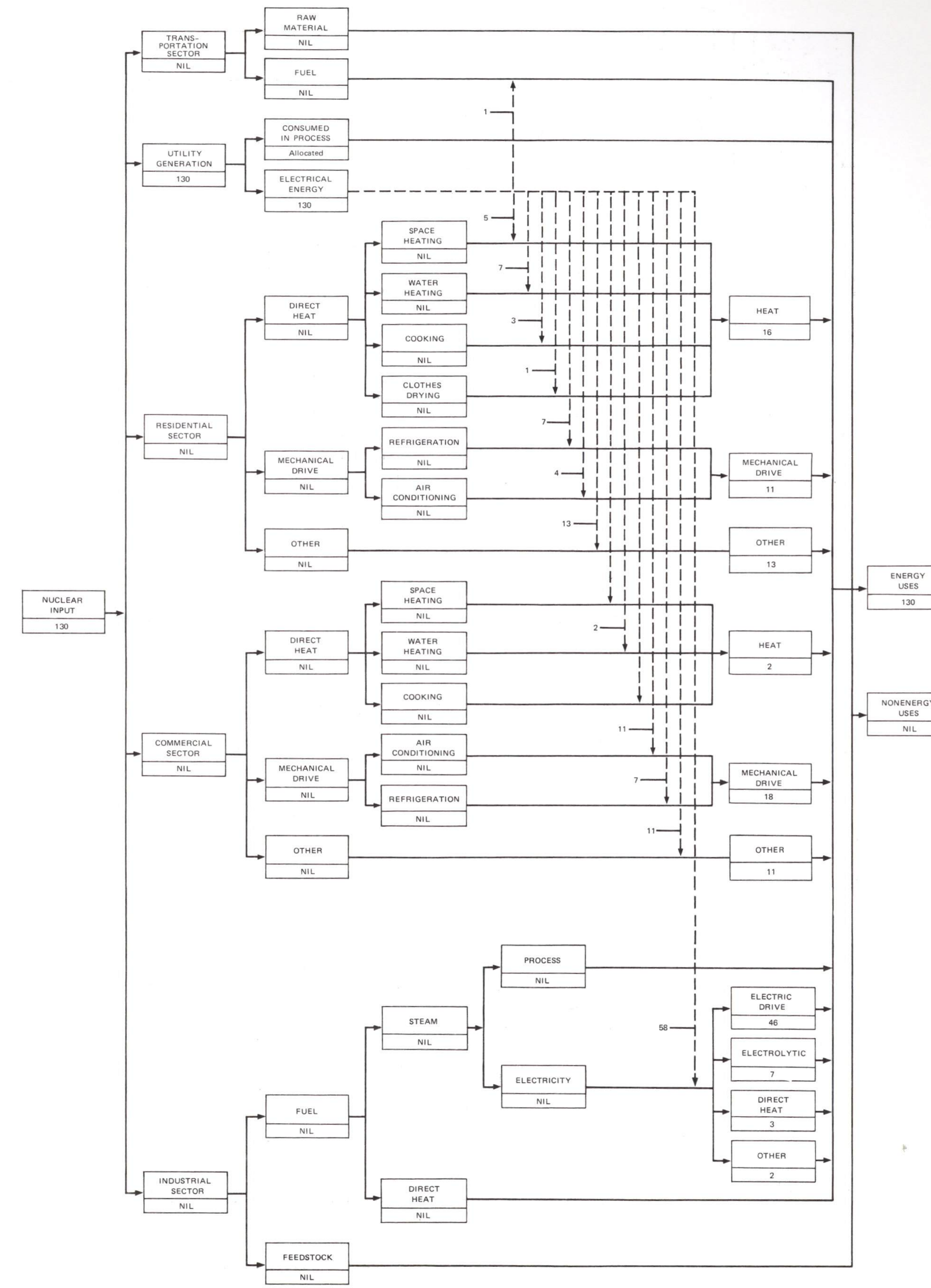


FIGURE 48 1968 CONSUMPTION OF NUCLEAR POWER (Trillions of Btu)

Appendix C

20 MAJOR SIC GROUPS*

Appendix C

20 MAJOR SIC GROUPS*

Major Group 20--Food and Kindred Products

This major group includes establishments manufacturing foods and beverages for human consumption, and certain related products, such as manufactured ice, chewing gum, vegetable and animal fats and oils, and prepared feeds for animals and fowls.

Major Group 21--Tobacco Manufactures

This major group includes establishments engaged in manufacturing cigarettes, cigars, smoking and chewing tobacco, and snuff, and in stemming and redrying tobacco. The manufacture of insecticides from tobacco byproducts is included in Major Group 28.

Major Group 22--Textile Mill Products

This major group includes establishments engaged in performing any of the following operations: (1) preparation of fiber and subsequent manufacturing of yarn, thread, braids, twine, and cordage; (2) manufacturing broad woven fabric, narrow woven fabric, knit fabric, and carpets and rugs from yarn; (3) dyeing and finishing fiber, yarn, fabric, and knit apparel; (4) coating, waterproofing, or otherwise treating fabric; (5) the integrated manufacture of knit apparel and other finished articles from yarn; and (6) the manufacture of felt goods, lace goods, bonded-fiber fabrics, and miscellaneous textiles.

This classification makes no distinction between the two types of organizations which operate in the textile industry: (1) the "integrated" mill which purchases materials, produces textiles and related

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* The source is Standard Industrial Classification Manual, Executive Office of the President, Bureau of the Budget.

articles within the establishment, and sells the finished products; and (2) the "contract" or "commission" mill which processes materials owned by others. Converters or other nonmanufacturing establishments which assign materials to contract mills for processing (other than knitting) are classified in nonmanufacturing industries; establishments which assign yarns to outside contractors or commission knitters for the production of knit products are classified in Group 225.

Major Group 23--Apparel and Other Finished Products Made From Fabrics and Similar Materials

This major group, known as the cutting-up and needle trades, includes establishments producing clothing and fabricating products by cutting and sewing purchased woven or knit textile fabrics and related materials such as leather, rubberized fabrics, plastics and furs.

Included in the apparel industries are three types of establishments: (1) the "regular" or inside factories, (2) contract factories, and (3) apparel jobbers. The regular factories perform all of the usual manufacturing functions within their own plant; the contract factories manufacture apparel from materials owned by others; and apparel jobbers perform the entrepreneurial functions of a manufacturing company, such as buying raw materials, designing and preparing samples, arranging for the manufacture of the garments from their materials and selling of the finished apparel.

Custom tailors and dressmakers not operating on a factory basis are classified in nonmanufacturing industries; establishments which purchase and resell finished garments but do not perform the functions of the apparel jobbers are classified in Wholesale Trade.

Major Group 24--Lumber and Wood Products, Except Furniture

This major group includes logging camps engaged in cutting timber and pulpwood; merchant sawmills, lath mills, shingle mills, cooperage stock mills, planing mills, and plywood mills and veneer mills engaged in producing lumber and wood basic materials; and establishments engaged in manufacturing finished articles made entirely or mainly of wood or wood substitutes. Certain types of establishments producing wood products are classified elsewhere. For example, furniture and office and store fixtures are classified in Major Group 25; pianos, musical instruments, toys and playground equipment, and caskets and coffins in Major

Group 39. Woodworking in connection with construction, in the nature of reconditioning and repair, or performed to individual order, is classified in nonmanufacturing industries.

Major Group 25--Furniture and Fixtures

This major group includes establishments engaged in manufacturing household, office, public building, and restaurant furniture; and office and store fixtures. Establishments primarily engaged in the production of millwork are classified in Industry 2431; cut stone and concrete furniture in Major Group 32; laboratory and hospital furniture in Major Group 38; beauty and barber shop furniture in Major Group 39; and woodworking to individual order in the nature of reconditioning and repair in nonmanufacturing industries.

Major Group 26--Paper and Allied Products

This major group includes the manufacture of pulps from wood and other cellulose fibers, and rags; the manufacture of paper and paperboard; and the manufacture of paper and paperboard into converted products such as paper coated off the paper machine, paper bags, paper boxes, and envelopes. Certain types of converted paper products are classified elsewhere, such as abrasive paper in Industry 3291, carbon paper in Industry 3955, and photosensitized and blueprint paper in Industry 3861.

Major Group 27--Printing, Publishing, and Allied Industries

This major group includes establishments engaged in printing by one or more of the common processes, such as letterpress, lithography, gravure, or screen; and those establishments which perform services for the printing trade, such as bookbinding, typesetting, engraving, photoengraving, and electrotyping. This major group also includes establishments engaged in publishing newspapers, books, and periodicals, regardless of whether or not they do their own printing. News syndicates are classified in Service Industries, (Industry 7351), and textile printing and finishing in Major Group 22.

Major Group 28--Chemicals and Allied Products

This major group includes establishments producing basic chemicals, and establishments manufacturing products by predominantly chemical processes. Establishments classified in this major group manufacture three general classes of products: (1) basic chemicals such as acids, alkalies, salts, and organic chemicals; (2) chemical products to be used in further manufacture such as synthetic fibers, plastic materials, dry colors, and pigments; (3) finished chemical products to be used for ultimate consumption such as drugs, cosmetics, and soaps; or to be used as materials or supplies in other industries such as paints, fertilizers, and explosives. The mining of natural rock salt is classified in mining industries. Establishments primarily engaged in manufacturing nonferrous metals and high percentage ferroalloys are classified in Major Group 33; silicon carbide in Major Group 32; baking powder, other leavening compounds, and starches in Major Group 20; and embalming fluids and artists' colors in Major Group 39. Establishments primarily engaged in packaging, repackaging, and bottling of purchased chemical products, but not engaged in manufacturing chemicals and allied products, are classified in trade industries.

Major Group 29--Petroleum Refining and Related Industries

This major group includes establishments primarily engaged in petroleum refining, manufacturing paving and roofing materials, and compounding lubricating oils and greases from purchased materials. Establishments manufacturing and distributing gas to consumers are classified in public utilities industries, and those primarily engaged in producing coke and byproducts in Major Group 33.

Major Group 30--Rubber and Miscellaneous Plastics Products

This major group includes establishments manufacturing from natural, synthetic, or reclaimed rubber, gutta percha, balata, or gutta siak, rubber products such as tires, rubber footwear, mechanical rubber goods, heels and soles, flooring, and rubber sundries. This group also includes establishments manufacturing or rebuilding retreaded tires, but automobile tire repair shops engaged in recapping and retreading automobile tires are classified in Services. This group also includes establishments engaged in molding primary plastics for the trade, and manufacturing miscellaneous finished plastics products. The manufacture of elastic webbing is classified in Major Group 22; products made of elastic webbing and garments made from rubberized fabrics in Major Group 23;

synthetic rubber in Industry 2822; and plastics materials in the form of sheets, rods, tubes, granules, powders, or liquids in Industry 2821.

Major Group 31--Leather and Leather Products

This major group includes establishments engaged in tanning, currying and finishing hides and skins, and establishments manufacturing finished leather and artificial leather products and some similar products made of other materials. Leather converters are also included.

Major Group 32--Stone, Clay, Glass, and Concrete Products

This major group includes establishments engaged in manufacturing flat glass and other glass products, cement, structural clay products, pottery, concrete and gypsum products, cut stone, abrasive and asbestos products, etc., from materials taken principally from the earth in the form of stone, clay, and sand. When separate reports are available for mines and quarries operated by manufacturing establishments classified in this major group, the mining activities are classified in mining industries; when separate reports are not available, the mining activities are classified herein with the manufacturing operations.

Major Group 33--Primary Metal Industries

This major group includes establishments engaged in the smelting and refining of ferrous and nonferrous metals from ore, pig, or scrap; in the rolling, drawing, and alloying of ferrous and nonferrous metals; in the manufacture of castings, forgings, and other basic products of ferrous and nonferrous metals; and in the manufacture of nails, spikes, and insulated wire and cable. This major group includes the production of coke.

Major Group 34--Fabricated Metal Products, Except Ordnance Machinery, and Transportation Equipment

This major group includes establishments engaged in fabricating ferrous and nonferrous metal products such as metal cans, tinware, hand tools, cutlery, general hardware, nonelectric heating apparatus, fabricated structural metal products, metal stampings and a variety of metal and wire products not elsewhere classified. Certain important segments of the metal fabricating industries are classified in other major groups, such as ordnance in Major Group 19; machinery in Groups 35 and 36; transportation equipment in Major Group 37; professional scientific and controlling instruments, watches and clocks in Major Group 38; and jewelry and silverware in Major Group 39. Establishments primarily engaged in producing ferrous and nonferrous metals and their alloys are classified in Major Group 33.

Major Group 35--Machinery, Except Electrical

This major group includes establishments engaged in manufacturing machinery and equipment, other than electrical equipment (Major Group 36) and transportation equipment (Major Group 37). Machines powered by built-in or detachable motors ordinarily are included in this major group, with the exception of electrical household appliances (Major Group 36). Portable tools, both electric and pneumatic powered, are included in this major group, but hand tools are classified in Major Group 34.

Major Group 36--Electrical Machinery, Equipment, and Supplies

This major group includes establishments engaged in manufacturing machinery, apparatus, and supplies for the generation, storage, transmission, transformation, and utilization of electrical energy. The manufacture of household appliances is included in this group, but industrial machinery and equipment powered by built-in or detachable electric motors is classified in Major Group 35.

Major Group 37--Transportation Equipment

This major group includes establishments engaged in manufacturing equipment for transportation of passengers and cargo by land, air, and water. Important products produced by establishments classified in this major group include motor vehicles, aircraft, ships, boats, railroad equipment, and miscellaneous transportation equipment such as motorcycles, bicycles, and horse drawn vehicles.

Major Group 38--Professional, Scientific, and Controlling Instruments; Photographic and Optical Goods; Watches and Clocks

This major group includes establishments engaged in manufacturing mechanical measuring, engineering, laboratory, and scientific research instruments; optical instruments and lenses; surgical, medical, and dental instruments, equipment, and supplies; ophthalmic goods; photographic

equipment and supplies; and watches and clocks. Establishments primarily engaged in manufacturing instruments for indicating, measuring, and recording electrical quantities and characteristics are classified in Industry 3611.

Major Group 39--Miscellaneous Manufacturing Industries

This major group includes establishments primarily engaged in manufacturing products not classified in any other manufacturing major group. Industries in this group fall into the following categories: jewelry, silverware and plated ware; musical instruments; toys, sporting and athletic goods; pens, pencils, and other office and artists' materials; buttons, costume novelties, miscellaneous notions; brooms and brushes; morticians' goods; and other miscellaneous manufacturing industries.

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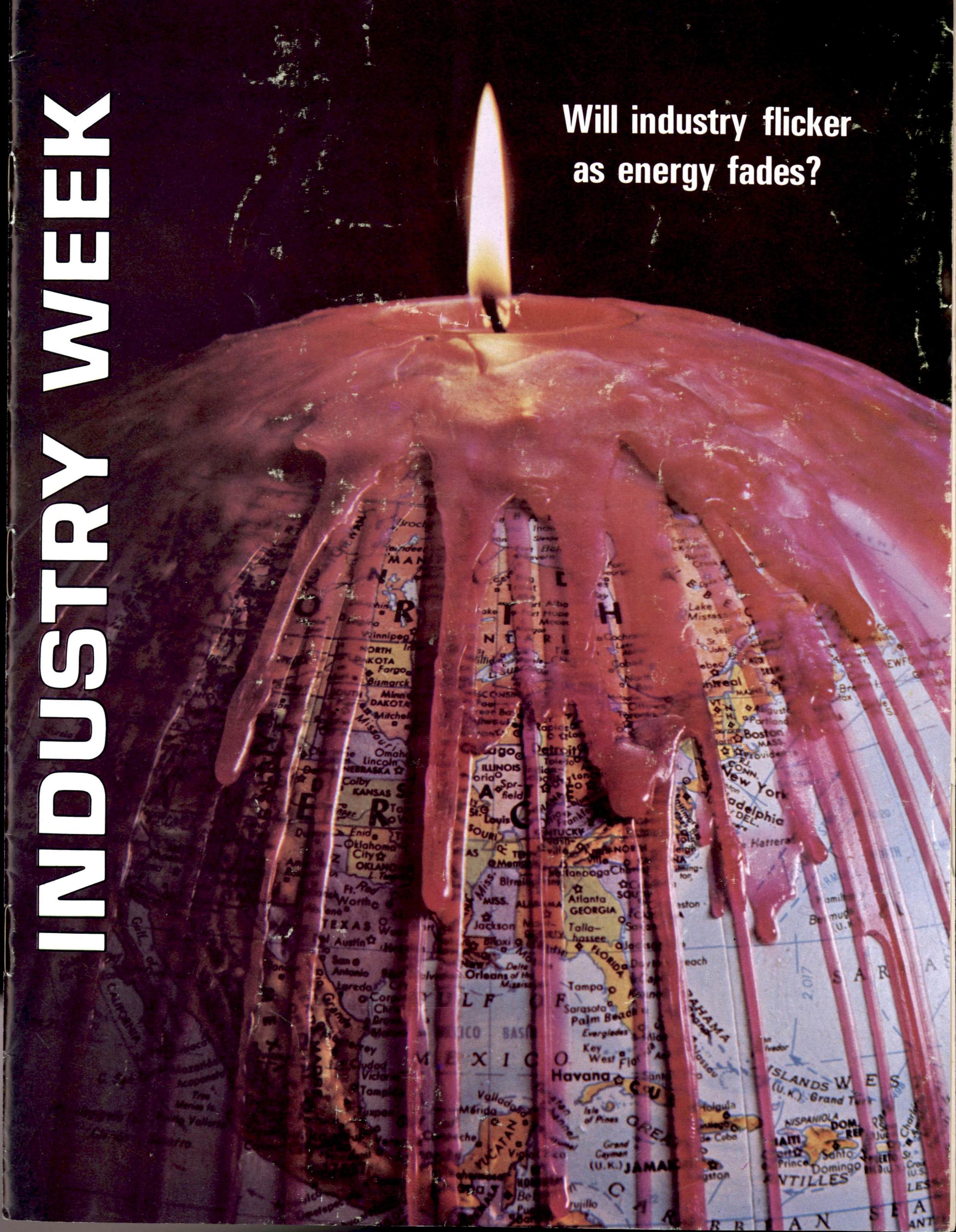
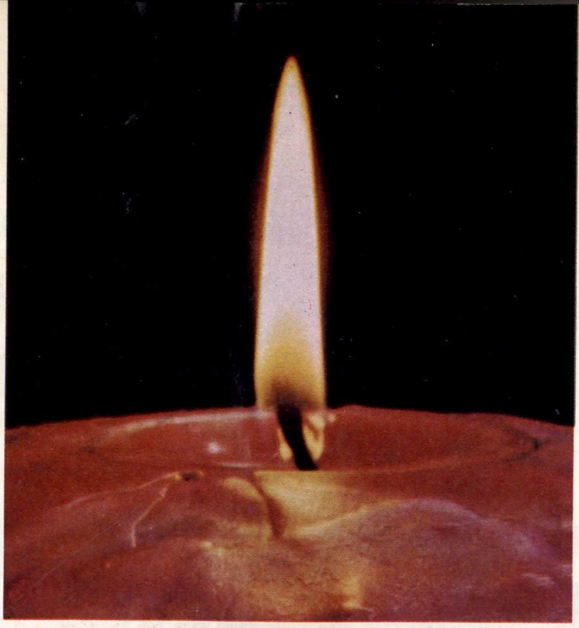
INDUSTRY WEEK

Will industry flicker as energy fades?





Will industry flicker as energy fades?

Prepared by **Floyd G. Lawrence**
and **William H. Miller**
with **David H. Larsen**

ENERGY RATIONING—just getting an allocation of any fuel at any price—could be the outlook industry faces in the next decade.

Incredible as that may seem, we have regulated ourselves into a dilemma: Increasingly, those fuels which are available cannot be used, and those fuels which can be used are not available.

The impact on our competitiveness in markets at home and abroad, on U. S. jobs, and on the pressure for U. S. industry to move overseas to survive, is only beginning to be felt. But it may dominate basic industry planning.

Natural gas and oil are the keys to the problem. Industry derives 78% of its primary energy from these fuels.

To satisfy that appetite, notes Secretary of Commerce Peter G. Peterson, "imports of oil and gas alone in 1970 amounted to $2.7 billion"—a figure exceeding the U. S. balance of trade deficit in 1971. He warns that our projected annual deficit in oil and gas by 1985, "assuming we import fuels at the level projected by the Interior Dept., is $25 billion."

To put this in perspective, *all* U. S. imports of manufactured goods ran only slightly more than $30 billion in 1971, Secretary Peterson points out, adding that from a security as well as an economic standpoint, meeting our energy needs through imports would be untenable.

"We could well go through a period during which energy won't be available, rationing would be introduced, jobs would be lost, and production would be cut back," says Gerald D. Gunning, associate energy economist, Chase Manhattan Bank, New York. The only alternatives he sees are very dramatic measures to increase development of domestic oil and natural gas, and steps "to turn this whole energy situation around." And it will take quite some turning.

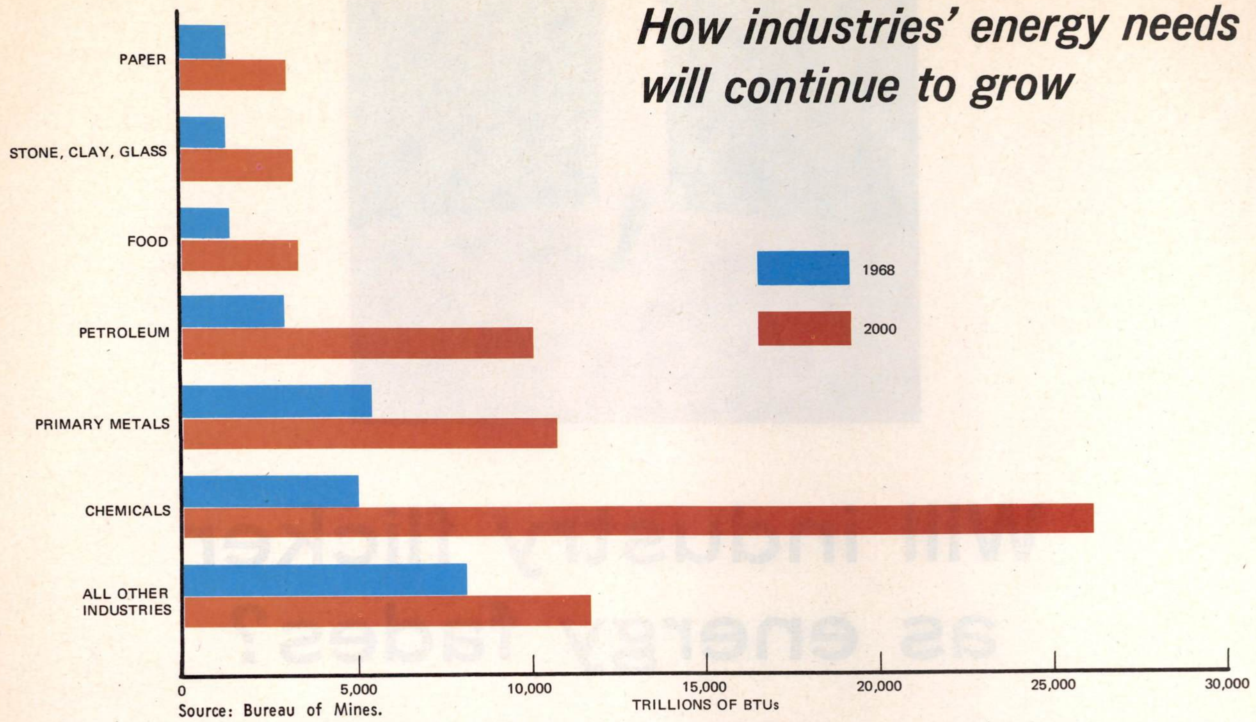
For decades the U. S. has ignored its utility bills. We have had a national energy policy: keep it cheap. We implemented that policy through regulatory distortion of free market relationships.

Energy *apparently* cheap and abundant was the result, and it played an important role in U. S. industrial growth. But we bought that cheap and abundant energy by borrowing against the future. Now our accounts are past due, and they will fall most heavily on industry.

In some cases supplies will be turned off. Prices will rise sharply. The reason is inexorably clear.

"Between now and 1985 the energy industries will have to invest more than $375 billion in new facilities to provide for our growing needs," esti-

How industries' energy needs will continue to grow



Source: Bureau of Mines.

mates John G. McLean, chairman of the National Petroleum Council's Committee on U. S. Energy Outlook as well as president of Continental Oil Co., New York.

And that figure, he says, is exclusive of new petroleum marketing, gas distribution, and electric distribution facilities.

Prices must go up because the energy companies can neither generate the necessary funds internally at today's profit levels nor attract the funds from outside sources at current rates of return on investment, Mr. McLean explains.

All industry will directly feel the effect of higher energy costs. But that effect will be compounded in higher material costs as well. For the basic industries—primary metals; stone, clay and glass; petroleum and coal products; paper; and chemicals together with food—account for two-thirds of all industry energy needs.

Further adding to the cost will be not only higher prices for existing energy sources, but in many cases the costs of switching to more expensive forms of energy in the face of shortages.

Anaconda Co., New York, for example has been advised that there will be no natural gas available this winter to fuel copper smelting operations in the Southwest. Plans are underway to convert the operation to fuel oil—but at double the energy costs, says Howard L. Edwards, vice president and secretary.

Others in the nonferrous metals industry are going further and converting to electric smelters—at a still higher energy cost. Anaconda is considering the move, says Mr. Edwards, but observes that "you get a lot less energy from the primary fuel by converting it twice."

Although electricity is three times as costly as gas in heat treating applications, Thomas A. Blanchard, product manager, special furnace equipment, Midland-Ross Corp.'s Surface Combustion Div., Toledo, Ohio, reports that "furnaces going to Illinois and Indiana are electric rather than gas or oil today."

The steel industry also is moving from natural gas to oil or oil standby for soaking pits, annealing furnaces, and other applications, reports E. L. Andrews, vice president-materials for Allegheny Ludlum Industries Inc., Pittsburgh, and chairman of the American Iron & Steel Institute's Critical Materials Supply Committee.

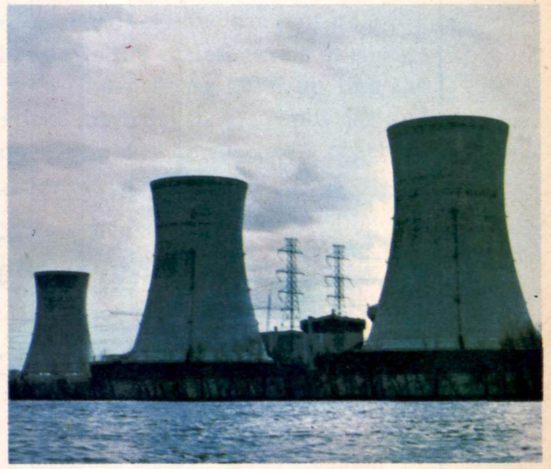
Mr. Andrews points out that the dual burner provision adds cost, as does the necessary storage capacity for the fuel oil. And not only is the cost of the fuel oil higher than that of natural gas, but "competition for the available oil has already pushed the price up 20 to 25%. Gas has been very important in annealing and processing in the steel industry," says Mr. Andrews, "but that day is gone."

Self-rationing?

Although natural gas today provides 46% of industry's primary energy, in the future "we believe

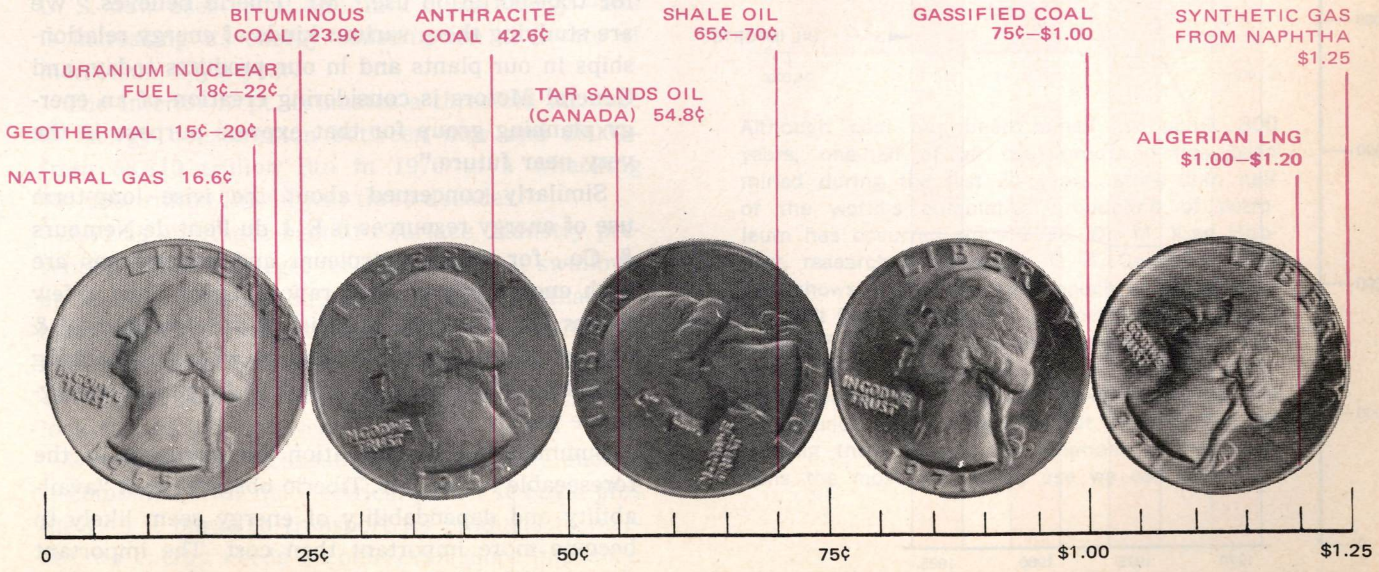
Vast complex of power stations built to supply the energy-thirsty Los Angeles area. Twelve fossil-fueled boilers with a combined capacity of 3 million kw are located in a 3-square mile area.

Huge and awe-inspiring, cooling towers dominate the skyline at Metropolitan Edison Co.'s nuclear generating station at Three-Mile Island near Middletown, Pa. These will become a more familiar sight as the demand for power increases.



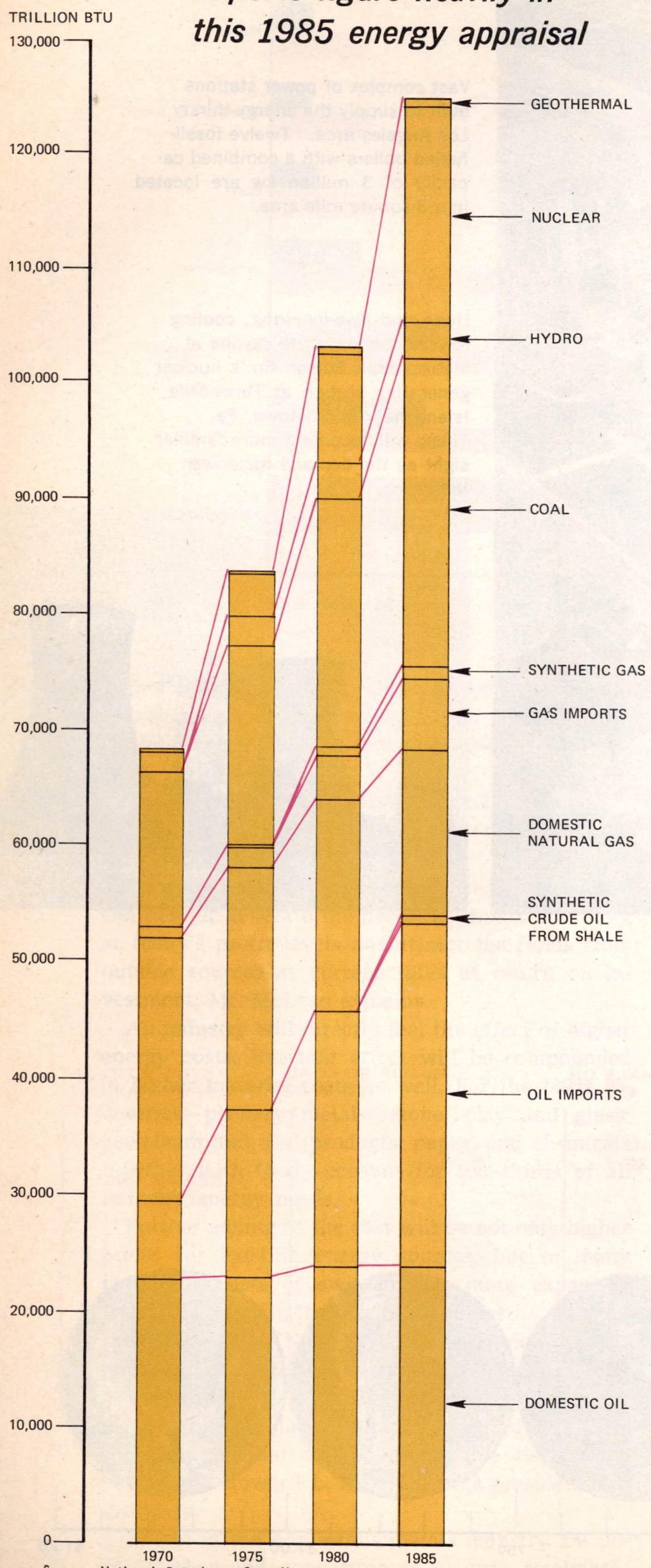
What will energy cost?

COST PER MILLION BTUs.



Source: Bureau of Mines and Atomic Energy Commission.

Imports figure heavily in this 1985 energy appraisal



Source: National Petroleum Council.

residential needs for gas should come first," says Gabriel N. Tiberio, director, Plant & Environmental Engineering Section of General Motors Corp.'s environmental activities staff. "Commercial needs like schools and hospitals should come next, and finally industry should be able to get its share for really high priority uses like heat treating in a protective gas atmosphere or in automatic soldering.

"Most natural gas applications of any nonessential kind in our plants will be replaced by electricity," says Mr. Tiberio, "and we must begin to consider the impact of that change back at the generating plant."

Petroleum, believes Mr. Tiberio, should be allocated in the future to transportation.

"Gasoline could be rationed as early as next year," observes Mr. Gunning at Chase Manhattan. He explains that "because natural gas is not available, many utilities and industrial customers are unable to get low-sulfur residual fuel oil and are turning to distillate. The yield on the refining pattern has been shifted to middle distillate to meet this demand. As a consequence, output of gasoline has been restricted.

"We're going from a situation where we had surplus gasoline to a situation where we don't have enough," says Mr. Gunning. "Unless we have a change in the import quotas allowing more imports of distillate oil this coming winter, we could have a situation where gasoline stocks drop to the point that rationing would be necessary."

"Because energy is a smaller cost component of manufacturing than of transportation, it may make sense for plants to pay more and conserve the oil for transportation use," Mr. Tiberio believes. "We are studying these various kinds of energy relationships in our plants and in our products today, and General Motors is considering creation of an energy planning group for that express purpose in the very near future."

Similarly concerned about the wise long-term use of energy resources is E. I. du Pont de Nemours & Co., for whom petroleum and natural gas are both energy sources and raw material. Just a few weeks ago, Du Pont established a Petrochemical & Energy Development Section to study changing supplies and costs in an effort to formulate a long-range plan.

Summarizing the situation for industry in the foreseeable future, Mr. Tiberio observes that "availability and dependability of energy seem likely to become more important than cost. The important thing will be: can we get it when we want it?"

Energy shortage casts lengthening shadows

INDUSTRY DOES seem destined to receive lower priority as energy resources tighten. The trend is already evident in the the allocation of natural gas, where the energy crisis is most immediately apparent.

Gen. George A. Lincoln, director of the Office of Emergency Preparedness (OEP) and chairman of the federal government's Joint Board on Fuel Supply & Transport, explains that one of the board's prime objectives is to insure that "human users" of natural gas—homes, hospitals, schools, and essential government facilities—are not deprived in times of emergency. "There is a strong case to assure priority" to those users over industry, he has testified before a Senate committee.

Indeed, the Federal Power Commission (FPC), which regulates natural gas sold interstate, pointed out in May that it plans to "arrive at a method of cost classification, allocation, and rate design which will produce strong economic pressure toward a more efficient allocation of our fuel reserves. This will be directed particularly to conserving natural gas for residential, commercial, and other uses for which this clean fuel is greatly needed *and to discouraging the use of gas for large volume industrial and boiler fuel purposes.*"

Regardless of priorities, industry and private consumers both face the same uncertain future. With less than 6% of the world's population, the U. S. now uses about one-third of its energy—and is increasing its energy consumption at a rate of more than 4% a year.

The Interior Dept. estimates a threefold increase in energy consumption between now and 2000—from 68,810 trillion Btu in 1970 to a whacking 191,556 trillion Btu in just three decades.

And as shortages begin to surface, industry presents a tempting target for curtailment. It swallows up 26.2% of the nation's primary energy (that obtained directly from fossil fuels), show 1970 statistics compiled by the National Petroleum Council (NPC), an advisory body studying the energy outlook for the Interior Dept.

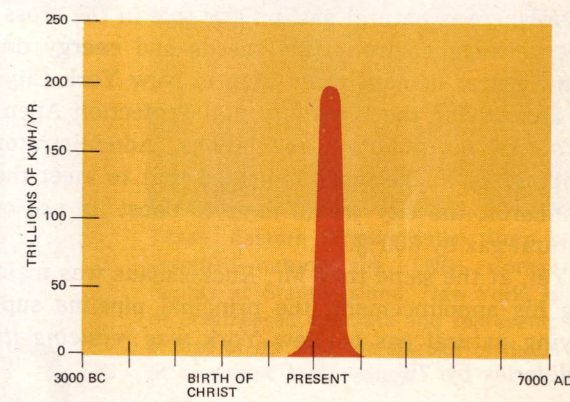
When industry's consumption of primary energy is combined with the electrical power it buys, plus the fuel it burns to transport its products to market, its energy needs become even more imposing. A study by Stanford Research Institute for the Office of Science & Technology pegs industry's 1968 share of total energy consumption at 41.1%.

Bottom of the jar

The nation's energy bind comes from relying for slightly more than 95% of its energy needs on three basic fuels: petroleum (which accounted for 43% of total U. S. energy consumption in 1971); natural gas (33%); and coal (20%). The rest comes from hydroelectric and nuclear power.

"Oil, gas, and coal are the easiest forms of energy to utilize, and we've been using them up like the little boy who sticks his hand in the candy jar and thinks the bottom will never be reached," observes

Fossil fuels: a brief candle



Although coal has been mined for about 800 years, one-half of all coal produced has been mined during the last 31 years. More than half of the world's cumulative production of petroleum has occurred since 1956. Dr. M. King Hubbert, research geophysicist, U. S. Geological Survey, shows in this chart the epoch of exploitation of fossil fuels in historical perspective from minus to plus 5,000 years from the present. If industrialization is to survive the decline of fossil fuels, other sources of energy and power of comparable magnitude must be found. But beyond that, is burning these unique combinations of hydrocarbons the most worthwhile use we can conceive?

Hollis Dole, assistant secretary of interior for mineral resources.

Now, there's evidence the U. S. is reaching the bottom of the jar. Availability problems exist, or loom on the horizon, in all three of the basic fuels which have long been so plentiful, accessible, and inexpensive.

The crisis has surfaced first in natural gas which not only is cheap because of controversial FPC price regulation, but also is the most desirable fuel from an environmental standpoint. Tough new air pollution regulations have intensified the already brisk demand for it and helped push the rate of demand increase for natural gas in 1970 to 7.2%—higher than any other fuel.

The demand for natural gas has been so heavy, in fact, that the industry's Future Requirements Committee direly warns that gas companies will be able to supply only 86% of the nation's requirements by 1975. To make up the difference, says Gen. Lincoln, "it seems clear that imports of LNG [liquefied natural gas] or SNG [synthetic natural gas] feedstocks, or both, will be necessary to provide needed supplies of pipeline gas."

Nowhere is natural gas' unique role in the crossfire between environmental needs and energy demand better demonstrated than in New York City. In announcing the Environmental Protection Agency's new air pollution regulations, Administrator William D. Ruckelshaus indicated that to meet the standards, the city would have to boost its use of natural gas by 300%.

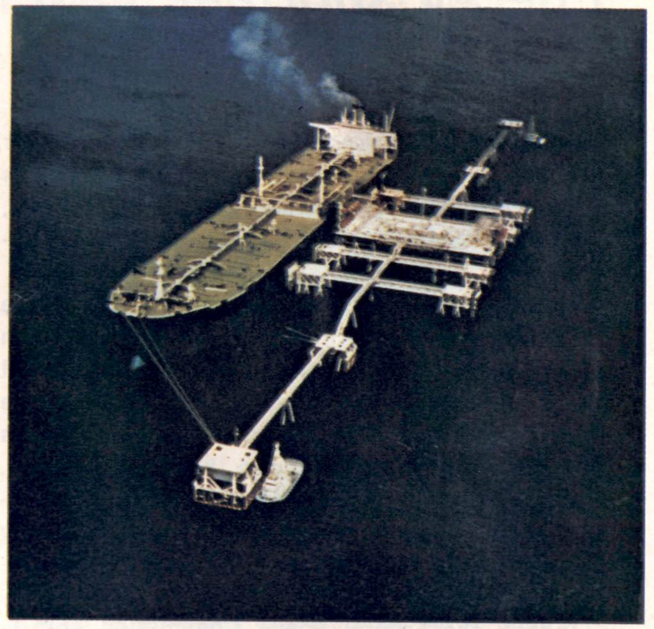
Yet, at the same time Mr. Ruckelshaus was making his announcement, the principal pipeline supplying natural gas to New York was *reducing its deliveries by* 7%.

Shrinking supplies

While demand soars, natural gas proved reserves (those which are known to exist and which can be economically produced by using conventional methods) have been dropping every year since 1967. Gas sales contracts now in force account for 95% of the 259 trillion cu ft of proved reserves, leaving only 5% available for new customers.

Even more alarming, gas reserves in 1970 totaled only 14 times the nation's annual production of natural gas, a sharp decline just since 1964, when these reserves were 18 times annual production.

In the oil industry, the situation is even worse. Proved oil reserves were 12½ times annual pro-



Offshore oil terminals are a solution to loading and unloading the giant supertankers now in use. Gulf Oil Corp.'s Asian Trans-Shipment Terminal at Okinawa can accommodate two tankers simultaneously.

A weak Arctic Circle sun silhouettes a drilling rig at work on Prudhoe Bay, Alaska. Varying estimates have been made of North Slope reserves, ranging from 10 billion to 20 billion barrels.

Coal preparation, storage, and conveying facilities at Peabody Coal Co.'s Black Mesa mine. From this point, coal is transported by slurry pipeline 275 miles to the Mohave generating station at Davis Dam in Nevada.

Texas Eastern Transmission Corp.'s liquefied natural gas (LNG) storage facility at Staten Island, New York, is of prestressed concrete and represents a first of its kind for storage of fluids at cryogenic temperature.

Oil, gas, and coal still the lifeblood of industry

New Benecia refinery of Humble Oil & Refining Co. processes 72,000 barrels of crude oil daily.

duction in 1957; today they're down to nine times annual production.

As a result of the supply pinch, the nation is forced to rely on imports for nearly 25% of its oil needs, and estimates are the figure will reach 50% by 1985. Even that projection anticipates that oil will be available from Alaska's North Slope, which remains highly questionable.

Beyond adversely affecting the U. S.'s already critical balance of payments, this strong reliance on foreign sources—particularly oil from the convulsive Persian Gulf countries—presents an uncertainty of supply that poses grave implications for national security. And as the State Dept. points out, it gives our country less flexibility in conducting its foreign affairs.

Reserves of coal, by contrast, are the nation's most abundant, and could last for centuries. However, environmental restrictions create problems today because most of the readily accessible coal near big Eastern markets has a high sulfur content.

"We have billions of dollars of investment in generating plants in the East that have not been amortized and must be kept going," points out Interior's Assistant Secretary Dole. "Either we're going to have to import low-sulfur coals or oil to utilize these plants, or devise a means for taking sulfur out."

Neither of those alternatives is attractive.

The role of energy costs in industry products

	Cost of purchased fuels and electricity as percentage of value added
Food	2.5
Tobacco	0.7
Textiles	3.5
Apparel	0.9
Lumber	4.2
Furniture	1.4
Paper	5.9
Printing	0.9
Chemicals	5.0
Petroleum	8.3
Rubber and plastics	2.6
Leather	1.3
Stone, clay, and glass	7.6
Primary metals	8.3
Fabricated metals	2.0
Nonelectrical machinery	1.3
Electrical machinery	1.2
Transportation equipment	1.4
Instruments	0.9
Miscellaneous and ordnance	1.2
Total manufacturing	3.0

Source: National Economic Research Associates Inc.

Out in the cold

But it's the natural gas shortage that is most immediately affecting industry. Managers around the country shuddered two years ago when, for example, gas deliveries in Cleveland were shut off to industrial customers because the East Ohio Gas Co. found itself hard put to supply homeowners during a cold spell; some 35,000 workers were laid off temporarily.

Even though last winter was comparatively mild, seven major pipelines across the country were forced to curtail service. Currently, 27 pipelines have filed curtailment plans with the FPC, reports Chairman John N. Nassikas.

Few gas companies in the East or Midwest are accepting new industrial customers. And several—including Washington Gas Light Co., which serves the nation's capital—have been accepting *no* new customers, residential or industrial, since last November.

Electrical power failures are causing uneasiness among executives, too. Demand for electricity has been averaging an annual growth of about 7%—and doubling every ten years. Of all electricity consumed in the U. S., 68% is for business purposes, and purchased electrical power represents more than a quarter of industry's overall energy needs.

Hot weather could bring problems yet this summer. Even with start-up of many of the 45 new generating plants scheduled to go into operation by September, capacity to meet peak loads will be in "critically tight supply" in parts of the Midwest and the Atlantic Seaboard, notes the OEP. It cites Chicago, Miami, and New York as "cities of special concern."

Despite planned new generating capacity, the electrical power situation seems acute enough that James R. Schlesinger, chairman of the Atomic Energy Commission (AEC), observes that he can "see the day when the country might have to ration electricity."

Energy poverty in the midst of plenty

HOW COULD a nation so rich in natural resources and technology find itself running out of energy?

"Well-qualified people could have predicted this crisis ten years ago," observes John O. Logan, president, Universal Oil Products Co., Des Plaines, Ill. "Unfortunately, the situation sneaked up on industry. Almost every firm that uses fuel had a contract that *appeared* to provide enough for the future. There was no reason to question that source of supply."

One development that "sneaked up" was the snowballing increase in energy demand. "Just in the last three or four years, the use of energy in the U. S. has increased faster than the gross national product," notes an Interior Dept. report, citing rapid growth of air conditioning in homes and automobiles; greater use of home appliances; more cars; expanded use of energy-intensive processing of raw materials; and a "running out of opportunities" to apply known technology to increase efficiency in the use of energy.

Government energy planners were slow in spotting the spiraling demand. For example, in 1964 the FPC estimated that electricity consumption would rise about 6.5% annually—far under the 9.2% increase posted in 1970.

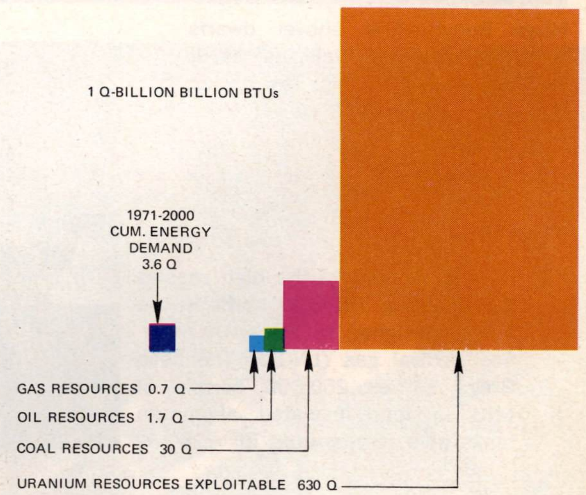
The nation's energy situation "is a mess," admitted Assistant Interior Secretary Dole in testimony before the Senate Interior & Insular Affairs Committee earlier this year. And, he concedes to Industry Week, we are "only today doing the planning that we should have done ten years ago."

Worse still, some 61 government agencies deal with energy matters. And frequently they work at crosspurposes.

Government itself concedes the many inconsistencies in its policies. OEP's Gen. Lincoln lists some:

- Although financing requirements for utilities and other energy developments call for higher utility rates, such increases are discouraged by President Nixon's economic stabilization program.
- The nation relies increasingly on imports of petroleum, yet discourages development of its own petroleum resources. Examples: environmental delays on construction of the transalaskan crude oil pipeline and cancellation of leases in offshore Louisiana oilfields.
- The U. S. has vast reserves of only one fuel—coal—yet it has placed environmental restrictions on its use, even though technology for its clean exploitation is still years away.
- Because of the danger of polluting the ocean, government is curbing offshore oil drilling, even though the alternative invites increased tanker traffic, which also poses pollution threats.
- The nation counts heavily on nuclear power—needed now—to check the rising demand for fossil fuels. Yet it delays development of nuclear plants and boosts the capital required for them through environmental and siting restrictions.
- At a time when the U. S. is running out of natural gas, government allows a wellhead price of only one-fourth of the amount proposed by companies to pay for imported gas to meet demand.

Atomic energy: the only hope?



Source: Atomic Energy Commission.

Deregulation the answer?

"Unhindered by such regulation, the current gas shortage would not have developed," says the American Gas Assn.'s immediate past chairman,

Huge Bucyrus-Erie shovel dwarfs more conventional vehicles as it harvests coal in Illinois. The bucket has a capacity of 140 cu yd.

One of the new breed of supertankers, the **Esso Malaysia** is rated at 190,000 dead weight tons and has been in service since 1968. Newer and larger tankers already in service are rated as large as 321,000 dwt.

Recent addition to the high seas is the "floating Thermos bottle"—the tanker designed to transport liquefied natural gas (LNG). The **Esso Brega** carries 250,000 barrels of LNG in four insulated aluminum tanks at a temperature of −260 F.

G. J. Tankersley, president of East Ohio Gas Co. "Higher prices would have established themselves based on the premium value of natural gas, which would have provided the necessary incentive for production and may have reduced demand for this fuel."

The FPC agrees that wellhead prices—which average about 25 cents per thousand cubic feet—are too low under today's circumstances. It recently recommended increases ranging from 10 to 35% in some areas, but even those boosts are being held up by court appeals.

However, mere increases in wellhead prices aren't enough, believe many energy experts. John Winger, Chase Manhattan vice president and energy economist, charges that "the idea that the consumer was being protected by the regulation has proved false. Instead, by creating an energy shortage, the controls have done the consumer and the nation a great disservice.

"Therefore," he continues, "the controls should be removed—not merely modified, but removed completely and quickly."

The FPC doesn't agree that complete decontrol is the answer. Such a move would cause "chaos in the market," Thomas Joyce, chief of the FPC's Bureau of Natural Gas, contends.

"If a company has a package of gas, it will hold it until it can get the highest price for it," he tells Industry Week. "You'd see gas prices skyrocket. Now is not the time for complete deregulation, for we still have a seller's market."

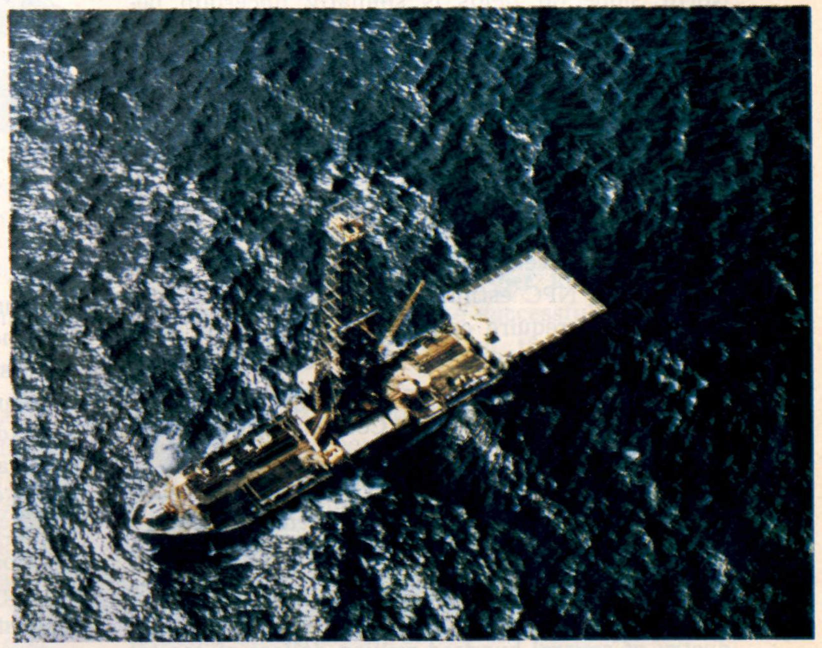
There's little doubt that FPC's controls have discouraged drilling. Exploratory wells drilled in 1971 hit a 24-year low and were less than half the number drilled in 1956. Investment in exploration has suffered a similar drop. Producers put $4.8 billion—65% of their wellhead receipts—into such activity in 1956; the dollar figure remained the same in 1970, even though demand for both oil and gas had more than doubled. But in 1970 the $4.8 billion investment figure represented only 38% of wellhead income.

Asks Frank N. Ikard, president of the American Petroleum Institute, Washington: "Why should investors put money into discovery wells where the chances of success are only 2 in 100 — and where the product, even if brought to market, is price controlled in a way that inhibits a fair return?"

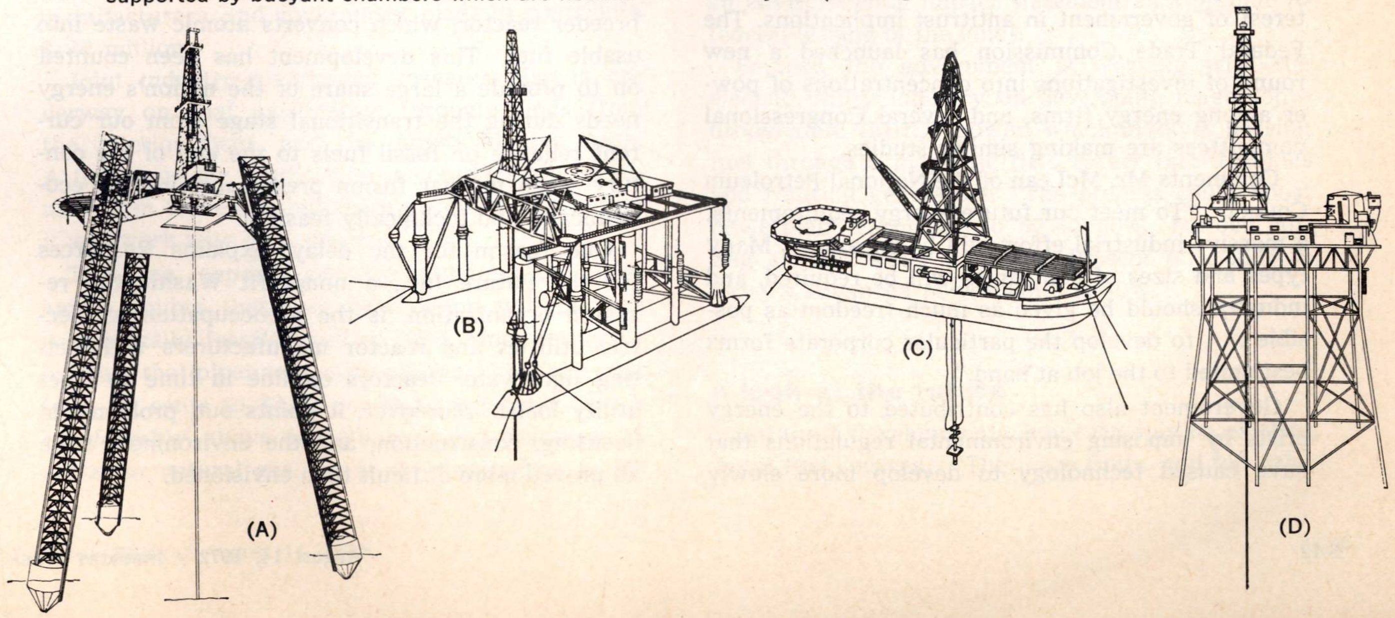
Environmental uncertainties, too, are having an effect on energy company investment. For instance, Thomas D. Barrow, director and senior vice presi-

The search for energy spawns giant equipment and new technology

Two technicians take moisture and density readings with a nuclear probe at the Fairbanks test facility of the University of Alaska. The tests are to determine the possible effect of the transalaskan pipeline system on the environment.



The search for oil and gas at sea has resulted in a unique breed of drilling rigs. The self-elevating rig (A) is towed to the site where its legs are lowered to the sea bed, and its platform jacked up above the water. In water deeper than 300 ft, however, floating rigs must be used. Semisubmersible rigs (B) are supported by buoyant chambers which are flooded with sea water and submerged. The drilling platform stays safely above the water. In very deep waters, ships are used for drilling (C). After a discovery, fixed platforms (D) are built to drill wells and handle production. The photo above is of the drilling vessel **Discoverer II** on location off the west coast of Sabah, Malaysia. (Drawings: courtesy Standard Oil Co. [New Jersey].)



The growing demand for "clean power" results in installations like this desulfurization plant in Amuay, Venezuela. Constructed and operated by the Creole Petroleum Corp., it is one of the first plants built to remove sulfur from heavy fuel oil.

dent of Standard Oil Co. (New Jersey), and former president of its Humble Oil & Refining Co. subsidiary, Houston, points out that in 1968 Humble spent $45 million for rights to oil in California's Santa Barbara Channel. But drilling there has been blocked by environmentalists' court suits, and "so far we haven't gotten one penny out of our investment," he laments. Humble's investment in Alaska's North Slope oil fields is similarly uncertain because of environmental snags.

Needed: big money

It's clear that to meet future demands, energy producers *must* commit massive new funds, not only for exploration and development, but for capital facilities as well.

While the NPC estimates that the U. S. energy industry will require capital expenditures of $375 billion between now and 1985, Kenneth E. Hill, executive vice president and director of Eastman Dillon, Union Securities & Co. Inc., New York, foresees an even higher figure of $475 billion.

Yet, despite the urgent need for capital, government has added to the poor investment problem.

Passage by Congress of the Tax Reform Act of 1969, which reduced the oil depletion allowance from 27½ to 22%, has "deprived the petroleum industry of several hundred million dollars of capital funds annually," says Chase Manhattan's Mr. Winger. That lost capital, he asserts, could have paid for discovery of 1 billion barrels of oil and 5 trillion cu ft of natural gas—enough to satisfy 10% of the nation's needs during the period the legislation has been in effect.

Energy executives bemoan, too, the increased interest of government in antitrust implications. The Federal Trade Commission has launched a new round of investigations into concentrations of power among energy firms, and several Congressional committees are making similar studies.

Comments Mr. McLean of the National Petroleum Council: "To meet our future energy requirements, a massive industrial effort will be necessary. Many types and sizes of companies will be required, and industry should be given as much freedom as possible . . . to develop the particular corporate forms best suited to the job at hand."

Government also has contributed to the energy crisis by imposing environmental regulations that have caused technology to develop more slowly than expected. Dr. Richard Balzhiser, assistant director and energy chief of the President's Office of Science & Technology, suggests that the meeting of rising environmental demands has "strained the research and development capability of the nation" and diverted attention from other needed technological work that might otherwise have taken place.

AEC Chairman Schlesinger points out another aspect of the problem:

Most of the technology required to offset today's energy shortages has been the responsibility of industry, he says. An exception is nuclear energy, which has been a government monopoly. As a result, Mr. Schlesinger asserts, the government has funded R&D money "in a lopsided manner," pouring most of it into nuclear research rather than into other energy sources. "We can see this in retrospect," he admits.

Adding to the technological lag has been the slower-than-expected development of the fast-breeder reactor, which converts atomic waste into usable fuel. This development has been counted on to provide a large share of the nation's energy needs during the transitional stage from our current reliance on fossil fuels to the end of the century when nuclear fusion presumably will be economically and technically feasible.

One reason for the delay, explains Resources for the Future Inc., a nonprofit Washington research organization, is the preoccupation of electric utilities and reactor manufacturers with getting light-water reactors on line in time to meet utility loads. Moreover, it points out, problems in licensing, construction, and the environment have all proved more difficult than envisioned.

Will energy darkness lead to dawn?

THE NATION'S "best hope today" for meeting the growing energy demand is the breeder reactor, said President Nixon in his energy message to Congress last year. But breeder technology is only one of three top priorities identified by the President for joint industry-government R&D efforts.

The other two: coal gasification (which would convert coal into a clean gas which can be transported through pipelines) and stack gas cleaning technology (which would remove sulfur from coal smoke before it is emitted into the air).

The government's logic in pushing these three technologies is to move the nation away from reliance on oil and natural gas and on to more abundant coal and uranium.

The technical feasibility of the breeder has already been proved, but problems remain in its commercialization and in environmental effects. Both problems seem solvable, believes Dr. Balzhiser of the Office of Science & Technology, who expects the breeder to be economically attractive around the mid-1980s.

"The breeder involves a high initial capital cost," he points out, "but it brings fuel costs way down. It should be a significant help in keeping electrical energy prices low."

Next step in the commercialization of the breeder is construction of a demonstration plant. Fund raising for the project, which is estimated to cost $600 million, is going well among electric utility manufacturers, and government plans to contribute $130 million.

Joint industry-government research also is underway on coal gasification through funds from the Interior Dept. and the American Gas Assn. A technique for gasification is commercially available from Germany, but there's a question whether it will work with U. S. coals.

This, too, appears solvable, although Dr. Balzheiser doubts that coal gasification will become economically feasible before 1980. Most estimates indicate that pipeline quality gas from coal will cost from 80 cents to $1.20 per thousand cubic feet—considerably above today's wellhead price of 25 cents for natural gas. "It is more attractive to remove sulfur from coal before combustion rather than at the stack, where stack gas cleaning systems could cost 20 to 25% as much as the whole generating plant," maintains Dr. Balzheiser.

Stack gas desulfurization is a shorter-range goal than either the breeder or coal gasification.

Several processes are being tested and scientists believe that one or more should be available for general use by electric utilities by 1980. Irwin M. Stelzer, president of National Economic Research Associates Inc., estimates that costs will run between 1 and 2 mills per kilowatt-hour—perhaps 1 mill higher if the successful process involves a throw-away product that requires disposal.

Using the rule of thumb that 1 mill per kilowatt-hour is the equivalent of 10 cents per million Btu in fuel costs, the present differential between high- and low-sulfur fuel oil is about 25 cents per million Btu, asserts Mr. Stelzer. That means, he concludes, "that desulfurization costs in excess of 2.5 mills for a proved process would make that process uneconomic—unless the price differential changes."

The government also is eying development of oil shale, huge potential resources of which lie under federal lands in the Rocky Mountains region. These have never been tapped commercially, but they offer such promise as a source of low-sulfur oil that President Nixon has ordered preparation of an environmental impact statement as a prelude to federal leasing of the lands.

Further, the government is working with the electric utility industry on developing magnetohydrodynamic (MHD) power, which involves passing fuel through a magnetic field rather than turbines and rotating generators. The process could boost powerplant efficiency to 50 to 60%, besides cutting air and water pollution. Present efficiency in today's advanced powerplants is 40%.

A look at the future

All these developments, however, rely on existing fossil fuel sources. "These are finite, and too valu-

New energy sources hold promise for the future

able for us to be burning for primary energy," observes Dr. Balzhiser. Ultimately, he says, the nation will have to switch to more advanced energy sources.

Of particular promise is nuclear fusion. This would use deuterium from the ocean, and offers "an infinite supply" of fuel if science can learn to control the nuclear reaction involved.

Promising, too, is geothermal energy—converting underground deposits of hot water or steam into energy. In the U. S., however, such deposits appear to be confined to the West. That makes still another form of geothermal energy—making use of hot rock, which is universally under the earth's surface—a more tempting research target.

Another long-range possibility is solar energy—heat from the sun which is converted into electrical energy by using solar cells. Presently, solar cells are too expensive for practical use.

Besides the Administration's technology push to ease the energy crisis, the problem is drawing heavy interest in both houses of Congress.

Despite all the attention within the Administration and on Capitol Hill, the nation has no official "energy policy." Many observers believe that, because of the number of agencies and economic sectors involved, formulating such a policy just isn't possible.

"What we really need, more than a pretty package labeled 'National Energy Policy,' is a reconciliation between environmental policy goals and the realities of the energy circumstances," says Bruce C. Netschert, vice president, National Economic Research Associates Inc.

President Nixon's energy message, however, was a step in the direction of a policy—particularly his proposal that all important federal energy resource development programs be consolidated under a new Dept. of Natural Resources. So far the proposal has made little headway in Congress.

Costs bound upward

Regardless of government actions, it is clear that industry must prepare itself for a future in which energy is going to be in shorter supply. And certainly more costly.

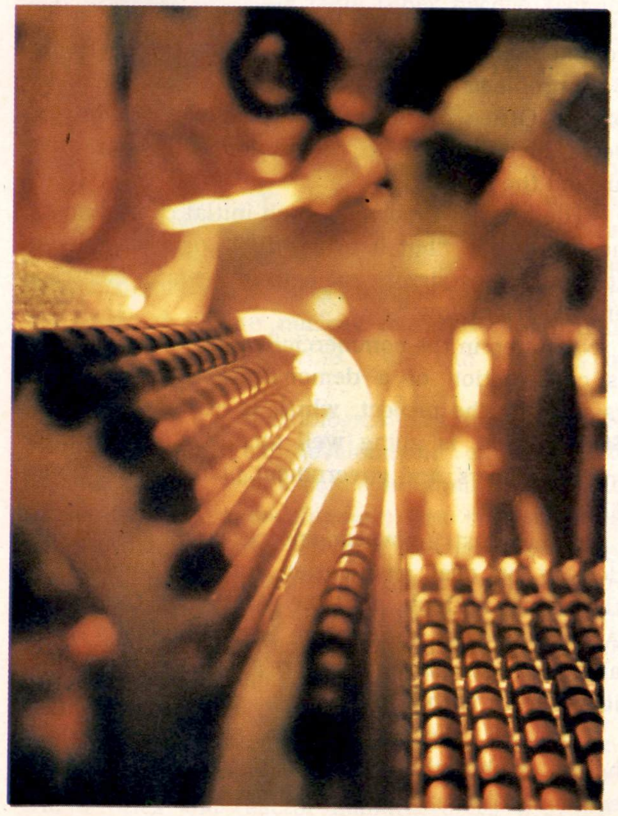
As Secretary Peterson recently told businessmen: "Few predictions I am likely to make will more likely turn out to be right than this one—namely, that the price of energy over the next decade will go up much faster than the cost of goods and services in general."

How much more costly will energy be?

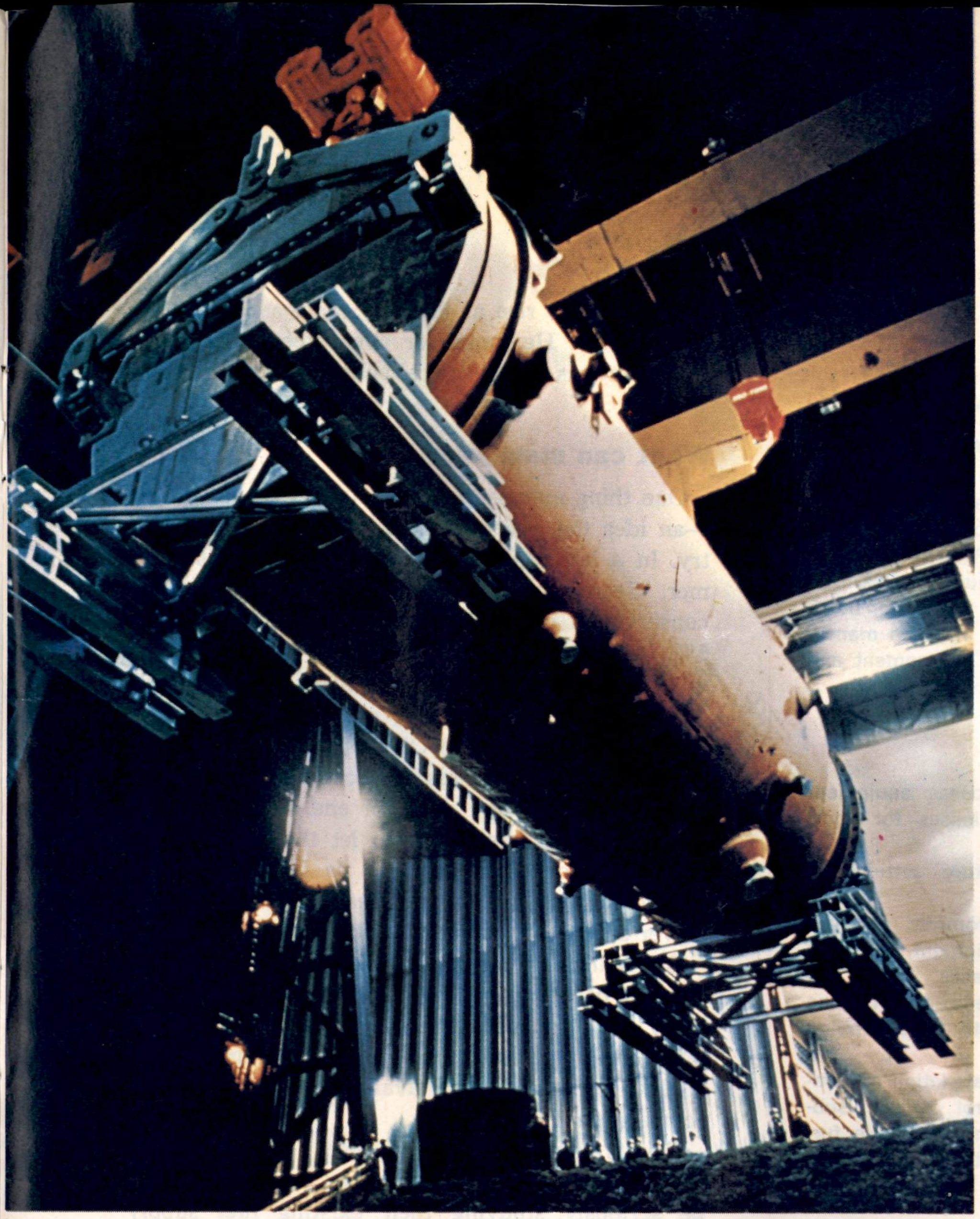
Unfortunately, no one knows. Officials in the coal, oil, and natural gas industries protest there are too many "ifs" involved for them to project future costs of their products.

For the newer fuel sources, however, there is some indication. Besides the 80 cents to $1.20 price per thousand cubic feet estimated for gas from coal, shale oil is likely to cost from $4 to $4.50 a barrel, the Interior Dept. estimates. And a preview of LNG prices came last month when the FPC approved imports of the product from Algeria by El Paso Natural Gas Co., but ruled that El Paso had to charge the actual cost of the import, rather than combine it with the price of its other gas sources. Result: a price of more than $1.50 per thousand cubic feet.

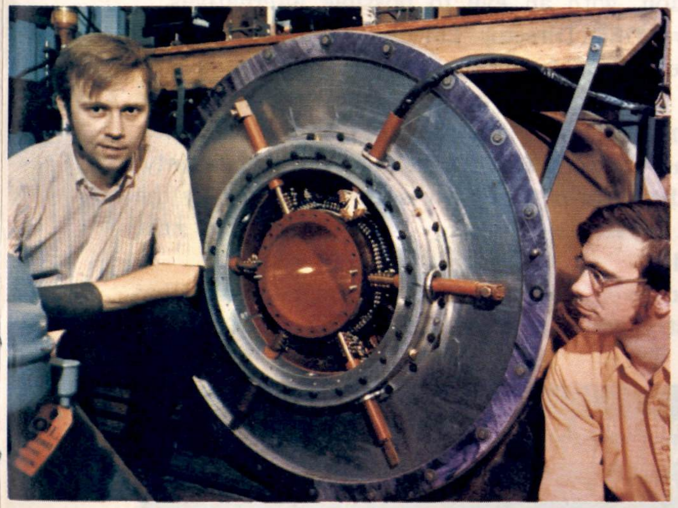
Price increases may come even sooner than many managers expect. Former White House energy adviser S. David Freeman has said he expects the



Tiny pellets of uranium dioxide, the fuel of a nuclear reactor, are manufactured under meticulous quality control conditions.



An 800-ton nuclear vessel leaves a Babcock & Wilcox Co. Mount Vernon, Ind., plant. When installed, heat from the nuclear reaction contained in the vessel will produce steam sufficient to generate 800,000 kw of electrical power. In another operation, nuclear fuel control rod guide assemblies are test assembled (below) in a reactor vessel simulator stand prior to shipment.



Superconducting generator developed at the Massachusetts Institute of Technology. Parts of the new generator will be operating at −452 F, only eight degrees above absolute zero.

Oil derived from shale is expected to play an increasingly important part in the nation's fuel economy. This oil shale development field program at Parachute Creek, Colo., includes demonstration of successful revegetation techniques.

What can you do now to conserve energy?

Government is pushing energy conservation in industry to help ease mounting fuel shortages. Such a program, says Commerce Secretary Peter G. Peterson, can reduce energy demand by as much as 5%.

Proper maintenance of equipment and better building insulation are two general areas in which managers can bring fuel savings, suggest government and private utility spokesmen. Other specific steps:

To conserve natural gas

- Rearrange schedules to use process equipment continuously to avoid heat-up losses for short runs.
- Shut down or reduce temperature settings at nights and on weekends.
- Reduce openings, close doors promptly, and use reflective heat shields on equipment such as heated ladles or slot forge furnaces.
- Limit excess air to actual needs and confine flames to heating areas; insulate lines carrying steam and hot liquids.
- Redesign equipment, including installation of temperature and air/gas ratio control devices, substitution of sealed-in burners for open hole furnace firing, repiping to return steam condensate to gas-fired boilers, and addition of heat recovery devices.
- Install new equipment such as shaft-type melting furnaces and radiant comfort heaters for high-bay factory areas; convert liquid heaters from underfiring to immersion or submersion heating, and large batch-type processes to continuous operation.

To conserve electricity

- Reschedule operations to off-peak periods when possible.
- Reduce current to electrical heating equipment such as oil heaters, core baking ovens, and annealing furnaces for brief periods; unload motor driven air compressors at intervals.
- Convert to higher voltage systems where practical; use standby generators in special cases during peak load periods.
- Cut ventilating air; turn air conditioning thermostats up or off in unoccupied areas at night and on weekends.
- Install photocell control switches and timeclock controls for lighting where applicable; turn off lights when not needed in certain areas—especially during peak load periods.

price of oil to rise at least 50 cents a barrel after the election. He looks for even steeper increases in natural gas and electrical energy.

What can managers do?

One thing managers can do now is conserve fuel—an idea the government is selling hard to industry. In a letter to 50,000 top executives this summer, Secretary Peterson contended that energy conservation could reduce demand by as much as 5%. And Gen. Lincoln thinks the practice is so vital that he suggests tax incentives to encourage it.

Managers can also speak out on energy. "Let's face it," says Universal Oil's Mr. Logan. "Perhaps we should take out ads in local papers. Perhaps firms that are heavy users of energy should consider mounting campaigns to let the public know how dangerous this situation is. They advertise for manpower and other valuable resources—and power definitely is a valuable resource."

But managers can, and should, do more. Rather than sit back and hope the crisis will somehow go away, they can insist through their elected officials that definitive estimates be made for future energy costs. None are currently available—which hampers company planning.

This is vital. Nearly every energy expert queried by INDUSTRY WEEK suggests that managers should be seriously studying their existing fuel supply situation, with an eye to possible alternatives.

Says OEP Director Lincoln: "When asked for advice on the future by industry, my office suggests provision for use of alternative fuels. We recognize the cost gets passed on to the consumer. But no one may foresee the future with certainty, and the costs of flexibility seem warranted by the bleak forecasts of energy supply over the next decade."

And even then, there seems no certainty that industry will not flicker as energy fades. □

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