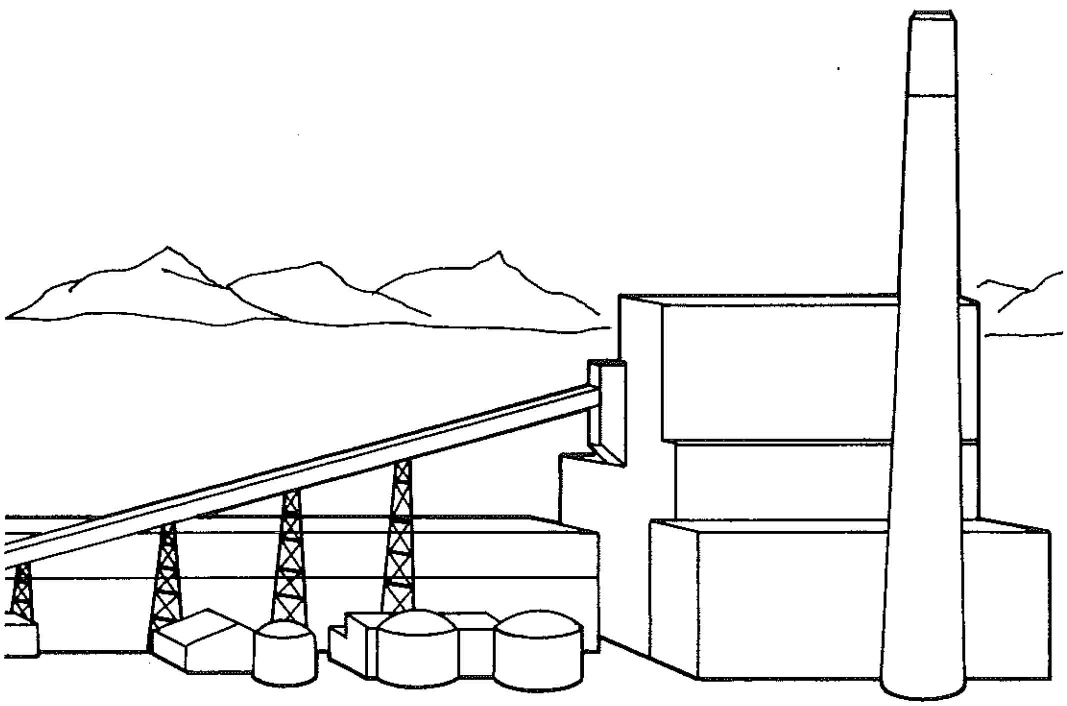

INDUSTRIAL USE OF COAL AND CLEAN COAL TECHNOLOGY

ADDENDUM REPORT

Irving Leibson, Chairman
Coal Policy Committee

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Study Group Chairman

JUNE 1990
THE NATIONAL COAL COUNCIL

THE NATIONAL COAL COUNCIL

U.S. DEPARTMENT OF ENERGY

The National Coal Council is a Federal advisory committee to the Secretary of Energy.

The sole purpose of the National Coal Council is to advise, inform, and make recommendations to the Secretary of Energy on any matter requested by the Secretary relating to coal or the coal industry.

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June 8, 1990

The Honorable James D. Watkins
Admiral, U.S. Navy (Retired)
The Secretary of Energy
United States Department of Energy
Forrestal Building - Room 7A-257
1000 Independence Avenue, S.W.
Washington, D.C. 20585

Dear Mr. Secretary:

On behalf of the National Coal Council, I am pleased to submit the attached addendum report entitled "Industrial Use of Coal and Clean Coal Technology." This report is a sequel to two reports issued in 1988, namely "The Use of Coal in the Industrial, Commercial, Residential and Transportation Sectors" and "Innovative Clean Coal Technology Deployment."

The goal of this report is to provide more specific recommendations pertaining to coal use in the Industrial Sector. We believe that there are many opportunities for coal in the Industrial Sector, but that there are also hurdles to overcome. The forecasts for the use of coal in the Industrial Sector are essentially flat and lack any optimism. The reasons can be attributed to concerns over potentially more stringent environmental law and regulation, as well as the current availability of relatively low-cost natural gas. These factors create severe economic uncertainties for the potential industrial user of coal.

A specific example presented in Chapter II is the domestic coke industry, which is currently the largest user of industrial coal. This industry may be facing a tenuous future due to more restrictive environmental law. The investment required to bring aging facilities into compliance may be too large to be economical and could lead to their abandonment. This will impact the domestic steel industry and all other industries which use steel in their products. A possible outcome may be that the steel industry will be forced to invest in direct reduction steelmaking for the future and will have to import coke during the interim period. All this will occur in a political/economic climate which for competing offshore suppliers will undoubtedly be less heavily regulated from an environmental point of view, than that existing for providers in the United States.

Furthermore, any impact such as this on a basic industry is significantly amplified by the ripple effects in the service sector, causing industry dislocations, unemployment, reduced tax revenues, and negative balance-of-trade accounts.

These types of concerns lead to two specific recommendations for your considerations:

- Increased emphasis should be placed on interagency review of the linkage between the national economy, national energy use, and the quality of life. The impact of the regulatory process with respect to cost benefit, the impact on energy use, as well as the effect on health and welfare should be given particular attention. The results of these reviews should be widely communicated on an ongoing basis.

- The Secretary of Energy should take appropriate action to expedite the resolution of regulatory uncertainties, and should continue to be actively involved to prevent future occurrences of such uncertainties.

The cogeneration of electricity by industry is the most promising avenue for increased use of coal in the Industrial Sector. Presently, transmission system capacities are causing difficulties in arranging transmission line access. Electric utilities are facing difficulties obtaining permits for additional transmission lines and are reluctant to share their existing transmission system capacity because of commitments to existing loads. Thus, we make the following recommendation:

- The Federal and State governments should be encouraged to ensure transmission line access and power markets for independent power producers and cogenerators.

Industrial Sector energy needs are very specific to particular industries because of the diversity of industrial processes. To provide for input from the Industrial Sector, the National Coal Council recommends the following:

An advisory committee should be established to advise on the research and development needs of industry with respect to increasing and upgrading the use of coal.

Other recommendations are included in the body of the report, but we chose to highlight the more significant ones in this letter.

The National Coal Council is pleased to be of service to you, and presents this report for your use in preparing a National Energy Strategy, particularly as this may impact the Industrial Sector.

Sincerely,

WCarr

William Carr,
Chairman

Preface

The National Coal Council is a private, nonprofit advisory group, chartered under the Federal Advisory Committee Act.

The mission of the Council is advisory only, providing guidance and recommendations as requested by the Secretary of Energy on general policy matters relating to Coal. The Council is forbidden by law from lobbying or carrying out other such activities. The National Coal Council receives no funds or financial assistance from the Federal Government. In relies solely on the voluntary contributions of the members for the support of its activities.

The members of the National Coal Council are appointed by the Secretary of Energy for their knowledge, expertise, and stature in their respective fields of endeavor. They reflect a wide geographic area of the United States. In 1990, there were members from 39 states reflecting a broad spectrum of diverse interests from business, industry, and other such groups as listed below:

Large and Small Coal Producers

Coal Users such as Electric Utilities and Industrial Users

Transportation interests from the Rail, Waterways, and Trucking Industries as well as Port Authorities

Academia

Research Organizations

Industrial Equipment Manufacturers

Environmental Interests

State Government, including Governors, Lt. Governors, Legislators, and Public Utility Commissioners

Consumer groups including special women's organizations

Consultants from scientific, technical, general business, and financial specialty areas

Attorneys

Special interest groups that are regional or state in concentration

Indian Tribes

The National Coal Council provides its advice to the Secretary of Energy in the form of reports on subjects requested by the Secretary and at no cost to the Federal Government.

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Introduction

This report was initiated June 7, 1989, by the National Coal Council in response to a request from former Secretary of Energy, John S. Herrington, dated January 19, 1989. In the spring of 1989, Secretary of Energy James D. Watkins reaffirmed the need for this report. The following excerpt is the request to which this report responds:

> *"Description of disincentives that currently impede coal and clean coal technology utilization in the industrial sector and identification of incentives that could be considered for implementation resulting in coal and clean coal technologies being considered a more viable option for the industrial sector."*

Late in 1988, two reports were delivered to the Secretary of Energy – namely, *The Use of Coal in the Industrial, Commercial, Residential, and Transportation Sectors* and *Innovative Clean Coal Technology Deployment.*

The goal of this report is to build upon the foundation of these 1988 reports, and to provide more specific recommendations to the Secretary pertaining to coal use in the Industrial Sector. To provide specific insights from the diverse industrial processes covered, the National Coal Council obtained assistance from industry associates whose contribution to this effort is greatly appreciated. The contributors and reviewers are listed in the Acknowledgement Section at the end of each chapter.

A Work Group was formed and met July 27, 1989, in Washington, D.C., and on September 21, 1989, March 1 and 2, and April 5, 1990, in Boston, Massachusetts. The report was reviewed by the Coal Policy Committee on May 4 and June 7, 1990, and adopted by the full Council on June 8, 1990.

The report reviews the major uses of energy in the Industrial Sector. The Executive Summary contains an Industrial Sector Overview, Conclusions, Impediments, and Recommendations which are presented to the Secretary for consideration. **Chapter I** addresses **Industrial Boilers** which are common to many industrial users; thus repeating similar information for each industry sector is not necessary. Subsequent chapters cover the following:

Chapter II – Coke, Iron, and Steel Industries
Chapter III – Aluminum and Other Metals
Chapter IV – Glass, Brick, Ceramic, and Gypsum Industries
Chapter V – Cement and Lime Industries
Chapter VI – Pulp and Paper Industry
Chapter VII – Food and Kindred Products
Chapter VIII – Durable Goods Industry
Chapter IX – Textile Industry
Chapter X – Refining and Chemical Industry

In addition, appendices supporting the contents of the study are provided.

Each chapter is specific to a segment of industry and covers the following topics as applicable:

- Energy Overview
- Basic Processes
- Foreign Experience
- Impediments to Coal Use
- Incentives That Could Make Coal a Fuel of Choice
- Current and Projected Use of Clean Coal Technology

- Identification of Coal Technology Needs
- Conclusions
- Recommendations
- References
- Acknowledgements

The basic scope of this report is to discuss industrial processes. All data presented in the study are in U.S. dollars and short tons, unless specifically noted. The base year for energy statistics is 1988. The Btu is the energy unit normally used. Electricity production is not treated in detail but is included in the energy statistical overviews. The process descriptions are brief, but the references should provide leads to locate detailed process descriptions. This report uses the Standard Industrial Classification (SIC) system to define industry groups, and to relate the data to the sources[1].

REFERENCE

The Standard Industrial Classification Manual, 1972, and the 1977 Supplement, U. S. Government Printing Office, Washington, D.C.

Executive Summary

INDUSTRIAL SECTOR OVERVIEW

The Industrial Sector is a nonhomogeneous group, thus making it difficult to obtain uniform energy data. The approach taken in this report was to select certain of the most energy intensive industries and report on these, leaving those industries with less energy consumption unreported.

The Industrial Sector energy consumption in 1988 was 21,700 trillion Btu of which coal provided 2770 trillion Btu[1]. The last comprehensive energy survey published by the Energy Information Agency was the Manufacturing Energy Consumption Survey: Consumption of Energy, 1985[2]. Table A–1 of this survey is repeated in Appendix A for information purposes. Also included in Appendix A is Table 940 (Table A–2) from the 1989 Statistical Abstract[3] which states the 1985 data in energy equivalents of trillion Btu.

During 1988, the principal consumers of industrial coal were[4]:

SIC Group		Thousand Short Tons
3312	Coke Plants	41,910
28	Chemicals Allied Products	14,898
32	Stone Clay Glass	13,792
26	Paper and Allied Products	12,437
33	Primary Metal Industries	7,691
29	Petroleum and Coal Products	7,190
20	Food and Kindred Products	6,431
37	Transportation Equipment	1,836
22	Textile Mill Products	1,497

The principal uses for coal in the Industrial Sector (in decreasing order of consumption) were[5]:

Coke Plants
Steam Coal
Direct Process Heat
Manufacturing Feed Stock

The Industrial Sector is also the principal non-utility electricity producer with an installed capacity of 22,479 MW. Table A–3 in Appendix A shows a breakdown of this electric generation capacity[6].

Electricity is used extensively in industry. Electricity is over 50 percent coal based; therefore, electricity is an indirect use of coal in industry. Table A–1 in Appendix A presents energy consumption data for the manufacturing portion of the Industrial Sector.

During the years from 1973 to 1986, U.S. Industrial Production Indices increased from 94 to 125 (1977 = 100). In this same time frame, energy intensity ratios decreased from 1.0 to 0.60 (energy intensity is: Energy Consumption ÷ Federal Reserve Board Industrial Production Indices, normalized 1973 = 1.0)[7]. These values reflect a general trend of increasing energy efficiency and energy conservation in the Industrial Sector. The principal reference for the commercial and economic data is the 1989 U. S. Industrial Outlook[8].

The Industrial Sector has reacted to energy price increases with conservation and has selected fuels on the basis of economics. Some industries rely heavily on coal. For example, the cement industry uses coal for 65 percent of its fuel needs. Within the same (SIC–32) classification, the glass industry uses little or no coal. No single solution applies; each industry should be reviewed on an industry–by–industry basis. Thus, we present our conclusions, impediments, and recommendations.

CONCLUSIONS

Energy consumption per output unit of production has been declining since the 1970s as a result of energy conservation and process improvements.

The processes used by the Industrial Sector vary considerably. The use of coal and clean coal technology is application specific, even within a given SIC group code; i.e., cement and glass.

Clean coal technologies (CCTs) are primarily applicable to Industrial Boilers. Some CCTs could be adapted to direct process heat applications with further study; i.e., glass.

Natural gas is the largest source of direct process heat. This points to one of the ways in which coal ultimately can be used in the industrial sector through the application of the coal gasification technology. The long-range availability of natural gas beyond the year 2000 at reasonable prices is a subject of concern.

Industrial cogeneration is a viable way to utilize coal in the Industrial Sector. Table A-4 in Appendix A indicates that of the 31,400 MW of nonutility generation capacity, 5,400 MW are derived from coal-fired units. Many of the nonutility generators using coal are engaged in cogeneration.

The impact of currently proposed environmental legislation (i.e., acid rain, air toxics, ozone nonattainment, greenhouse) in the aggregate will cause severe industrial dislocations causing many industries to go off-shore seeking locations where more favorable environmental regulations exist. The public view may be that industrial growth will be sacrificed in favor of environmental controls. The reality is that the sacrifice will be not only *growth* but that *whole industries* will leave.

IMPEDIMENTS

The variability of different coals, both in form and chemical analysis, makes it more difficult for industrial users. A more uniform, properly sized product, deep-cleaned at the source "ready-to-use" fuel would be less difficult for the smaller industrial energy user.

The installed cost of coal handling, coal burning, and environmental controls can result in a capital cost for coal that is 2.5 to 4 times higher for coal than for natural gas. The uncertainty of new regulations further complicates the issue. Potential users of coal have the difficult task of justifying coal in the face of higher capital cost and uncertain environmental regulations.

Several industries are seasonal or have low capacity factors due to the manufacturing process. These cases usually favor lower initial capital cost.

The environmental regulatory processes at both the Federal and State levels, are viewed as a detriment to coal use in several important respects:

- emission standards are based on a percent reduction instead of relating emissions to unit of output;
- best available control technology is specified without consideration of cost justification; and
- the smaller size of units being brought under compliance requirements has made only the larger installations practical.

The public perception that coal is a dirty fuel needs to be changed. Coal can be used in an environmentally acceptable manner.

Transmission line access for independent power producers and cogenerators is difficult to arrange. There is concern about the adequacy of the electrical transmission systems in the United States as reported in the National Coal Council's June 1986 report, Interstate Transmission of Electricity.

RECOMMENDATIONS

The Department of Energy should continue to support and expand the development of technology for the conversion of coal into liquids and coal into gas.

Increase the emphasis on interagency review of the linkage between the national economy, national energy use, and the quality of life. The impact of the regulatory process with respect to cost-benefit, the impact on energy use, as well as the effect on health and welfare should be given particular attention. The results of these reviews should be widely communicated on an ongoing basis.

The Secretary of Energy should encourage research and development to evaluate the best means of using coal for direct process heat in processes such as glass manufacturing. This research and development should be undertaken with the participation of the specific industry, i.e., glass.

It is recommended that one of the clean coal technology programs be the demonstration of processes that prepare, deep-clean, and size coal (ready-to-use fuel) for industrial use.

Industry should make use of available technologies to clean, dewater, dry, and prepare coal fines rejected by the coal preparation plants. Making beneficial use of these coal wastes would reduce future waste liabilities and improve the coal industry's image.

The Secretary of Energy should take appropriate action to expedite the resolution of regulatory uncertainties and should continue active involvement in preventing future such uncertainties.

The Secretary of Energy should encourage Federal and State Governments to ensure transmission line access and power markets for independent power producers and cogenerators.

The Department of Energy should continue to support and expand the research on chemicals derived from synthesis gas from coal.

The Secretary of Energy should appoint an industry advisory committee, which should include members representing the chemical and petroleum refining industries, to advise on the research and development needs of industry with respect to increasing and upgrading the use of coal.

The Secretary of Energy should continue efforts to improve the public's awareness that there is an important role for coal and that the technology exists to burn coal in an environmentally compliant manner.

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Chapter I

Industrial Boilers

DESCRIPTION OF THE INDUSTRIAL BOILER SECTOR

The importance of industrial steam is clear – approximately two-thirds of all fuel burned by United States industry is consumed to raise steam. Our entire manufacturing base virtually depends on steam to produce its products either for process use, to drive mechanical equipment (e.g., pumps and fans), for space heating, or for the onsite generation of electricity.

Thus, the industrial boiler population is heterogeneous by nature. Loads and capacity factors vary widely as do fuels used, with many industries using self-generated wastes – solid, liquid, and gaseous.

The boilers in service today range in size from about 3.5 MWt to 350 MWt, or from about 10,000 pounds per hour of steam capacity to 1,000,000 pounds per hour. Aggregate nameplate capacity is roughly 860,000 MWt, with about 25 percent designed for coal use. It is estimated that only about 17 to 20 percent of the overall total is now burning coal, thus accounting for only about 7 percent of the total United States coal consumption.

Because a manufacturing plant has many uses for steam – process heat, space heat, and the generation of electricity – it is able to use the maximum amount of heat present in the steam that can be extracted. This fact, combined with the vigorous energy conservation practiced across United States industry since 1973, means that each unit of heat combusted at a manufacturing facility typically contributes twice the useful output achieved in a typical utility generating plant. At utilities, approximately two-thirds of the potential heat is wasted since there is only one use for it – the production of electricity.

SYNOPSIS OF THE INDUSTRIAL BOILER MARKET

There are approximately 54,000 industrial boilers in the United States today with a mean nameplate input size of 54 million Btu/hr. New units are being added at the rate of about 200 per year. Since about 80 percent of these boilers are sold as replacement, the nation's industrial boiler inventory is growing only slightly, if at all.

Based on recent boiler sales, leading user industries are as follows:

Forest Products	37 percent
Chemicals	23 percent
Food	21 percent
Petroleum	19 percent

According to the American Gas Association, the fuel energy intensity ratio – energy use per unit of production excluding electricity – declined 48 percent between 1973 and 1985[1]. This annual rate of decline shows no evidence of any significant slowing so that future manufacturing fuel use will grow only slightly, or perhaps remain flat.

Insofar as industrial coal is concerned, the National Coal Association predicts an average annual use increase of only 0.5 percent between 1987 and the year 2000[2] as shown in Table 1.

Table 2 presents data from a recent study done for the U.S. Environmental Protection Agency (EPA). In this table, industrial boiler fuel use to the year 2000, as well as coal's share, is shown to be flat, with the slight decline in oil use being picked up by natural gas.

TABLE 1
Industrial Coal Consumption by Industry Type[2]
(millions of tons)

Industry	1985	1987	1990	1995	2000
Chemicals	17.8	16.6	16.9	17.0	17.0
Stone, Clay, & Glass	16.9	15.4	15.5	14.4	12.7
Paper	13.0	13.4	13.3	13.2	12.4
Primary Metal Products	8.5	8.5	8.6	8.4	7.6
Petroleum & Coal Products	5.6	8.5	8.6	8.9	9.5
Food	5.7	6.9	7.2	6.5	5.8
Subtotal	67.5	69.3	70.1	68.4	65.0*
Others, Including Nonutility Generation	7.9	5.9	9.9	16.6	20.0
Total	**75.4**	**79.2**	**80.0**	**85.0**	**85.0**

Note:
* Forecast of an actual 6.7 percent *decline*, 1987–2000, in coal use by the *manufacturing sector.*

TABLE 2
Industrial Boiler Fuel Demand Forecasts in 2000[3]
(quadrillion Btu)*

	Low Sulfur Fuel Beginning in:		
	Baseline	1995	2000
Natural Gas	3.3	3.5	3.5
Oil	0.5	0.3	0.3
Coal	1.1	1.1	1.1
Total	**4.9**	**4.9**	**4.9**

Note:
* One quadrillion Btu (quad) equals 10^{15} Btu. One quad is approximately equivalent to 46 million tons of coal, 172 million barrels of crude oil, or 980 TCF of natural gas.

Low Capacity Utilization – While capacity factors for energy–intensive industries (e.g., pulp and paper, chemical, and primary metals) can range up to 80 or 90 percent, other industries such as automobile and equipment manufacturers, who use steam almost exclusively for space heating, have capacity utilization rates of only 20 to 25 percent. On average across the industrial spectrum, a mean capacity factor of 45 to 55 percent is widely estimated.

These low capacity factor values make it difficult to justify the high capital costs of coal–fired systems.

Need for Properly Sized and Treated Fuels – About two–thirds of coal industrial boilers are fired by stokers, which typically require a greater degree of coal preparation and sizing. These higher quality fuels are not nearly so widely available as standard, run–of–mine coals. In those instances where a supply of such a product is available, distance and the resultant high transportation costs may render its use uneconomical.

High Capital Costs – The installed cost of a small coal–fired boiler without pollution control equipment will be about $35 per pound of hourly rated steaming capacity, compared to a $10 to $15 cost for the same size oil– or gas–fired unit. Therefore, the coal–fired unit must rely on a substantial fuel cost differential and/or a high capacity factor to compete.

The addition of a particulate control system which is able to meet the 1989 New Source Performance Standards (NSPS) will increase the $35 unit capital cost 20 percent to $42. If sulfur dioxide ($SO_2$) control is added, as required on the large industrial boiler sizes, capital costs will go up by 50–70 percent. In these cases, coal will simply not be considered.

Lack of Initiatives for Coal Producer – There is a strong need for a coordinated, state–by–state promotional and marketing effort. While this program should include all interested parties – users, state energy and economic offices – it must be launched and driven by producer interests and company and state associations.

Environmental regulations such as those pertaining to SO_2 control, have made coal use unduly restrictive and, in some cases, virtually impossible in industrial boilers. Furthermore, even more stringent laws pertaining to air, water, and solid waste, could seriously impede the use of coal in a major segment of industrial boilers.

Environmental regulations generally impose control requirements on industrial boilers independent of size. Regulations based on size consideration, and on total emission of pollutants, would provide needed sound economic thresholds and offer small sources a renewed incentive for coal use, thus preserving and expanding this coal use in medium and small industrial applications. Even if the regulatory requirements were to exclude these small sources of emissions, the cumulative environmental impact would be insignificant.

New Source Performance Standards – The 1986 NSPS for industrial boilers in the 100–250 million Btu per hour input range requires a 90-percent reduction on SO_2 emissions, regardless of the fuel sulfur content. The 1989 NSPS extends this requirement down to 70 million Btu per hour. Thus, industrial boiler owners "enjoy" a much more stringent regulation than owners of the much larger utility boiler (30X) which needs only a 70-percent reduction with certain low sulfur coals.

Bellwether States – Many states, led by California's example, require advanced forms of nitrogen oxides (NOx) control, none of them as yet in wide commercial use, with capital costs in some cases exceeding those of flue gas desulfurization systems. In urban areas, these NOx reduction requirements are being applied to boilers as small as 10 million Btu per hour, and could virtually eliminate continued coal use in small boilers and adversely impede coal burning in many large boilers.

Wisconsin Electric Power Decision – A recent Federal Circuit Court decision largely upheld an EPA edict that a retrofit project must undergo a Best Available Control Technology review, leading to abandonment of the project or installation of a flue gas desulfurization system on the project's 40-year-old boilers. Industrial boiler owners, who may wish merely to switch fuels, could find this ruling another barrier to increased coal use in existing units.

Drastic environmental policies, particularly those lacking verifiable and adequate scientific support, such as those pertaining to acid rain, air toxics, ozone nonattainment, and global warming, could adversely affect the use of coal in the Industrial Sector.

Emerging Technologies – New source performance standards should stimulate – rather than dampen – industry's drive to develop and demonstrate new, innovative technologies and fuels so as to reduce emissions and, at the same time, advance the nation's energy goals in a cost-effective manner.

It is important that Federal standards regulating the emissions from boilers using such technologies not specify "proposed" until valid EPA test data from a representative group of such installations across U.S. industry have been tabulated and reviewed. Only at this point can the appropriate emission levels be set. Premature proposal of such standards would inhibit and retard their development and commercial demonstration.

ROLE OF COGENERATION

Cogeneration is defined as the sequential use of steam for power generation and some other purpose(s) – process heat, mechanical power, or space heat – realizing a total cycle efficiency of up to twice that of conventional condensing cycles. Thus, not only is more useful output gained per unit of fuel burned, an increase in energy efficiency, but the volume of pollutants released per unit of output is lower as well.

A recent survey by the Utility Data Institute of Washington, D.C., shows that an additional 34,000 MW of nonutility generation is also scheduled to enter operation before the year 2000[4]. This represents a significant opportunity for coal use in the Industrial Sector. In fact, 1989 was the first time that nonutility electric capacity additions were greater than electric utility additions in the United States[5].

OPEN ACCESS TO THE TRANSMISSION GRID

Without open access to the transmission grid, cogenerators under the Public Utilities Regulatory Policies Act, i.e., qualified facilities, will have limited electricity markets open to them. True marketplace conditions include multiple buyers as well as multiple sellers; this means free, nondiscriminatory access to the grid. Since approximately 20 percent of these facilities in the pre-construction stage will be coal-fired, open access is needed for this added increment of coal use.

Also, as reported by the National Coal Council in its June 1986 report, Interstate Transmission of Electricity, there is concern regarding the adequacy of the United States' electrical transmission systems to keep pace with the projected requirements in view of the difficulties in obtaining permits.

CURRENT COAL BURNING SYSTEMS

Virtually all of today's industrial coal-fired boilers use pulverized coal (PC) or stoker systems; approximately two-thirds are stoker fired. The latter are generally used in units with an input less than 300 million Btu per hour, while PC boilers dominate the larger sizes.

Fluid bed systems are rapidly gaining acceptance in the industrial, cogeneration, and small power sectors. In the United States, roughly 170 units with an aggregate steaming capacity of about 41 million pounds per hour are in operation or being installed; worldwide, these totals are 350 units and 75 million pounds per hour, respectively.

EMERGING AND FUTURE COAL BURNING SYSTEMS

Two other technologies particularly well-suited for industrial retrofit application, coal-water mixtures and micronized coal, hold promise. The former has been demonstrated at several industrial sites, most notably at a Memphis chemical plant and at least one utility power station. The latter has been installed at some 15 installations, one having been in service for 7 years. There is also one fluid bed retrofit installation at an Illinois edible oils plant. All of the applications were undertaken on units originally designed to burn oil or gas, with derating necessary on some boilers.

In addition, the slagging, or entrained, combustor has been demonstrated in a 35-million Btu per hour boiler which has supplied space heating steam since 1985 to a large Cleveland manufacturing plant.

Finally, the co-firing of natural gas and coal, with gas supplying a few percent to 30 percent of the total heat input, is a well-proved but little used procedure which can offer the following potential advantages:

- increased boiler efficiency;
- improved load-followed capability;
- enhanced boiler availability;
- reduction in emissions – PM, SO_2, NOx; and
- ability to burn a wider range of coals.

CLEAN COAL TECHNOLOGY DEVELOPMENT

The major focus of the clean coal technology programs has been on the enhancement of technologies which offer a greater potential for the reduction of acid rain precursors from electric utilities. Technologies aimed at improving the performance and emission characteristics of industrial sources also must be encouraged and supported. Participation by the private sector in clean coal technology programs to develop new fuel forms and low cost, environmentally clean fuels from coal is vital to the survival and growth of coal use in the industrial sector. Clean coal fuels, available at competitive prices, would protect continued coal use in industrial applications. Availability of such fuels could very well stimulate and trigger further major expansion in the application of coal for new industrial sources.

CONCLUSIONS

Approximately two-thirds of all fuel burned in the Industrial Sector is consumed to raise steam.

Energy conservation and process improvements have reduced energy consumption per output unit of production which has been declining significantly (35 percent) since the early 1970s.

Industrial cogeneration is a viable use for coal in the Industrial Sector.

Fluid bed systems are gaining acceptance in the industrial, cogeneration, and small power sectors.

Many small industrial coal users exist in Europe. These smaller units, however, are not subjected to the 90 percent SO_2 reduction requirements of the United States.

IMPEDIMENTS

The variability of different coals, both in form and chemical analysis, makes it more difficult for industrial users. A more uniform, properly sized product, deep-cleaned at the source ready-to-use fuel would be less difficult for the smaller industrial energy user.

The installed cost of coal handling, combustion, ash handling, and environmental control usually results in a total capital cost for a coal-fired unit that is 2.5 to almost 4 times that of a comparable natural-gas-fired boiler[6]. The real potential of even more stringent emission requirements exacerbates this enormous cost handicap and sets up a tough barrier for would-be coal users to overcome.

Several industries are seasonal or have low capacity factors due to the manufacturing process. These cases usually favor lower initial capital costs. In those cases where the energy costs are a small percentage of product cost, lower initial capital costs are also favored.

The environmental regulatory processes at both the Federal and State levels are viewed as a detriment to coal.

A major deterrent to the use of coal is the public perception that it is a dirty fuel. Coal can be mined, transported, stored, and used in an environmentally acceptable manner.

Transmission line access for independent power producers and cogenerators is difficult to arrange.

RECOMMENDATIONS

Increase the emphasis on interagency review of the linkage between the national economy, national energy use, and the quality of life. The impact of the regulatory process with respect to cost-benefit, the impact on energy use, as well as the effect on health and welfare should be given particular attention. The results of these reviews should be widely communicated on an ongoing basis.

The energy content of various industrial products should be evaluated and published as a useful indicator of which industrial processes are more susceptible to energy impacts. Thus, as relative energy costs vary, the potential use of coal could be targeted in the most effective manner.

It is recommended that there be further research and development focused on processes that prepare, deep-clean, and size coal (ready-to-use fuel) for industrial use.

Emission standards should not require specific technology but should leave open the method of compliance.

Emission standards should not require a percentage reduction based on input but should be based on unit of output.

Establish aggressive technology transfer programs between industry and government.

Develop small coal firing systems for boilers with an input of less than 100 million Btu per hour, applying some of the clean coal technologies.

The Secretary of Energy should encourage the coal industry to take the lead in promoting the increased use of coal in the Industrial Sector.

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Chapter II

Coke, Iron, and Steel Industries

INTRODUCTION

There are seven basic process steps in the iron and steel industry. These are agglomeration, coking, ironmaking, steelmaking, primary finishing, secondary finishing, and heat treating.

Agglomeration prepares the iron ore feedstock for input to the blast furnace. Coking converts metallurgical coal to coke for use primarily in blast furnaces. Ironmaking converts the iron ore to elemental iron in the blast furnaces. The iron is converted to steel in either open hearth, electric, or basic oxygen furnaces. The steel is then changed to products in primary finishing, secondary finishing, and heat treating. These process steps can be accomplished using more than one method and each method has energy requirements.

ENERGY OVERVIEW

The following are the primary uses of energy in each process step.

Agglomeration	
Pelletizing:	Coke Breeze, Fossil Fuel, (normally natural gas or residual oil)
Sintering:	Coke Breeze, Natural Gas
Coking	
Coke Ovens:	Metallurgical Coal
Ironmaking	
Blast Furnaces:	Coke, Fossil Fuel
Steelmaking	
Basic Oxygen Furnace:	No External Fuel Supplied
Electric Furnace:	Electricity
Open Hearth:	Coal, Oil, Gas, Blast Furnace Gas, Coke Oven Gas (COG)
Primary Finishing	
Continuous Casting:	Electricity
Ingot Casting – Soaking Pits Roughing Mill:	Electricity, Coke
Secondary Finishing	
Direct Rolling:	Electricity
Reheat Furnace, Rolling Mills:	Natural Gas, COG
Heat Treating:	Natural Gas, COG

The energy consumption in million Btu per ton of net steel shipments for 1987 is presented below [1,2]:

Purchased Energy	Consumption
Natural Gas	5.2
Fuel Oil	0.5
Coke	10.7
Other Coal	0.6
Electricity	2.0
Internally Generated Fuels	
Coke Oven Gas	2.3
Blast Furnace Gas	2.8

Coke provides more than 70 percent of the energy input to the ironmaking and steelmaking processes when internally generated fuels are included. Coke also fulfills the important function of being a reductant in the process.

BASIC PROCESSES

Coke Industry

In 1989, the United States coke oven industry consisted of 39 facilities which utilized 43 million tons of coal.

The coke industry processed 42 to 43 million tons of metallurgical coal and operated at 99 percent plus capacity. In addition, approximately 2.7 million tons of coke were imported for use within the industry.

Coke manufacturing is a vital United States industry, supplying the steel, automobile, metal casting, and other industries with an irreplaceable raw material. A long-term, secured supply of domestic coke for both foundry and steelmaking purposes is an essential element of our military hardware system and national security. Foreign coke is not, nor will it be, of adequate quantity or quality to meet United States industry requirements.

The U.S. Bureau of Mines has classified metallurgical coals as coking bituminous coals containing not more than 8 percent ash and 1.25 percent sulfur. While it is possible to produce coke from only one or two coals, state-of-the-art practice dictates that several coals be used in a blend. Some facilities have used over 100 different coals in a single blend to make coke.

Coke is the solid char which remains after the destructive distillation, or pyrolysis, of metallurgical-grade coal. Coke used in the iron and steel industry is a strong yet porous material, capable of supporting a charge of iron ore or iron metal while burning hot enough to sustain the desired temperature in the cupola and/or blast furnace.

In the coke-making process, the various blends of coal are charged into heated coke ovens where the reactions take place in three steps. In the first step, coal breaks down at temperatures below 700°C (1292°F) to primary products consisting of water, carbon monoxide, carbon dioxide, hydrogen sulfide, olefins, paraffins, aromatic hydrocarbons, and phenolic and nitrogen-containing compounds. The second step occurs when the primary products react as they pass through the hot coke and along the heated oven walls at temperatures above 700°C (1292°F). This results in the formation of aromatic hydrocarbons, the evolution of hydrogen, and the decomposition of nitrogen-containing compounds – hydrogen cyanide, pyridine bases, ammonia – and nitrogen. The third step results in the formation of hard coke by the progressive removal of hydrogen.

Gases evolved during coking leave the coke oven at 760°C to 870°C through standpipes, pass into goosenecks, and travel through a damper valve to the gas collection main that directs them to the by-product plant.

Two major grades of coke are blast furnace coke and foundry coke. Blast furnace coke is used along with iron (oxide) ore and limestone for the reduction of iron ore. Burning coke in the blast furnace provides sufficient temperatures to melt iron metal but not other impurities in the ore. In burning, coke is converted to carbon monoxide which, in turn, converts iron ore to iron metal. Impurities in the ore and ash in the coke combine with limestone to form a molten slag which is collected and removed from the blast furnace.

Foundry coke is generally a higher grade of coke by virtue of its lower ash, larger size, and greater stability. Longer coking times are required for foundry grade coke. Foundry coke is used to remelt scrap metal in a vessel called a cupola. In addition to providing heat and support for the charge, some of the carbon in the coke goes into the metal.

Coal tar produced by the coke industry as a coke oven by-product is the raw material and the sole basis of the coal tar processing industry. Tar is a complex mixture of many hydrocarbon materials. Every coke oven battery produces a different quality of tar. Some tars are of little value as produced and must be blended with other tars from other sources to be suitable for production of specification pitch products – electrode binders, foundry binders, and protective coatings.

Crude tar is separated in the tar plant through fractional distillation into several broad fractions – pitches of various consistencies, creosote, and chemical oils. Chemical oils are further processed and refined into their final form as industrial chemicals.

Pitches derived from tar have unique properties for various industrial purposes. They have outstanding qualities of water resistance and adhesiveness resulting from their high aromatic benzine ring structure. These qualities and their resultant commercial applications cannot always be duplicated by petroleum-based products. For industrial purposes, oil-based and tar-based products are not the same chemical.

The chemical distillates from the refining of coal tars are the primary material in the manufacture of dyes, drugs, paints, plastics, and synthetic rubber. While synthetically derived petrochemical foodstocks are now paramount in these industries, coal-tar-based materials are still a significant factor.

FORM COKE

Form coke, a blast-furnace-grade coke product made from steam coal, is a possible alternative to coke produced in coke ovens. The process of making form coke involves a number of steps including coal pyrolysis, binding, briquetting, and calcining. By utilizing fluidized bed reactors, many of the problems of batch-operating coke ovens are avoided. However, the process is complex and relatively expensive. A small commercial plant has been operating for over 20 years, and over 20,000 tons of form coke from this plant were tested in a blast furnace located in the United States[3].

NONRECOVERY COKE OVENS

Prior to the advent of modern, by-product recovery coke ovens, industry depended upon nonrecovery, or beehive coke ovens. In beehive ovens, all gases and tars are vented to the atmosphere. The modern successor is the Thompson coke oven, an example of which is currently operated by the Jewell Company in Vansant, Virginia. This plant produces 600,000 tons per year of merchant blast furnace coke[4]. These ovens are called nonrecovery coke ovens because they burn the by-products resulting from coke making to heat the coke oven and produce electricity.

Both the Thompson oven and the conventional by-product oven have inherent advantages and disadvantages. The Thompson oven has lower initial capital and operating cost requirements but has a shorter projected life than does a by-product oven. Although the Thompson oven has lower hydrocarbon emissions than a by-product oven, the economic efficiency of burning coke-oven gas and tar to produce electricity is less favorable than recovering those products for sale as a chemical feedstock. Finally, a comprehensive conversion of the coke-making industry to the Thompson oven would have the impact of eliminating an important source of chemicals and chemical products along with the associated jobs in by-product-dependent industries.

FOUNDRY INDUSTRY

The foundry industry utilizes just under 10 percent of the coke produced in the United States for the production of metal castings in cupola operations; this is approximately 55 to 65 percent of the iron metal castings produced. The remaining iron castings are produced in electric melt or induction furnaces utilizing carbon electrodes which, for the vast majority, are made from coal tar.

An estimated 90 percent of all durable goods manufactured in the United States require metal castings. Dependent industries include farm implements, construction equipment, petroleum, chemicals, mining equipment, automobile, transportation, railroad, electric generation, plumbing, aerospace, shipbuilding, military, and machine tools.

Changes are taking place within the foundry industry. Direct injection of pulverized coal and utilization of oxygen injection is replacing some of the coke currently utilized. It is expected that a substitution of 25 percent may be practical. It is not anticipated that complete replacement of coke is feasible for cupola operations.

Electric melt of iron has increased; however, this process is dependent upon low electricity prices. Electrodes utilized in this process are produced from coal tar generated from the coking of coal.

STEEL INDUSTRY

The steel industry is the largest consumer of coke, and there are no immediate alternatives to coke for continued domestic production of steel.

The steel industry also is one of the largest industrial consumers of electricity for processes such as electric arc furnaces. In recent years, the major growth in steel making has been by the "mini mills" which are based on electric arc furnace processing of scrap metal[5]. In 1985, the United States steel industry (SIC 3312) consumed over 39 billion kWh of electricity[6]. As most steel mills are located in areas of coal-based electric generation, the electricity used in electric furnaces is equivalent to about 16.5 million tons of steam coal. In addition, several of the large integrated steel mills generate some of their own electricity and steam requirements. In 1985, the steel industry directly consumed 2.2 million tons of steam coal in addition to 37.7 tons of metallurgical coal[6].

Coal Injection in Blast Furnaces

In a technology developed 20 years ago by Armco Steel and Babcock & Wilcox Co., coal can be added directly into the blast furnaces to reduce the coke requirements. This process involves the direct injection of dry pulverized coal into the hot air tuyeres of the blast furnace. At the Armco Steel Mill in Ashland, Kentucky, over 1.7 million tons of coal have been utilized in this fashion[7]. This technology is currently used in a number of steel mills outside the United States[8]. In the United States, natural gas injection in blast furnace tuyeres is currently favored over coal due to the relatively low price of gas, the significantly lower capital cost, and the safety factors associated with handling dry, pulverized coal.

The coke requirements on a modern blast furnace are about 0.57 ton of coke per ton of hot molten iron produced[9]. The injection of coal in the blast furnace tuyeres may reduce the coke requirements per ton of iron produced by up to 25 percent. At this level, the steam coal requirements are 0.15 ton per ton of iron produced.

Coal Injection in Basic Oxygen Furnaces

Coal can be injected in a modified basic oxygen furnace. This increases the carbon content in the molten metal and enables high amounts of scrap addition to the furnace. This technology, developed and demonstrated in West Germany, is known as the KMS process[10].

MINERAL WOOL INDUSTRY

The mineral wool industry consists of 15 manufacturing facilities which supply approximately 3000 contractors and/or mineral wool products utilized in the building industry. The preferred method for the production of mineral wool, remelting blast furnace slag, is dependent upon cupola melting which requires the use of coke.

The mineral wool industry is the smallest segment of the industries using coke; however, sales in 1987 were $3.2 million.

ALUMINUM INDUSTRY

In the aluminum industry, two primary processes are employed in the electrolytic reduction of the ore mixture to pure aluminum. Both of these processes require coal tar pitch as the binder for the carbon producing anode.

ADVANCED STEELMAKING AND USE OF CLEAN COAL TECHNOLOGY

One of the clean coal technologies applied to the coke and steel industries includes coke oven gas desulfurization with benzine removal. This project is being jointly funded under the Department of Energy's Round Three Clean Coal Technology Program at Bethlehem Steel Corporation's coke plant in Sparrows Point, Maryland. The technology being demonstrated could possibly be applied to 24 of the facilities being operated in the United States[11].

A number of direct reduced iron (DRI) processes are currently in operation with a worldwide production of over 12 million tons[12]. These processes avoid blast furnaces and related activities. However, most DRI processes are quite small compared to integrated steel mill operations and most use natural gas. Based on current data, direct reduction steel making, if feasible, will not be in place for at least 30 years.

COREX Process

One of the advanced coal-based ironmaking technologies being considered is the COREX process[13]. This process involves an oxygen-blown coal gasifier/ iron melter and a shaft reduction furnace.

In November 1989, ISCOR in South Africa began full-scale operation of a 300,000-ton per year COREX process iron production facility. The COREX process uses coal instead of coke to produce reduction gases. By engineering design, the COREX process is able to dispense with the requirement for strong, porous coke to support the blast furnace charge.

U.S DEVELOPMENT

A consortium of United States integrated steel companies is currently developing an advanced steelmaking process. A 120–ton per day (molten steel) pilot plant is under construction at a USX facility near Pittsburgh, Pennsylvania[14]. The process details have not been made public; however, it will be based on coal and oxygen and will utilize both ore and scrap to produce steel in a one–step process.

Conventional coal gasification processes could possibly be effectively integrated with conventional iron ore reduction and iron melting technology. This combination has the potential to greatly reduce development cost and time, since all three technologies have been demonstrated on a commercial scale. Promising coal gasification processes include the Texaco, Dow, and Shell processes. All three processes have been successfully demonstrated and are commercially offered by their respective developers. The synthesis gas from these coal gasification processes could possibly be used in shaft reduction furnaces developed for the use of synthesis gas derived from steam methane reforming. The coal–based synthesis gas is actually better for this application than natural gas–based synthesis gas because of the much higher carbon monoxide content of coal gas.

Midrex Corporation, of Charlotte, North Carolina, a leader in natural–gas–based DRI installations, has researched the integration of its DRI shaft furnace with conventional coal gasification processes[15]. In addition, solid direct reduced iron produced by coal gasification could be effectively melted in oxygen/coal gas burner systems (identical to natural gas/oxygen melters) or electric arc furnaces. Furthermore, direct reduced iron produced by coal gasification could be integrated with coal gasification combined cycle electric power generation to reduce the cost of both technologies[16].

FOREIGN DEVELOPMENT

There are a number of foreign developments in advanced coal–based ironmaking and steelmaking processes. Kobe Steel and CRA are jointly developing a process based on the Kloeckner/CRA molten iron bath coal gasification process. The Swedish Royal Institute of Technology and Nippon Steel are jointly developing a system based on a similar coal gasification process. Kawasaki Steel and Sumitomo Metals are each separately developing a system based on a blast furnace modified to be an oxygen–blown coal gasifier/melter. The coal gas from the gasifier/melter is utilized to pre–reduce and pre–heat iron ore which is then fed to the gasifier/melter.

CONCLUSIONS

No increase is expected in the utilization of coal in the coke, iron, and steel industries; to the contrary, it appears there will be reductions of coal use in these industries.

Environmental regulations and laws could result in the closure of coke oven operations within 10 years, thereby reducing domestic consumption of coal by 42 million tons per year. Realistically, since large capital expenditures would be required to maintain production for these 10 years, the closing of coke oven facilities could occur much earlier.

Existing coke ovens are essential to the United States steel industry. Furthermore, coke oven by–products are essential to other industries. Although some cost–effective alternatives to coke ovens and coke oven by–products exist, they are limited by their high capital cost (related to the continued use of existing coke ovens) and by their state of development. Therefore, coke ovens should remain an integral part of the steel industry for the foreseeable future.

Closure of coke oven tar processing facilities and potential elimination of the coke industry will make the United States dependent on foreign countries for a key raw material for iron and steel production and/or the supply of iron and steel themselves. The mineral fiber industry, building construction, iron manufacturing, the automotive industry, by–product refining, and cosmetics and drug manufacturing also will be adversely affected.

In the worst case, potential losses resulting from the closure of coke oven facilities are:

- Coke industry employment – 12,000 direct employees.
- Associated employment in coal industry, which supplies the coke industry with 43 million tons of coal per year (approximately 12,000 employees).
- Annual wages/benefits and goods/services purchased by the coke industry – $2.7 billion.
- Annual taxes paid by the coke industry – $98 million.

Coke and coke-derived products are essential to many United States industries and will be imported if domestic supplies are unavailable. Current United States coke producing facilities are among the most environmentally sound in the world and would likely be displaced by facilities in eastern Europe and the developing world which have virtually no environmental controls. Therefore, domestic legislation intended to reduce emissions of certain substances will instead substantially increase worldwide emissions.

IMPEDIMENTS

The single largest impediment to increased coal use in the steel industry is the high cost involved to bring coke ovens into expeditious compliance with environmental regulations. The fundamental problem is that the coke oven process is a batch operation at atmospheric pressure. The batch operations of coal charging and coke "pushing/quenching" steps are difficult and expensive to achieve at low emission rates. Alternatives currently exist to reduce coke requirements in the blast furnace or to produce coke by other processes. However, large-scale use of these processes would require significant additional investments relative to adding cost-effective emission control technology to the existing coke ovens. Furthermore, these alternative processes would reduce the availability of coke oven by-products, which are essential for many specialty chemical and binder applications.

Coal-based ironmaking technologies, which totally avoid the coke oven and blast furnace, are potentially attractive because they avoid the fundamental problems of coke ovens. However, the impediment to their use is their state of development; essentially, these processes are currently at a pilot plant or a first-of-a-kind demonstration state of development.

RECOMMENDATIONS

The Secretary of Energy should, through the Strategic Materials Committee, initiate procedures to designate coke and coal tar products strategic materials for the United States.

The Department of Energy should encourage research projects leading to cost-effective control technologies for coke ovens and development of advanced ironmaking processes.

It is considered of extreme importance to identify global impacts, both environmental and economic, of replacing United States-produced coke with imported sources. Such an undertaking, however, is beyond the scope of this report. Therefore, it is recommended that the Secretary of Energy initiate, through the Department of Commerce or other entity, a program which will identify such impacts.

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BASIC PROCESS OR ENERGY APPLICATION

The refining and smelting of a metal requires large amounts of energy because metals, in their natural form, are chemically attached or bonded to other elements and compounds. Refining and smelting is the process of removing these impurities. The energy used in smelting and refining takes the form of heat, power, electricity, and that of a reducing agent. The heat provides for high reaction rates and the reductant takes part in the reaction to liberate combined metal.

The step in which a metal is transformed to the metallic form is called either smelting or reduction. Reduction commonly takes place through the application of a reductant. Carbon-based electrodes and electricity are common reductants used in the primary metal industry. The type of reductant selected depends upon the metal involved as well as the smelting process selected.

Refining is a preparatory step carried out either before or after smelting (reduction) to attain the required grades of metallic product required. Refining also is energy intensive, normally requiring high temperatures for the chemical transformations to occur. For aluminum, refining occurs before smelting but for copper, as with most metals, refining occurs after smelting.

The refining step for aluminum is called the Bayer process. In this process, crude bauxite ore is upgraded and dehydrated to produce a relatively pure product, alumina. This is accomplished by treating the ore in a high temperature caustic environment and then submitting the product to a high temperature calcining step. Large quantities of steam are used to obtain the high temperatures, and large amounts of electrical power are required. The steam is raised by the application of the most economically available fuel. Natural gas and fuel oil are used to obtain the required high calcining temperatures.

After the bauxite has been refined, it is converted into primary aluminum through the application of the Hall-Heroult Electrolytic Process. In this process, the alumina is reduced to metallic form through the use of electricity and carbon-based electrodes. In the United States, this process requires, on the average, 15,000 kWh of electricity per ton of primary aluminum produced[3]. Worldwide the main source of electricity in the aluminum industry is hydroelectric power; however, coal also is used to provide electrical power. Coal as well as other reductant sources, i.e., petroleum coke pitch, is used to supply the carbon for the electrodes.

Each metal in the nonferrous group has its own particular smelting and refining process as well as energy requirement, and the amount of energy required is a function of the reactivity of the metal being processed. The application of coal to a specific smelting and refining process depends upon the metal and the specific process.

Coal has two primary functions in the processing of these metals, as a fuel and as a reductant. As a fuel, coal provides a source of heat, power, and electricity in the pyrometallurgical processing steps. Also, coal is used as a source of carbon for the reductant in the chemical reactions to liberate the metal. As a fuel, coal provides heat directly or indirectly in the form of steam or electric power. As a reductant, coal also may be used directly or it may be converted to a more pure form of carbon – coke – before being added to the process. Because carbon is both a fuel and reductant, coal can serve both applications in the processing of a particular metal. The application of coal to a specific metal production process will vary for each metal.

For application as a reductant, coal essentially provides a source of carbon which is a reducing agent. As a reductant source, coal must have a high carbon content, a low impurity level, and a low level of volatile gases. These characteristics are typical of anthracite coal which can be used as a heating source.

Coals without these properties can be processed (destructive distillation) to provide carbon in another form – coke. These reductants, coal and coke, are used directly as reducing agents or form the main components for carbon-based electrodes used in the electrolysis reduction process for smelting and refining some metals.

For the case of a fuel application, coal is used directly to provide heat or indirectly to provide power (steam) and electricity. The electricity, in turn, is used for both power and as a reducing agent. Coal used in this application does not have the same restrictions as coal used directly as a reductant. Normally softer coals such as bituminous, semi-bituminous, and lignite are used for heat and/or electricity generation.

As previously stated, in 1985 approximately 1.8 million tons of coal were used for those metals other than iron and steel production. Soft coals made up the major portion used.

In 1985, the amount of anthracite coal used in industry and miscellaneous applications outside of heating applications was 0.54 million short tons[4]. A major portion (0.3 million short tons) of this is used in titanium metal reduction.

In summary, the amount of coal used as a reductant for the nonferrous metals is relatively small in comparison to that which is used to provide heat, power, and electricity.

There is significant potential for the use of pure carbon as a reductant for nonferrous metals. AMAX Inc., is currently developing a technology that will produce pure carbon from coal. This project is partially supported by the Department of Energy.

In the aluminum industry, for example, a half-pound of carbon is used for each pound of aluminum produced. Thus, there is a potential market for about 3 million tons of carbon in the United States and about 7 million tons worldwide, at $250 per ton, for the reduction of alumina to aluminum.

FOREIGN EXPERIENCE

The technology and processing steps used for the production of aluminum and the other metals are essentially the same in the United States as those used in other countries.

In foreign countries, the role coal plays as a fuel in the processing of these materials is, in general, less than that of the United States. This is attributed to the fact that in some countries less expensive sources of fuel are available, i.e., hydroelectric power and flare gas.

IMPEDIMENTS TO COAL UTILIZATION

In the production of aluminum and other metals, as a fuel to supply heat, power, and electricity, coal is in competition with the other energy sources such as gas, liquid hydrocarbons, and in conjunction with hydroelectric sources for electric power. A small portion of coal is used as a reductant material. Here, other carbon sources, i.e., the coal by-products, coke breeze and petroleum coke, provide competition. In both these applications, economic restraints limit additional coal consumption.

The bottom line, however, is that even under the best of circumstances (favorable cost, quality, environment, etc) coal will never be heavily used in the aluminum and other metals group.

INCENTIVES TO INCREASE COAL USE

The use of coal in the production of aluminum and other metals appears to be limited by the economic competitiveness of the other fuel sources and alternate carbon reductant sources. However, even if coal were used extensively in these applications, the numbers would not impact this portion of the primary metal industry group significantly.

CONCLUSIONS

The ferrous group uses the major portion of coal in the primary metals industry. The tonnage of coal used in the production of aluminum and the other metals is relatively small and has not been quantified by any agency.

In the process of primary metals manufacturing, the smelting and refining steps are energy intensive.

In the aluminum industry, by far the greatest percentage of the coal used is as a fuel to provide electrical energy. Only small quantities find use as a reductant or as an electrode component.

The use of coal appears to be limited by the economics of other fuels and carbon sources.

RECOMMENDATIONS

The Secretary of Energy should encourage the research and development of technologies which can economically convert coal to pure carbon, thus expanding the markets for coal in the primary metal industry. Such a carbon also may be the ultimate clean coal (free of ash, sulfur, and nitrogen impurities) to produce electricity through more efficient heat engines.

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Chapter IV

Glass, Brick, Ceramic, and Gypsum Industries

GLASS - ENERGY OVERVIEW

The glass industry consists of four categories: Glass Containers, Flat Glass, Pressed and Blown Glass, and Mineral Wool.

Energy consumption per pound of product for each category is presented in Table 4.

TABLE 4
Energy Consumption in Btu Per Pound of Product[1]

	Flat Glass	Glass Containers	Pressed and Blown Glass	Mineral Wool
Direct heat	5,565	5,792	6,045	4,400
Electricity Net*	375	616	7,788	1,060
Steam	-	-	-	1,870

Note:

* a. Btu ÷ 3,412 = kWh

b. Net Electric Btu ÷ Efficiency of electric generation (approximately 0.33) = Btu input

BASIC GLASS PROCESSES

The principal stages in the production of glass are batch handling and preparation, melting, forming, and post forming.

Batch handling includes the grinding and blending of raw materials. Electricity is the primary energy requirement in this process. The raw materials are sand; lime; soda; and cullet, which is waste or recycled glass, and other materials which give the glass special properties. There are over 100,000 differing glasses[2], and the raw materials used in each are specific to the type of glass.

Melting is the most energy-intensive step and is accomplished in regenerative furnaces, unit melters, electric melters, and day tank/pot melters.

A typical regenerative glass furnace will require approximately 5 million Btu per ton of glass and reaches temperatures of 2800°F[3]. The high temperatures required are achieved by direct combustion radiant heating. Glass melters typically use natural gas. Unit melters also use natural gas but do not use regenerative (reradiating furnaces). Electric melters and pot melters are used where smaller capacities and specialty glasses are being processed.

A brief discussion of mineral wool production can be found in Chapter II, Coke, Iron, and Steel Industries.

After the glass is molten and raised to the required temperature, it is formed. The four main methods of forming are blowing, pressing, drawing, and casting.

The post forming stage may include several steps[4] depending on the final product. These steps are annealing (pressed and blown, containers, flat glass); tempering (flat glass); and drying and curing (fiberglass).

IMPEDIMENTS TO COAL USE

The presence of ash in the combustion products is a major impediment in using coal to directly melt the glass. When coal is used, it will likely be gasified and substituted for natural gas.

Another impediment to the use of coal for the glass industry is the attendant need for SO_2 emission controls due to the various air quality regulatory requirements. The glass industry is currently using natural gas which has fewer requirements for air quality emission controls. A conversion to coal would cause a quantum change in necessary pollution control equipment.

These impediments plus the increased capital and operating and maintenance costs for coal handling and coal combustion equipment have not created an economic climate favorable to converting to coal.

OPPORTUNITIES TO INCREASE COAL USE

It would be desirable to research the glass industry to determine the best means of applying coal to the glass melting process and overcoming the impediments. Glass manufacturing is energy intensive and employs a large amount of direct process heat. For this reason, there would be a significant potential for coal use. While certain attempts to apply coal to glass manufacturing have been made in the past[3], more work is needed in the next 10 years. This work should include the participation of the glass industry. This industry, as currently operating, has no real experience with the use of coal, and it could not be expected to undertake a conversion to coal without demonstrated technology and benchmark costs for guidance.

The Vortec Corporation of Collegeville, Pennsylvania, with funding support from the Department of Energy, is developing a Cyclone Melting System (CMS) for glass and mineral wool manufacturing applications. The heat rate for the system is typically in the range of 3.5 to 5.0 million Btu per ton of glass produced. Gas co-firing is used with this system. No discoloration of glass was observed with coal thermal inputs up to 50 percent. At the higher coal thermal input levels, some glass coloration toward amber was noted. Based on these encouraging results, it appears that a co-fired operation at approximately 50 percent of coal thermal input can be used in the production of flint and green glasses. The production of amber glasses, insulation fiberglass, and mineral products at coal utilization levels approaching 100 percent also appears to be a likely application of the technology[5].

When the difference in fuel cost between natural gas and coal is sufficient, the use of coal will come into its own. By the year 2000, it is expected that this difference could be as much as $2 per million Btu[6]. The economic incentives then may be sufficient to create an opportunity for coal.

Another incentive to coal use would be the availability of coal as a fuel compared to natural gas. The availability of economical natural gas beyond the year 2000 is subject to considerable speculation. Recent estimates of domestic natural gas reserves show a 12.5-year availability at current consumption levels[7]. Industrial users may face difficulties in ensuring long-term (beyond the year 2000) supplies at reasonable prices.

CLEAN COAL TECHNOLOGY DEVELOPMENT

There are no current applications of clean coal technologies to the glass industry. Certain developments, supported by the Department of Energy and private industry, which could be of use in the glass industry are as follows:

- ceramic heat exchangers to 2100°F;
- high temperature particulate filters to 1600°F;
- circulating fluid bed heat exchangers; and
- coal gasification.

If the direct use of coal in glass melting is to be feasible, it will require a very clean combustion process as glass melters cannot tolerate ash particles in the product. This has to be accomplished at a combustion temperature of 2800°F.

Because of the previously mentioned problem, a technology that heats the melter air in two stages may be desirable: a preheat stage based upon coal and a final heat stage based upon natural gas. The preheat stage could utilize clean coal technology with particulate control.

It also may be possible to use a mild coal gasification process where the char could be used in the preheat phase and the coal gas used in the final heat phase.

Deep cleaning of raw coal may be a requirement in either of the above technologies to make them practical in the glass melting scheme.

CONCLUSIONS

The glass industry currently supplies its energy needs from natural gas and electricity.

A major shift in the cost of fuel will be necessary to create economics favorable to coal. This shift in fuel cost could occur in the years beyond 2000.

Considering the lead times necessary to implement technology[8], it would be prudent to start climbing the learning curve now.

RECOMMENDATION

The Secretary of Energy should encourage research and development to evaluate the best means of applying coal to glass manufacturing and what new technologies may be required. This research and development should be undertaken with the participation of the glass industry.

BRICK AND STRUCTURAL CLAY PRODUCTS - ENERGY OVERVIEW

Brick (SIC 3251) is the oldest manufactured building material - sun-dried bricks have been in use since approximately 6000 BC[9]. Residential construction is the major market for bricks; in 1988, an estimated 7.1 billion bricks were shipped. Foreign trade in clay brick and structural tile is small. The brick industry is likely to experience slow growth over the long term[10].

Pertinent energy information about the United States brick industry is presented in Table 5.

TABLE 5
United States Brick Industry Energy Information [1,11]

Pieces Produced (billion)	7.1
Unit Weight (lb)	4.0
Tonnages (million short tons)	14.2
Electricity (Btu/lb)*	300
Direct Heat Energy (Btu/lb)	2329
Total Btu/lb	2629

Note:
* a. Btu ÷ 3,412 = kwh
b. Net Electric Btu ÷ Efficiency of electric generation (approximately 0.33) = Btu input

The energy content of bricks is estimated at an average of 2.3 million Btu per ton (it ranges from 2 to 4 million Btu per ton[10]). Energy cost accounts for about 20 percent of overall cost. The contact of coal ash with the product is usually not a problem in the manufacture of red brick and tiles[11]. Therefore, all other factors being equal, coal would be favored as a fuel because of its lower cost in dollars per million Btu, its availability, and the high energy requirement of the manufactured product.

After bricks are formed (extruded and cut), they are dried and then fired. The drying process uses direct heat to raise the temperature gradually in the range of 100°F to 300°F. Care is exercised in the drying process to avoid shrinking and heat cracks in the brick.

The firing process uses direct heat to raise the temperature in the range of 1800°F to 2200°F to give the brick a proper surface finish. Many varieties of brick and structural clay products are made to serve the construction demands. The value of shipments in 1988 was $1.39 billion (1988 dollars).

CONCLUSIONS

Since bricks and structural clay products are manufactured from red clay, the use of coal is facilitated because coal ash in the product is not a problem.

The energy content of bricks and structural clay products make them a potential candidate for coal use.

GYPSUM, PORCELAIN, AND CERAMIC PRODUCTS

Gypsum, porcelain, and ceramics manufactured from white or light burning kaolin clays typically would experience difficulty with coal ash impurities in the product. As such, they normally use natural gas in their direct heat applications. Gypsum consumed about 5 percent of the SIC 32 energy consumption in 1985; clay products consumed 10 percent of the SIC 32 energy consumption in 1981.

CONCLUSION

Gypsum, porcelain, and ceramics are more akin to glass in production problems. Therefore, the conclusions and recommendations for glass can be applied here as well.

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Chapter V

Cement and Lime Industries

PORTLAND CEMENT - ENERGY OVERVIEW

Coal usage in United States cement plants increased steadily during 1978–1983; since then it has dropped slightly followed by a leveling off as shown in Table 6 (page 30).

During 1988, the 80 reporting member plants of the Portland Cement Association (PCA) used 246,100 billion Btu to produce 54,653,164 tons of cement. Average energy consumption was 4.9 million Btu per ton of cement. There were 116 plants operating in the United States during 1988, producing a total of 74,074,000 tons. Extrapolating the PCA figures, it is estimated that the overall U.S. cement industry used 333,522 billion Btu in 1988. Typically, energy cost comprises about one-third of cement production costs split about evenly between fuel and power. The breakdown by fuel types for the PCA plants[2] was:

Fuel Type	Quantity	Btu (billions)	Btu Per Ton*
Coal (tons)	6,929,655	159,881	3,168,643
Gasoline (gal.)	1,442,282	182	3,625
LPG (gal.)	202,705	19	380
Middle Distillates (gal.)	19,756,355	2,974	58,955
Natural Gas (Mcu ft)	216,651	22,098	437,961
Petroleum Coke (tons)	950,463	27,546	545,932
Residual Oil (gal.)	7,056,170	980	19,430
Wastes		7,354	145,765
Total fossil fuel		**221,038**	**4,380,694**
Electricity (1000 kWh)	7,345,199	25,061	496,691
Total Btu		**246,100**	**4,877,385**

Note:
* Equivalent ton. Equivalent tons of production are weighted sums of clinker and finish cement production; the weights for energy efficiency are 92% clinker and 8% finish cement production.

Extending the coal tonnage shown above to produce 54.6 million tons of cement to that required for the overall U.S. output of 74.1 million tons indicates a coal consumption of 9.4 million tons in 1988. The PCA projects some 85 million tons of domestic cement production in the year 2000. This would require about 10.8 million tons of coal at the 1988 rate of coal usage.

PROCESS DESCRIPTION

Portland cement is produced by pulverizing clinker consisting essentially of hydraulic calcium silicates along with some calcium aluminates and calcium aluminoferrites and usually containing one or more forms of calcium sulfate (gypsum) as an interground addition[3].

Materials used in the manufacture of Portland cement must contain appropriate proportions of lime, iron, silica, and alumina components. During manufacture, analyses of all materials are made frequently to ensure a uniformly high quality Portland cement. Steps in the manufacture of cement are illustrated on Figures 1 and 2. While the operations of all cement plants are basically the same, no flow diagram can adequately illustrate all plants. There is no typical Portland cement manufacturing plant; every plant has significant differences in layout, equipment, or general appearance due to variations in weather, topography, and raw materials.

Selected raw materials are crushed, milled, and proportioned in such a way that the resulting mixture has the desired chemical composition. Either a dry or a wet process is used. In the dry process (Figure 1), grinding and blending are performed with dry materials. In the wet process (Figure 2),the grinding and blending take place with materials in slurry form.

TABLE 6
Percent of Plants Using Different Kiln Fuels[1]

	1978	'79	'80	'81	'82	'83	'84	'85	'86	'87	'88
Coal	72	77	87	93	96	98	96	97	94	94	94
Oil	2	2	1	0	0	0	0	0	0	0	0
Natural Gas	13	10	10	5	2	1	1	1	4	5	6

After blending, the ground raw material passes through the pyroprocessing system where raw feed is first calcined at a temperature of approximately 1655°F; then heating continues so that at a temperature of about 2600°F hydraulic calcium silicates are formed. The raw mix passes through the kiln at a rate controlled by the slope and rotational speed of the kiln. Fuel (powdered coal, fuel oil, or gas) is burned in the lower end of the kiln with a flame temperature of 3200°F to 4000°F changing the raw material chemically into cement clinker.

The clinker is cooled and then pulverized. During the pulverizing operation, a small amount of gypsum or anhydrite is added to regulate the setting time of the cement. It is ground so fine that about 90 percent of it passes through a sieve with 105,000 openings per square inch (164 openings per square millimeter). This extremely fine gray powder is Portland cement.

FOREIGN EXPERIENCE

In the past two decades, the United States cement industry has drawn heavily on foreign sources for manufacturing technology, particularly in the area of energy conservation. Following World War II, the Japanese, Germans, and Danes concentrated on fuel saving designs because energy was so precious in their countries. Nearly all plants built in this country since the late 1960s have employed these designs. All of the principal machinery suppliers to the industry are European-owned. Approximately 60 percent of the United States cement industry is presently foreign-owned so the technology transfer continues.

IMPEDIMENTS TO COAL USE

As indicated in the Energy Overview, at least 98 percent of this country's cement kilns are equipped to burn coal. The primary economic impediment to coal burning is price. So long as natural gas or oil are closely competitive with coal, most producers will opt for them due to ease of use and cleanliness. Typically, a cost of about 20¢ per million Btu must be added to the delivered price of coal to compare its cost with alternate fuels – this covers the expense of coal unloading and handling, equipment maintenance, and coal mill power. Cement kilns can burn relatively high sulfur (3–4 percent) and high ash coals without harming product quality.

Cement kilns are alleged to be major contributors to global climate change through carbon dioxide emissions. An industry spokesman contends that cement manufacturing makes a small contribution (1–2 percent) to the problem as compared to utilities and combustion engine sources[4]. Inappropriate pursuit of this matter by regulatory agencies and environmentalists could significantly impact the cement industry. Attempts by regulators to limit coal sulfur also can be counterproductive since, as mentioned above, the cement process has the ability to absorb sulfur in the finished product.

There are no particular societal impediments to coal burning. In the past 3 years, there has been a notable trend toward the use of hazardous-waste-derived fuels (HWDF) in kiln firing. This material is supplied at very low cost or at no cost; some provides important income to cement companies. This activity has caused some natural concern by communities near the plants, but exhaustive stack emission testing and continuous emission monitoring have allayed these concerns for the most part. HWDF replaces part of the coal burned and as part of the process of being co-fired with coal, HWDF is beneficially used.

OPPORTUNITIES TO INCREASE COAL USE

Most plants can burn coal, light or heavy oil, natural gas, petroleum coke, HWDF and other waste-derived fuels, or combinations that will yield a 3200°F flame temperature. The price of the fuel, with due allowances for the handling and processing to get it ready for the kilns, determines what fuel will be used.

CLEAN COAL TECHNOLOGY DEVELOPMENT

Clean coal technologies (CCT) are proposed to "directly remove SO_2 and NOx acid rain precursors and substantially reduce the amount of CO_2 generated when combusting coal."[5] As mentioned above, the cement process can absorb large amounts of SO_2 and proper flame control can hold NOx within acceptable limits. The primary constituent of kiln feed stock is limestone (80 to 90 percent) resulting in large quantities of CO_2 being released during the calcination phase ($CaCO_3$ + heat → CaO + CO_2) of the process. A lesser amount (some 40 percent of total CO_2 emitted) comes from fuel burning. To achieve the high temperature calcium silicate reactions, high flame temperatures are required. These would not be available from CCT; CCTs would not enhance the cement process.

Any developments in mining and preparing coal for cement kiln firing that would reduce the cost per million Btu as fired would be beneficial. Mining, crushing, and screening techniques should be examined along with any possible improvements in coal pulverizing methods.

CONCLUSIONS

At least 98 percent of cement plants in the United States are equipped to burn coal. In 1988, 65 percent of the energy consumed by the industry was through coal combustion in cement kilns.

Utilization of foreign fuel saving technologies has been extensive and continues. Average Btu per ton of cement has dropped from 6.7 million in 1972 to 4.9 in 1988, a 27.7 percent improvement.

Improvements in mining and preparing coal for cement kiln firing to reduce fuel cost would be beneficial and enhance coal use.

Looking ahead to the year 2000, all indicators are that the "bubble" of cheap gas will probably burst in 1990. The possibility of another OPEC oil pricing debacle is ever present. Use of coke and waste-derived fuels of all types will continue to increase; however, coal will remain the primary fuel for the cement industry.

IMPEDIMENTS

Primary impediments to coal usage in cement processing are cost, transportation, and regulatory uncertainty. Cement kilns are equipped to burn all types of fuels. Essentially, cost determines what fuel will be used.

Clean coal technologies will not help the cement industry. Indeed, cleanup costs dictated by the regulators will affect the power industry and increase power costs for cement manufacturing.

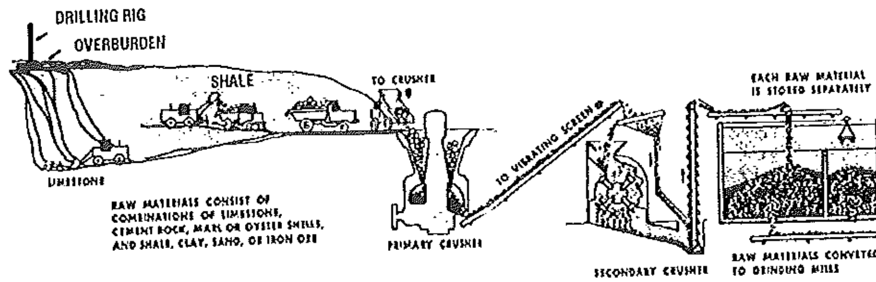
RECOMMENDATIONS

Industry should make use of available technologies to clean, dewater, dry, and prepare coal fines rejected by the coal preparation plants. This product could then be marketed to the cement industry.

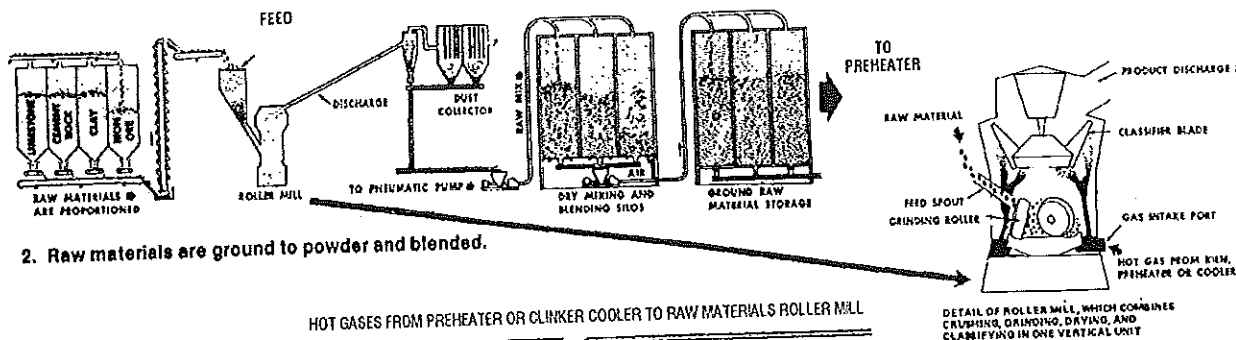
The Secretary of Energy should take appropriate action to expedite the resolution of regulating uncertainties and should continue active involvement in preventing future such uncertainties.

The Secretary of Energy should encourage expanded research and development of slurry technologies.

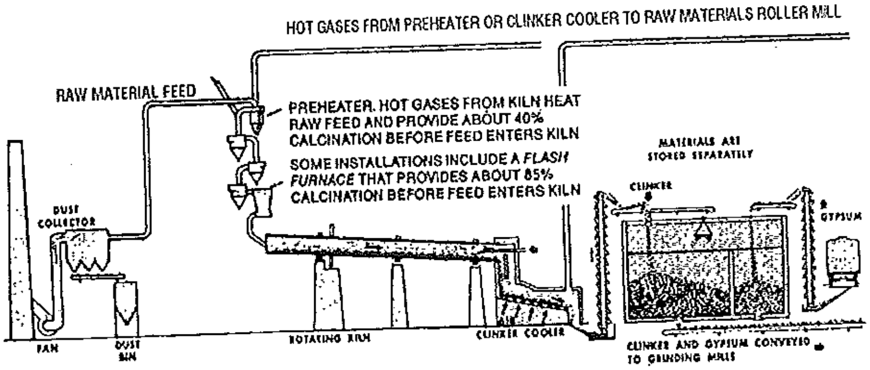
FIGURE 1 New Technology in Dry-Process Cement Manufacture



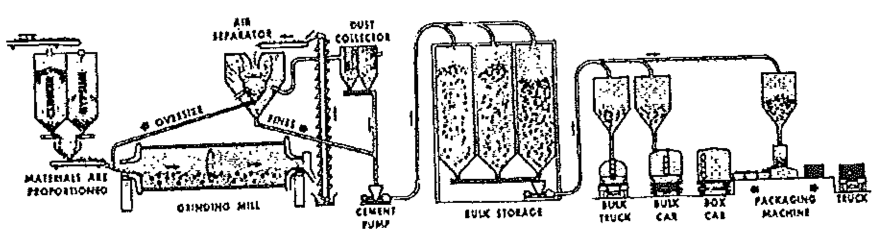
1. Stone is first reduced to 5-in. size, then to ¾-in., and stored.



2. Raw materials are ground to powder and blended.

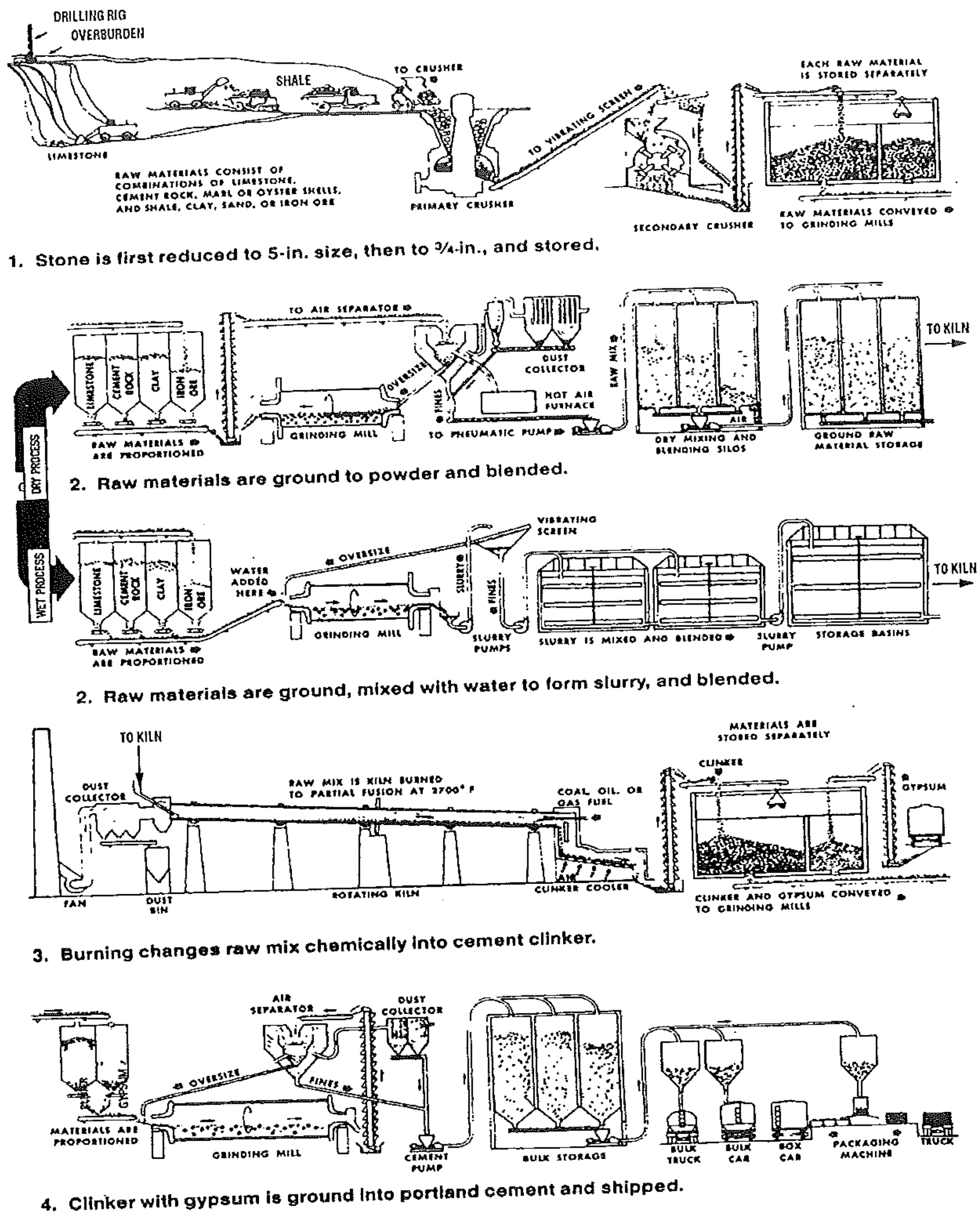


3. Burning changes raw mix chemically into cement clinker. Note four-stage preheater, flash furnaces, and shorter kiln.



4. Clinker with gypsum is ground into portland cement and shipped.

FIGURE 2 Wet Process Manufacture of Portland Cement



LIME - ENERGY OVERVIEW

Lime industry energy consumption was not surveyed during 1988. The most recent survey of the members of the National Lime Association (NLA) covered the year 1985. During 1988, according to the U.S. Bureau of Mines, 73 companies produced 17,293,000 tons of quicklime in 115 plants[6]. A 1975 NLA survey reported a weighted average of 7.37 million Btu per ton of lime produced[7]. Assuming a modest 10 percent improvement in burning efficiency since 1975 of approximately 6.67 MBtu/ton, energy consumption in 1988 can be estimated at 115,344 billion Btus. The following tabulation shows the breakdown of energy requirements:

	NLA Member Plants (1985 DOE Survey)			All U.S. Lime Plants (1988 Estimate)
Energy Source	Quantity	Btu (billions)	Percent	Btu (billions)
Coal (tons)	1,525,820	34,458	80.87	93,278
Gasoline (gal.)	144,000	18	0.04	46
LPG (gal.)	83,770	8	0.02	23
Middle Distillates (gal.)	3,432,110	476	1.12	1,292
Natural Gas (Mcu ft)	3,290	3,354	7.87	9,078
Petroleum Coke (tons)	51,690	1,557	3.65	4,210
Coke (tons)	25,540	664	1.56	1,799
Residual Oil (gal.)	2,211,240	331	0.78	900
Other		10	0.02	23
Total Fossil Fuel		**40,876**		
Electricity (1000 kWh)	508,200	1,734	4.07	4,695
Total Btu		**42,610**	**100.00**	**115,344**

Based on the above figures, it can be assumed that the United States lime industry consumed about 4.13 million tons of coal in 1988. An estimate by the NLA projects lime production of 21 million tons in the year 2000, which would require 140,000 billion Btu assuming no major breakthroughs in lime burning technology in the next decade. By the year 2000, the probable coal consumption could reach 5 million tons at the rate of 1985 usage.

PROCESS DESCRIPTION

Lime is produced by calcining high calcium or dolomitic limestone which has been quarried, crushed, screened, and classified to the proper size for burning in a kiln. There are three types of kilns used by the United States lime industry: rotary, vertical shaft, and rotating hearth. Kiln temperatures in the calcining zone can range from 1900–2450°F for high calcium limestone and usually range from 1750–2250°F for dolomitic limestone. The stone passes through the kiln at a rate controlled by the slope and rotational speed of a rotary kiln, the speed of the discharge mechanism of a vertical kiln, and the hearth speed of a rotating hearth type. More than 85 percent of U.S. lime tonnage is made in rotary kilns, about 10 percent in verticals, and 5 percent in rotating hearth units and others[8].

Fuel is fired into the lower end of a rotary kiln counter-flow to the movement of the limestone feed. Most rotaries are equipped to burn powdered coal or coke, fuel oil, or natural gas. Rotary kiln operators prefer coal over natural gas because of its lower cost and higher thermal efficiency due to its higher heat value and radiant flame characteristics. A rotary kiln consists of a feed/preheating zone, a calcining zone, and a cooling/discharge zone. Various types of contact coolers are employed to reduce the lime temperature to less than 150°F.

The vertical kiln is divided into four distinct zones. From top to bottom the sequence is: stone storage – a vertical or often a modified hopper-shaped zone; a preheating zone – designed to heat the stone to near dissociation temperature (where CO_2 is driven off); a calcining zone – where combustion occurs; and a cooling and discharge zone – usually shaped like an inverted, truncated cone at the bottom of which the lime is discharged. Fuel is fired through multiple burners at the bottom of the calcining zone and heat is pulled upward counter-current to the limestone flow by the kiln exhaust fan. Vertical kiln operators prefer gas to coal or oil because of better combustion control and improved lime quality.

Rotary hearth kilns have a stone feed bin above the hearth which also acts as a preheater since hot exhaust gases are pulled through it by the exhaust fan. The circular, rotating hearth has a precalcining zone and a calcining zone and, through instrumentation, precise temperatures can be maintained throughout the kiln. These zones, coupled with the adjustable hearth speed, enable the operator to control time of calcination for various stone sizes and to "tailor-make" special lime. Gas is the preferred fuel, then oil; however, some of these kilns also have been equipped to burn pulverized coal. Lime is discharged from the hearth into a cooler to reduce its temperature to less than 150°F.

The cooled lime is screened to remove fines and is sized for various markets as pebble and lump quicklime, or crushed and milled into ground or pulverized quicklime. Fines and the smaller sizes are hydrated to produce high calcium and dolomitic hydrated lime.

Figure 3 shows a simple flow diagram of a typical lime operation from the stone processing through the hydration of the quicklime. Figure 4 illustrates 1988 shipments by Market Segment for the U.S. Lime Industry (from Dravo Lime).

FOREIGN EXPERIENCE

Post-World War II kiln designs were developed mainly in Germany, Switzerland, and Austria. These are vertical kilns designed to improve fuel efficiency and to burn coal and coke. Antique mixed-feed kilns which process fuel mixed with limestone have been refined in Europe. They exhibit low fuel consumption but produce inferior quality lime. Many large captive lime plants in the U.S. beet sugar industries prefer these kilns because of the concentrated CO_2 gas that emits from the stacks when operated at optimum efficiency which is recovered for use in sugar refining.

IMPEDIMENTS TO COAL USE

Some impediments were noted above concerning vertical and rotary hearth kilns, but coal cost is certainly the primary economic hindrance to coal usage for burning lime. It must be significantly cheaper than alternate gaseous or liquid fuels because of the higher cost of receiving and processing coal. As in cement manufacturing, this cost differential is about 20¢ per million Btu to cover coal handling, coal mill maintenance, and coal pulverizing power costs. Most plants made the large capital investment for coal conversion (storage, handling, pulverizing, etc) during the energy crunch of the late 1970s. As the Energy Overview indicates, over 80 percent of lime industry fuel is coal, 99 percent of which is pulverized bituminous coal.

Coal quality also can be an impediment. Coal of moderate to low reactivity is most adaptable to lime burning. Ash content should be low as possible; it possesses no heat value; it fuses to kiln linings, accelerating deterioration; and it reduces lime quality by introducing silica, alumina, and other "impurities." The importance of low sulfur content (1 percent or less) cannot be overstressed. Sulfur is absorbed by lime and is strictly limited by the steel industry, a major lime market, to a maximum of 0.03 percent. As a practical matter, for economic reasons or by necessity, many mills are successfully using lime with 0.05–1 percent sulfur. No quality requirement is as costly for most lime manufacturers to meet as that for sulfur. The pulp and paper industry uses rotary lime kilns but cannot burn coal due to ash contamination.

FIGURE 3 Simplified Flow Sheet of Integrated Lime Operation

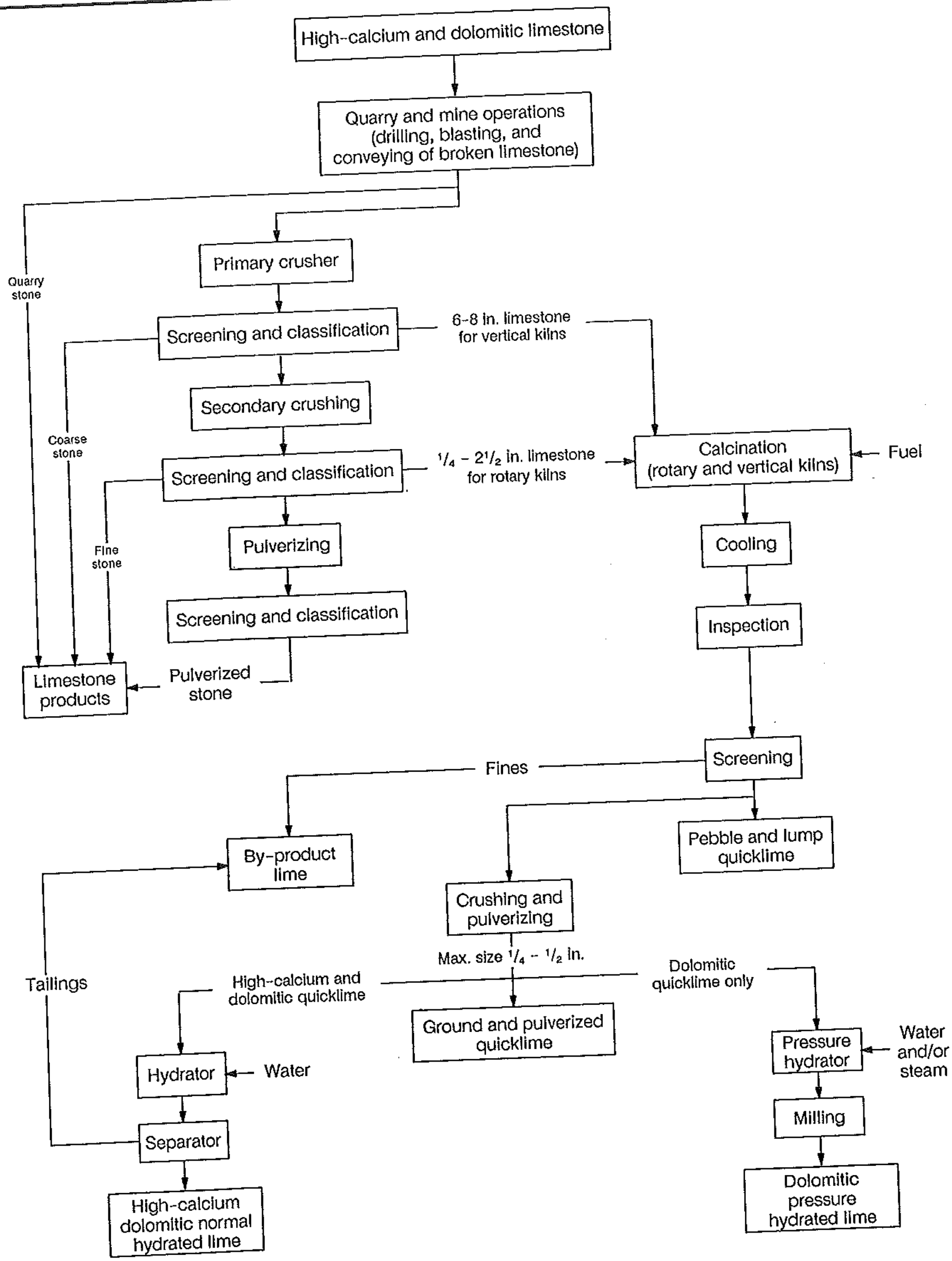
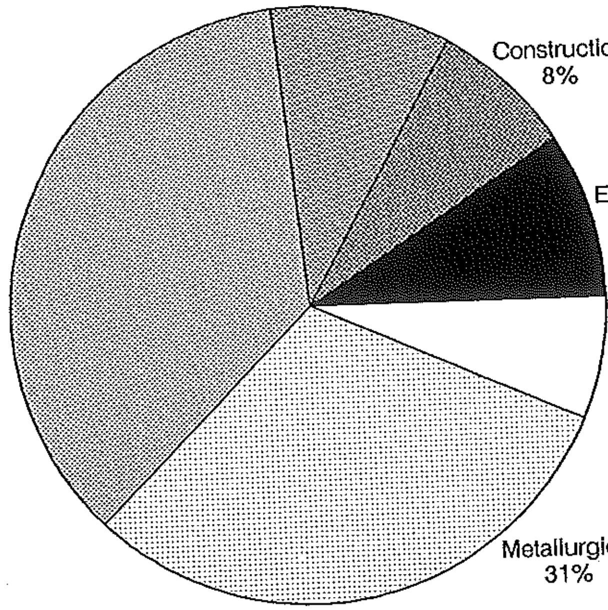


FIGURE 4 U.S. Lime Industry – 1988 Shipments by Market Segment



TOTAL TONS - 17,318,000

Source:
Dravo Lime

As with the cement process, the primary process of calcining limestone releases large quantities of carbon dioxide (CO_2) along with the CO_2 generated by burning fossil fuels:

limestone ($CaCO_3$) + *heat* → *lime* (CaO) + *carbon dioxide* (CO_2).

The lime and cement industries make a minuscule contribution to the worldwide emission of CO_2, but environmentally concerned citizens and regulatory bodies are proposing to set limits on CO_2 emissions to reduce the alleged greenhouse effect and global warming. If carried far enough, such regulations could destroy the lime industry. It is ironic that lime can be considered beneficial in solving numerous environmental problems and yet be threatened with extinction by debatable theories.

Societal impediments to coal use in the cement and lime industries appear to be environmental: concerns by lime plant communities over fugitive dust, noise from coal handling operations, and odors from incomplete combustion excursions.

OPPORTUNITIES TO INCREASE COAL USE

Some observers believe that better quality coal at the lowest price possible could result in coal exceeding 90 percent of total lime producing energy requirements. Better quality control by the coal supplier is needed to eliminate trash, dirt, rocks, and so on from the product. Improved handling and more efficient grinding systems would be helpful.

It has been suggested that a major way to increase coal use would be better working relationships between the railroad, coal, and lime industries. This could entail negotiating better rail rates to the various lime plant sites. Perhaps a standing committee from the coal, railroad, and lime trade associations could be formed to better address such concerns.

CLEAN COAL TECHNOLOGY DEVELOPMENT

Improved precombustion cleaning of coal for lime burning would be beneficial provided the cost is competitive with gas. Chemical or biological coal cleaning appears to be capable of removing as much as 90 percent of the total sulfur (both pyritic and organic) and 99 percent of the ash in coal. Economical coal gasification or liquifaction processes would greatly improve the application of coal to the vertical shaft and rotary hearth processes[9].

CONCLUSIONS

Over 90 percent of lime producing plants in the United States have coal firing capability. Approximately 80 percent of the energy consumed by the lime industry is through coal combustion.

Improved lime production through use of foreign technology has been modest and of minor impact on coal consumption.

Clean coal technologies may significantly impact lime industry coal consumption, provided precombustion cleaning can be improved at a reasonable cost.

Coal mining, preparation, and processing improvements would increase coal usage.

Through the next decade and beyond, coal will continue to be the primary fuel for the lime industry.

IMPEDIMENTS

Major impediments to increased coal usage are coal costs, transportation, and quality.

RECOMMENDATIONS

The Secretary of Energy should encourage the further development of clean coal technologies for direct heat application in the lime industry.

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Chapter VI

Pulp and Paper Industry

OVERVIEW

North America is the most significant pulp and paper producing region in the world, accounting for approximately 50 percent of worldwide pulp making capacity and 40 percent of worldwide paper and paperboard capacity. It appears that this position will not be relinquished soon, since the pulp and paper producing areas have access, for the most part, to abundant supplies of the resources required for continued development of the industry.

Appendix B presents a detailed discussion of the pulp and paper industry, its energy trends, and its estimated fuel and energy uses. This chapter highlights and summarizes information contained in Appendix B.

BASIC PROCESSES

Sources of Fiber

Wood is the principal source of fiber for papermaking in the industry. A great variety of species is used, both hardwoods and softwoods.

Pulp is produced from other fiber sources, namely textile fibers, flax, bagasse, and straw, for producing specialty papers. However, the mills using fibers from these sources are few in number by comparison, and their output is generally small, particularly in the United States. On a total production basis and an energy consumption basis, the effects of not addressing the mills using these special fiber sources will be insignificant.

Pulping Methods

Either mechanical or chemical methods are used in the production of wood pulp.

Mechanical Pulping – This pulping method uses primarily a softwood supply to produce a high yield from the wood furnish (normally in the order of 90 percent plus) to give a comparatively low quality pulp. Pulp furnish for producing newsprint is normally in the order of 80 percent mechanical pulp. Mechanical pulping consumes large blocks of power, but uses little, if any, energy in the form of steam. Therefore, cheap sources of electric power or hydro–mechanical power are essential if mechanical pulp is to be produced economically.

In 1988, about 9.7 percent of the total wood pulp in the United States was produced by mechanical pulping methods. The only self–generated fuel produced from mechanical pulping would be the bark and wood refuse generated as a by–product of processing the wood supply.

Mechanical pulp is produced by one of two generic procedures.

Stone Groundwood Process – debarked groundwood is pressed against a rotating grindstone and ground into mechanically produced pulp.

Refiner Mechanical Pulping Process – wood chips are mechanically reduced to pulp between the rotating plates of a disc refiner. There are several variations such as Thermo–Mechanical Pulp and Chemi–Thermo–Mechanical Pulp.

Chemical Pulping – This pulping method involves the steaming and cooking of wood chips under pressure in a digester vessel in the presence of a cooking liquor solution of certain chemicals in order to separate the fiber in the wood from the lignin material. Compared to mechanical pulping, chemical pulping produces a higher quality pulp at a lower yield, consumes substantial quantities of energy in the form of process steam, and uses significantly less power. The various types of chemical pulping are generally identified and designated by the chemistry of the cooking liquor involved.

Alkaline (Kraft) Pulping – the wood chips are cooked in an alkaline solution consisting basically of NaOH, NaS, and NaCO. In 1988, over 78 percent of all wood pulp produced in the United States (including mechanical pulp) was produced using kraft pulping technology. This pulping method lends itself to the production of large quantities of pulp in any given installation, and is employed by most of the large chemical pulp producers in the country. The process can be applied equally well to both softwood and hardwood furnish. Spent pulping liquors separated from the wood fibers after the digester cook provide the greatest source of self-generated fuel in the industry as the liquors are fired in black recovery boilers, where the inorganic chemicals are reclaimed and steam is generated as a byproduct.

Sulphite Pulping – the wood chips are cooked in an acid solution consisting of sulphite or bisulphite salts of magnesium, sodium, or ammonium. In 1988, only about 2.5 percent of all wood pulp produced in the United States was produced by all the various sulphite processes. In general, these processes produce less self-generated fuel in the spent pulping liquors than the kraft pulping process.

Dissolving Pulp – produced using either a modified kraft or sulphite process to produce a chemical cellulose for conversion into such products as rayon, cellophane, and cellulose acetate. In 1988, only about 2.2 percent of all wood pulp produced in the United States was dissolving pulp.

Semi-Chemical Pulp – the introduction of chemicals during mechanical pulping, a modification of mechanical pulping. In 1988, about 7.1 percent of all wood pulp in the United States consisted of semi-chemical pulp.

Secondary Fiber (Recycled Paper) – Use of recycled paper is increasing as a source of secondary fiber to supplement the use of virgin wood pulp fibers in certain grades of paper. At present, recycled waste paper is supplying approximately 25 percent of the total fiber furnish for U.S. paper and paper board production, amounting to an annual use in excess of 20,000,000 short tons of wastepaper. The use of secondary fibers has been increasing, and some years in the future may approach 40 percent of total fiber furnish.

Recycled wastepaper is used as a lower grade alternative to virgin wood pulp in such papers as newsprint, folding cartons, construction paper and board products, and others. Pulping wastepaper is significantly easier than pulping wood and uses substantially less energy.

Mill Types

Pulp and paper mills basically can be divided into three separate categories: Market Pulp, Straight Paper, and Integrated Pulp and Paper. Appendix B discusses these in detail.

ENERGY TRENDS IN THE PULP AND PAPER INDUSTRY

The general trends in both the use and supply of energy to the pulp and paper industry can be observed from data available for the years 1972 and 1988. Presumably future trends will continue in the same directions, but the rates of change may be slower.

In 1988, the pulp and paper industry consumed an estimated 13,412,000 tons of coal, representing about 32 percent of all purchased energy, both fuel and electric power, used by the industry. It also represents about 14 percent of all energy used by the industry, including both purchased energy and self-generated and residue fuels.

In 1988, the energy supplied by coal to the industry was about equal to that supplied by natural gas, but was about 85 percent greater than that supplied by residual fuel oil.

TABLE 7
Total Energy and Energy per Ton for 1972 and 1988[1]

	Fossil Fuel & Purchased Energy	Self-Generated & Residue Fuels	Total Energy
1988 Energy Consumption (billion Btu)	1,011,963	1,360,547	2,372,510
Total Production (thousand ton)	76,557	76,557	76,557
Energy Use/Ton (millions Btu)	13.2	17.8	31.0
1972 Energy Consumption (billion Btu)	1,245,505	847,074	2,092,579
Total Production (thousand ton)	53,843	53,843	53,843
Energy Use/Ton (millions Btu)	23.1	15.7	38.8

Energy Usage – Table 7 indicates, for the years 1972 and 1988, the energy used in the pulp and paper industry both on a total basis and on an average basis per ton of production of pulp and paper. A further breakdown is presented to show the energy furnished by fossil fuels and purchased energy as well as self-generated and residue fuels energy.

The trend for fossil fuel and purchased energy per ton of pulp and paper production for the years 1972 to 1988 is shown on Figure 5.

In fossil fuels, the trend curves from 1972 to 1988 show that:

- The use of oil has declined substantially so that oil provides less total energy to the industry than either gas or coal.
- The use of natural gas has declined but not to the extent that the use of oil has declined.
- The use of coal has increased substantially to the point where the energy supplied by coal is about equal to that supplied by gas.
- The total energy supplied in 1988 by oil, gas, and coal combined was less than the total amount supplied by these fuels in 1972, and was less than the energy supplied by spent pulping liquors alone in 1988.
- The thrust throughout the pulp and paper industry is the reduction of fossil fuel use in the pulp mills.
- For the most part, nonintegrated paper mills will have to continue to rely solely on the use of fossil fuels.
- Any major interruption in the supply of imported oil will shift these trend lines more strongly toward the use of self-generated and residue fuels and the use of coal.

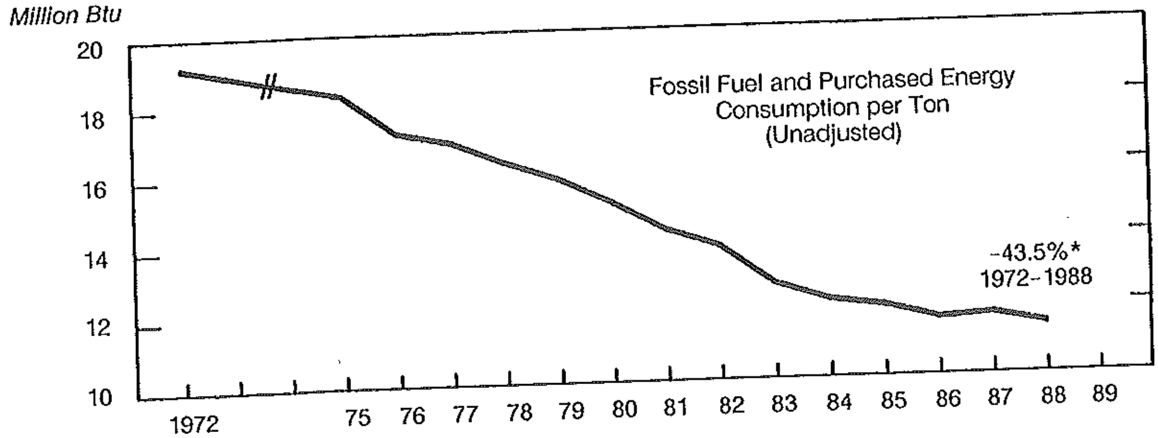
Energy Supply – Table 8 indicates the sources of fuel and energy from which the pulp and paper industry met its needs in 1988, contrasted with corresponding data for the year 1972, the year before the Arab oil embargo. Consumption figures are presented in percent of total energy and fuel usage.

The trend for self-generated energy in percent of total energy used between 1972 and 1988 is shown on Figure 6.

INDUSTRY-WIDE ESTIMATED FUEL AND ENERGY USE

Table 9 provides data for the pulp and paper industry for the entire United States for 1988, 1987, and 1972. A detailed breakdown is given for Total Purchased Fossil Fuel and Energy and for Total Self-Generated and Residue Fuels.

FIGURE 5 U.S. Pulp, Paper, and Paperboard Industry[2]



August 1989

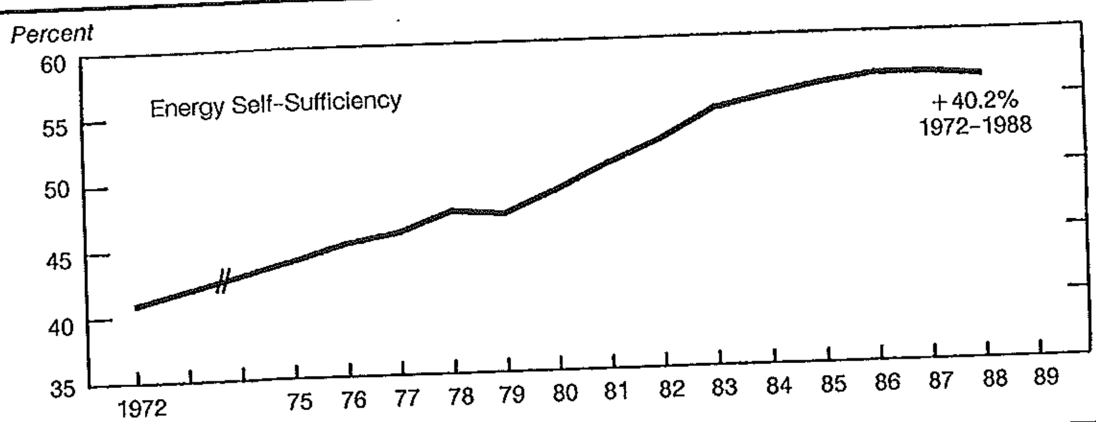
Note:

* On an adjusted basis. Adjustments made for process changes between the base year and current year which affect energy efficiencies.

TABLE 8
Fuel Sources – 1988 Versus 1972[2]

Purchased	1988 (%)	1972 (%)	Self-Generated	1988 (%)	1972 (%)
Purchased Electricity	6.6	4.4	Wood Residues	11.1	2.0
Coal	13.9	10.7	Bark	5.2	4.5
Residual Fuel Oil	7.5	21.2	Spent Pulping Liquors	39.2	33.3
Distillate Fuel Oil	0.4	1.0	Self-Generated Hydropower	0.5	0.4
Natural Gas	14.0	21.1	Other	0.5	0.1
Other	1.1	1.3			
Total	**43.5**	**59.7**		**56.5**	**40.3**

FIGURE 6 U.S. Pulp, Paper, and Paperboard Industry[2]



August 1989

Analysis of Data

The 1988 fuel and energy use figures presented in Table 9 show that:

- Self-generated and residue fuels provided 56.5 percent of the total energy used by the industry compared to 43.5 percent for all purchased fossil fuels and energy.
- Spent pulping liquors provided 39.2 percent of the total energy used, making this energy source the largest single contributor to the total requirements. The industry derived more total energy from spent pulping liquors than from coal, oil, and gas combined.
- Together, bark and hogged fuel provided 16.3 percent of the total energy used, thereby providing more energy than any one of the fossil fuels - coal, oil or gas. This makes bark and hogged fuel the second largest contributor to the overall energy package, after spent pulping liquors.
- Coal provided 13.9 percent of the total energy requirements, about equal to the 14.0 percent obtained from natural gas, and almost double the 7.5 percent figure for residual oil.
- The total estimated tonnage for the coal used was 13,412,000 tons. If the assumptions are made that all oil and gas could be replaced with coal, and that self-generated and residue fuels would make no further inroads on the use of fossil fuels, then presumably the annual use of coal could be increased to a level of approximately 35,000,000 tons per year based upon 1988 production levels for pulp and paper.

Table 9 compares the fuel and energy use figures for 1972 (the year before the Arab oil embargo) with the corresponding figures for 1988.

- In 1972, self-generated and residue fuels provided only 40.3 percent of the total energy used by the industry compared to 59.7 percent for all purchased fossil fuels and energy.
- Total energy supplied by self-generation and residue fuels increased over this 17-year period, from 847,074 billion Btu to 1,360,547 billion Btu, for a net increase of about 61 percent in total energy furnished.
- In 1972, spent pulping liquors provided 33.3 percent of the total energy used by the industry compared to 39.2 percent in 1988. Over this 17-year period the total energy supplied by spent pulping liquors increased from 698,393 billion Btu to 944,298 billion Btu, for a net increase of about 35 percent.
- In 1972, bark and hogged fuel provided 6.5 percent of the total energy used by the industry compared to 16.3 percent in 1988. Over this 17-year period the total energy supplied by bark and hogged fuel increased from 136,532 billion Btu to 392,858 billion Btu, for a net increase of about 188 percent. The use of hogged fuel made a much larger contribution to this increase than the use of onsite bark.
- In 1972, coal provided 10.7 percent of the total energy compared to 13.9 percent 1988. Total energy from coal increased from 224,737 billion Btu to 335,514 billion Btu, an increase of about 49 percent.
- In 1972, natural gas provided 21.1 percent of total energy compared to 14.0 percent in 1989. Total energy from natural gas actually decreased from 443,916 billion Btu to 338,080 billion Btu, a decrease of about 24 percent in total energy supplied.
- In 1972, residual fuel oil provided 21.2 percent of total energy compared to 7.5 percent in 1988. Total energy from residual fuel oil actually decreased from 447,382 billion Btu to 181,527 billion Btu, a decrease of almost 60 percent.

These figures indicate that in the fossil fuel industry coal use is on the rise and natural gas and residual oil use is declining.

Between 1972 and 1988, the industry output of pulp, paper, and paperboard increased by more than 42 percent.

TABLE 9

U.S. Pulp, Paper, & Paperboard Industry Estimated Fuel & Energy Use
Full Years – 1988, 1987, 1972[3]

		1988*			1987*			1972*		
Source	Units	Estimated Use	Billion Btu	% of Total+	Estimated Use	Billion Btu	% of Total+	Estimated Use	Billion Btu	% of Total+
Purchased Electricity	MM kWh	47,125.1	160,297.8	6.6	43,468.5	147,838.8	6.1	27,559.5	93,698.4	4.4
Purchased Steam	MM lb	19,199.7	21,180.9	.9	14,081.1	17,364.0	.7	19,548.3	22,613.0	1.1
Coal	M ton	13,412.0	335,513.7	13.9	13,432.0	335,087.0	13.9	9,033.6	224,737.1	10.7
Residual Fuel Oil	M 42 gal. bbl	28,849.3	181,527.3	7.5	25,393.4	159,818.4	6.6	71,121.2	447,381.5	21.2
Distillate Fuel Oil	M 42 gal. bbl	1,748.5	10,437.5	.4	1,423.6	8,499.8	.4	3,698.9	22,020.9	1.0
Liquid Propane Gas	M gal.	29,281.6	2,689.3	.1	29,806.6	2,737.3	.1	28,566.8	2,628.9	.1
Natural Gas	MM cf	331,948.7	338,080.0	14.0	338,602.4	345,437.7	14.4	435,459.9	443,916.3	21.1
Other Purchased Energy			2,258.0	.1		24,823.7	1.0		1,634.0	.1
Energy Sold			(–40,021.2)			(–35,386.5)			(–13,125.0)	
Total Purchased Fossil Fuel & Energy			1,011,963.3	43.5		1,006,220.2	43.2		1,245,505.1	59.7
Hogged Fuel (50% Moisture Content)	M ton	31,904.6	267,033.9	11.1	30,961.7	258,089.4	10.7	5,191.2	42,103.2	2.0
Bark (50% Moisture Content)	M ton	14,592.4	125,823.8	5.2	16,779.3	134,869.3	5.6	10,348.2	94,428.9	4.5
Spent Liquor (Solids)	M ton	76,659.8	944,298.3	39.2	76,918.4	949,556.5	39.6	55,175.5	698,393.4	33.3
Self-Generated Hydroelectric Power	MM kWh	3,365.1	11,446.5	.5	3,448.0	11,662.2	.5	2,696.4	9,171.3	.4
Other Self-Generated Energy			11,944.6	.5		10,177.4	.4		2,977.4	.1
Total Self-Generated & Residue Fuels			1,360,547.1	56.5		1,364,354.8	56.8		847,074.2	40.3
Total Energy			2,372,510.4	100.0		2,370,575.0	100.0		2,092,579.3	100.0

Notes:
* Based on a sample of 92.9% total dried pulp, paper and paperboard production for 1988, 91.3% for 1987, and 90.1% for 1972.
\+ Determined by using "Total Energy" + "Energy Sold" as a denominator.

OPPORTUNITIES TO INCREASE COAL USE

Given the limited reserves and dwindling domestic production of oil and natural gas plus the reliance on imported oil for somewhere near one-half of the country's petroleum requirements, questions might occur regarding the adequacy and reliability of the supply of oil. Any interruption in the supply of imported oil increases the demand for natural gas and exacerbates the problems of adequate pipeline capacity for delivery. With coal, the supply is abundant. Problems in obtaining coal would be associated with mining production and transportation, the solutions for which would be within the domestic jurisdiction and control of the United States.

Over the long term, coal will be the dominant fossil fuel. There may be a few decades or more remaining in the domestic reserves for oil and gas, but the domestic reserves for coal appear to be adequate for the next several hundred years. Over the long term, most mills may have to rely on coal for their fossil fuel supply.

In areas where steam is already cheaper to produce with coal than with oil or gas, and where the boilers are designed and equipped to burn the available coal, in all likelihood coal is already being used. In other areas, a changing price structure which produces a competitive advantage will take place when, in the future, shortages of oil and natural gas occur at the same time.

Overall, the demand for fossil fuels and the potential demand for coal will be greatest in those mills which do not have a source of self-generated and residue fuels. A market pulp mill which produces all of its energy from self-generated and residue fuels is not a potential customer for coal. Some of the older and less energy efficient market pulp mills will indeed require fossil fuel.

On the other hand, nonintegrated paper mills must use purchased fossil fuels for their entire fuel supply. Integrated pulp and paper mills generally will be between market pulp mills and nonintegrated paper mills in the percentage of energy produced by fossil fuels.

IMPEDIMENTS TO COAL USE

Coal generally will not be used where its delivered price produces steam at a higher cost than oil or natural gas. This is the greatest single impediment to increased coal use in the pulp and paper industry.

For mills located a great distance from the coal fields, conversion to coal firing would probably be implemented only if coal could be delivered in an economically competitive manner.

Coal is a bulk commodity well suited for rail shipment, particularly where large quantities of coal and long distance shipping are involved. However, over the past decade, railroads have been engaged in the sale or abandonment of short lines, branches, and sidings to improve profitability. Wherever this policy prevents delivery of coal directly into a particular mill property, it can only increase the delivered cost of coal to that mill and reduce the chances that the mill will use coal.

Whether a coal burning plant is installed new or from the conversion of existing boilers, the required capital cost is substantially greater than that required for a comparable oil or gas fired installation. This presents a major obstacle to the use of coal.

Compliance with environmental regulations governing air pollution is more expensive with coal than with oil or gas. Such regulations may well be the greatest obstacle to the increased use of coal in the pulp and paper industry.

With available landfill sites at a premium, the disposal of bottom ash and fly ash from coal firing is becoming more difficult and more costly. Residue from SO_2 removal systems further adds to the volume of material that must be sent to the landfill site.

In mills producing a high brightness bleached pulp or white papers, fugitive coal dust must be kept out of the product.

Most boilers in the pulp and paper industry operate 24 hours per day, between 350 and 360 days per year. Failure to achieve this level of availability will usually result in lost production and reduced revenues, since few mills are willing to invest in standby boiler capacity.

The most recent trend in the design of coal fired boilers in industrial sizes normally used by the pulp and paper industry seems to favor the solids circulating fluidized bed (CFB) boiler design. Early installations have had a poor history of reliability and availability due to problems with erosion in the gas passages, refractory maintenance, and the like. However, it appears that CFB boilers will continue to be used for coal firing due to their inherent advantages in limiting SO_2 and NOx emissions, and also due to the more readily disposable nature of the discharged ash.

CONCLUSIONS

In spite of the industry thrust to minimize the use of fossil fuels by economizing on the use of energy in the mills and by increasing the amount of energy from self-generated and residue fuels, there will always be a demand for fossil fuels in the industry. The total use of fossil fuels should increase, driven by a continuing rate of expansion in the production of pulp and paper which will more than offset the economies in energy use per ton of production.

The paper industry is a major industrial source of cogenerated electricity, with approximately 6500 MW on-line in 1987 (Appendix A, Table A3). Gas-fired cogeneration accounts for about 12 percent of the existing industry total compared to 27 percent for coal[4].

This industry has many applications for low-pressure steam, making it a good match for cogeneration systems.

Pulp and paper coal usage has increased steadily from 1972 to 1988, both in total quantity and as a percentage of the total energy consumption, while the reverse has been true for both residual fuel oil and natural gas. It is expected that this trend will continue, driven by market forces and by the availability of oil and gas.

RECOMMENDATIONS

Pursue increased coal usage in areas where coal already enjoys a competitive advantage over oil and natural gas. Competitive pricing is the key to increased usage of coal. Coal is most likely to be competitive in mills located near major coal fields.

For areas and mills where coal is not presently used, determine the price structure for all fossil fuels and be prepared to move in with coal as soon as the price structure changes in its favor.

The quality of coal across the country is not constant. A higher quality coal could be defined as one with a lower content of ash, sulphur, and moisture, a higher ash fusion temperature, and a higher heating value. If a higher quality coal can be offered, a customer will be faced with fewer operating problems in firing equipment, furnace and boiler, and ash collection and disposal.

Pursue increased coal usage particularly in mills with a significant need for fossil fuels. This would include the larger mills and those which do not generate most of their energy from self-generated and residue fuels.

There is substantial diversity between states in environmental permitting procedures and implementation of the various regulations; this is a major deterrent to coal use. Expediting the resolution of these regulatory uncertainties will go a long way in expanding the use of coal.

It is probable that any mill of significance will have an adequate rail siding suitable for adaption for rail car deliveries of coal. Any substantial quantities of coal that must be delivered over any great distance will require rail delivery. Efforts for coal use should be directed first at those mills with suitable rail access and facilities.

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Chapter VII

Food and Kindred Products

ENERGY OVERVIEW

Total energy use in the food and kindred products industry falls between 800 and 1,000 trillion Btu annually. Boiler fuel accounts for an estimated 66 percent of consumed energy[1] while electricity and direct fuel account about equally for the balance. Food is not considered an energy intensive industry with energy typically contributing less than 10 percent to total production costs. Gas is used for 48 percent of thermal energy with coal a distant second at about 14 percent. The industry has been strong in energy conservation, reducing total energy consumption 22 percent from 1973–1985[1]. The intensity of energy use, measured as energy used per constant–value dollar of value added, has fallen more dramatically. The 1971 estimated 18,553 Btu per 1982 dollar value–added was reduced 51 percent to 9,038 Btu by 1985.

Energy Consumption by Energy Form in SIC 20 Industries[2] (trillion Btu)

Energy Source	
Coal	131.7
Coke	N/A
Natural Gas	458.9
Oil	65.1
Net Electric Purchased	165.8
Wood, Bark, Refuse and Others	132.19
Total	954.3

BASIC PROCESSES

Nine SIC classifications exist for the food and kindred products industry:

- 201 Meat Products
- 202 Dairy Products
- 203 Canned and Preserved Fruits and Vegetables
- 204 Grain Mill Products
- 205 Bakery Products
- 206 Sugar and Confectionery Products
- 207 Fats and Oils
- 208 Beverages
- 209 Miscellaneous Food Preparations and Kindred Products

The use of coal in the food industry is generally limited to large facilities with high energy requirements and high annual load factors such as brewers, distillers, and grain millers. Several companies in these areas are successfully using coal–fired stokers and fluidized bed combustion boilers. However, there are problems with boiler sizes below about 50,000 pounds per hour steaming capacity. The available and operating experience of coal–fired boiler technology at small sizes is limited. In addition, the capital and operating cost of small coal–fired boilers is quite high on a unit cost basis.

As previously mentioned, about 66 percent of the SIC 20 energy is consumed in boiler fuel. Industrial Boilers are discussed in Chapter I and the comments there are applicable to SIC 20 industries.

Steam is used for drying raw materials and cooking in addition to cogenerating electricity for internal use as well as external sales to utilities and adsorption chilling. When steam is used in cooking, reboilers may be used to avoid product contamination with boiler water chemicals and impurities. The use of coal in this sector is almost entirely in the industrial boiler area.

Direct heat application is used for drying and cooking. Natural gas is the primary fuel although electricity also is used. Coal is not considered because ash contamination of the product is not acceptable.

Because this industry involves many processes in sequence, forms of energy that are easily deployed are favored. For this reason, steam, electricity, and natural gas are used. Processes such as Wet Corn Milling, SIC 2046; Beet Sugar Processing, SIC 2063; Meat Packing, SIC 2011; and Malt Beverages, SIC 2082 are all presented in books on the subject. The reader is referred in particular to Energy Analysis of 108 Industrial Processes[3] for a more detailed energy review.

FOREIGN EXPERIENCE

Many foreign countries have limited air emission regulations. The burning of coal, when available at economical prices, is not uncommon. In addition, many plants use process by-products for fuel. The use of coal, however, is sometimes limited by the lack of cost-effective transportation. Gas and petroleum liquids are still quite common in most foreign areas where favorable prices and availability make them the fuel of choice.

IMPEDIMENTS TO COAL USE

The food industry is a mature United States industry, with any project evaluated for its economic value in maintaining a competitive edge. It is significant to note that practically no food plants are known to be planning new coal burning equipment in the near future. The reasons are almost all economic. While coal is almost always less costly to purchase on a raw dollars/Btu basis, the cost of coal burning equipment typically erases the fuel savings. This is currently more evident due to the narrow difference between the cost of oil/gas and coal.

Regulatory requirements make coal burning and storage impractical in all but the largest systems. There are a number of factors driving this trend. As systems become larger, the economies of scale naturally work toward coal's favor as unit and installation size increase. The larger systems typically are installed in plants which run on or close to a base load factor. Corn millers, distillers, and brewers all have good capacity factors as well as support large unit capacities. Many of the SIC 20 industries, such as canneries and crop processing, are seasonal and unit sizes tend to be smaller. Lower capacity factors and smaller unit sizes favor installations with lower initial capital costs and drive fuel selection toward natural gas.

The larger units typically take advantage of cogeneration using extraction or extraction/condensing turbines, which can have a significant impact on overall economics depending on local power costs.

The societal impacts of coal use in the food industry are possibly more significant than any other. The thought of open coal storage adjacent to a food preparation facility has influenced the choice of gas/oil over coal. This is more of a problem in high density areas both from an esthetic and a space-available basis. The perception that coal is dirty has contributed to the reduced use of or rejection of coal as a fuel. Few realize that many existing and new coal plants produce lower sulfur and other harmful emissions than older plants allowed to burn oil with unlimited sulfur content.

INCENTIVES TO INCREASE COAL USE

A real incentive can be achieved by amending environmental regulations to specify what is required in terms of emissions and *not* in terms of percent reduction or best available control technology. The current "percent reduction" system of reducing emissions is an impediment. The requirement to reduce 90 percent of the sulfur emissions serves to penalize those with good access to low sulfur coal. This regulation requires 90 percent of the sulfur be removed regardless of the total as fired sulfur content.

Cogeneration can reduce fuel consumption by almost 50 percent when used in conjunction with heating and cooking. The environmental impact would be nil and would provide increased opportunities for coal use.

CLEAN COAL TECHNOLOGY DEVELOPMENT

Advanced clean coal technologies which may be the most appropriate to the food industry are those that avoid major capital and facilities investments at the food processing plant. This is because of the small scale and low annual load factor of energy equipment at many food processing plants. Pre-processing of coal at larger central facilities has the important advantages of economies of scale and high annual load factors. These clean coal technologies could include coal gasification, coal liquefaction, and advanced coal preparation. The advanced coal preparation would likely favor ultra-clean coal which is predried and micronized. These technologies also would have the potential benefit of retrofitting existing small natural gas package boilers.

To enhance the viability of burning coal in the food industry, it is necessary to develop a low cost, dependable, environmentally acceptable technology for combustion of coal. This could be the development of a coal cleaning process which renders coal clean enough as fired to eliminate the need for additional abatement equipment onsite. Or it may include highly dependable, onsite emission reduction equipment which requires moderate amounts of capital, even more moderate operating costs and extremely high dependability. Future technology may be in the form of coal gasification equipment working in conjunction with gas distribution systems which ultimately provide fuel to food plants but may not necessarily be located at the plant site. This technology, of course, would not be limited to fuel plants; once installed, any plant in a gas distribution system would be able to benefit from the technology. The primary driving force in the competitive food industry is life cycle cost.

CONCLUSIONS

The food and kindred products industry is not a major user of coal and it is not likely to become one.

The perceived idea of coal as dirty has contributed to the reduced use of and rejection of coal as a fuel.

Coal is not used in direct heat application because the end product cannot tolerate ash particles.

Energy cost is a low percentage of the value added in the SIC 20 sector.

SIC 20 is the largest industry group in terms of value of shipment for the manufacturing industries but ranked fifth in total energy consumption.

The potential for cogeneration within SIC 20 is especially promising.

IMPEDIMENTS

Regulatory requirements make coal burning and storage difficult for small systems.

The requirement to reduce sulfur emissions by a fixed percentage serves to penalize those businesses with access to low sulfur coal.

RECOMMENDATIONS

Dependable, quality coal burning equipment in smaller sizes typically found in food manufacturing plants must become available. These smaller units exist in Europe; however, they are not required to meet the 90 percent SO_2 reduction requirements of the United States.

The Secretary of Energy should encourage a realistic and responsible national policy that balances the cost of environmental controls with the benefits to society.

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ACKNOWLEDGEMENT

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Chapter VIII

Durable Goods Industry

INTRODUCTION

The durable goods industry represents essentially all of the United States manufacturing industry, including SIC Codes 25, 30, 34, 35, 36, 37, and 38. It does not include those industry segments which are specifically discussed in separate chapters of this report.

ENERGY OVERVIEW

The durable goods industry uses approximately 1.4 quads of energy annually. Coal represents only .08 quad, or 6 percent of that total, and essentially all of it is consumed in steam boilers. Industrial Boilers, covered in Chapter I, will not be discussed further here. Chapter I also addresses self– or cogenerated electricity which is a small but growing energy source for the manufacturing industry.

Purchased natural gas and electricity at 43 percent and 38 percent, respectively, of the total energy input are the dominant energy sources that drive the durable goods industry.

Energy typically represents a relatively small percentage (1 to 3 percent) of the value of shipments of durable goods, and approximately 2 to 6 percent of the value added cost. Consequently, energy reliability, availability, and ease-of-use can outweigh concern over cost.

In spite of the relatively low cost impact of energy, the durable goods industry has achieved significant energy efficiency improvements over the last decade. Consumption per dollar of value added decreased from 4,100 Btu to 2,800, or 32 percent, between 1975 and 1985. New processes and material technologies are expected to yield substantial and continuous additional improvements in the future.

BASIC PROCESSES

The durable goods industry utilizes practically every manufacturing process, machine, and production system known. Most have relatively low energy input, low annual load factor, and are disbursed throughout a typical manufacturing facility. This general lack of energy concentration and energy density puts a premium on ease of distribution and control of energy. Gas and electricity meet this criteria particularly well, and thus are the dominant energy sources for the great majority of the durable goods industry processes and energy applications. Coal does not meet these criteria and is not used, except in central boiler plants.

The following briefly lists the more significant processes and their typical energy inputs.

Building Space Heaters – Current practice favors gas-fired heaters. Steam is used where central steam generation systems can be justified.

Furnaces and Heat Treating – Natural gas is most commonly used. Some shift to electricity is evident.

Ovens (i.e., Paint Curing Ovens) – Natural gas is used extensively in the United States. High pressure steam/water is common in Europe.

Machining and Forming (i.e., Grinders, Presses) – Exclusively driven by electric motors.

Plastics Processes (i.e., Granulators, Extruders) Primarily powered by electricity.

Soldering/Welding – Primarily powered by electricity, some gas.

IMPEDIMENTS TO COAL USE

The processes and equipment used in the durable goods industry can generally operate only on the fuels for which they were designed. Solid coal is not an alternative. Coal gasification, with the gas meeting pipeline quality standards, theoretically could replace all gas usage.

Impediments to coal use include high capital cost, current environmental constraints and the uncertainty of future regulation, the lack of small and proven gasification equipment, the likely conflict between the limited-load-following ability of a gasifier, and the high degree of variability of the processes.

INCENTIVES TO INCREASE COAL USE

Incentives are not likely to make coal a fuel of choice in the processes and energy application of the durable goods industry. However, those incentives detailed in Chapter 1 related to increased coal use in boilers can result in increased coal usage.

CLEAN COAL TECHNOLOGY DEVELOPMENT

The development of small-scale gasification, possibly tied to combined-cycle electric generation, theoretically may provide an alternative for the natural gas and electricity now used in the durable goods industry. Practically, however, the chances for success seem remote.

More likely to be of value to the durable goods industry is the development of truly cost-effective large gasification/liquifaction (perhaps powdered coal in oil)/combined-cycle electric generation. Such a development would help to maintain the reliability of reasonably priced electrical and gas supplies for relatively small users like durable goods manufacturing plants.

CONCLUSIONS

The durable goods industry is not an intensive user of energy.

Energy represents a relatively small share of the industry's costs and is not a top priority issue.

The industry relies primarily on purchased electricity and gas.

The durable goods industry is not a major user of coal and will not likely become one.

IMPEDIMENTS

In the durable good industry, energy use is normally distributed throughout a typical manufacturing facility. This general lack of energy concentration and density puts a premium on ease of distribution and control of energy. Coal does not meet these criteria; therefore, it is not used except in central boiler plants.

RECOMMENDATIONS

The Secretary of Energy should encourage a high-level of research and development into small size combustion systems.

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Chapter IX

The Textile Industry

INTRODUCTION

The textile industry, a small industrial coal using group, includes SIC Codes 22, 31, and 23. In 1985, this group of industries consumed approximately 1,733,000 tons of coal. As such, they used only about 1.8 percent of the total industrial coal consumed. Because of the small size of the industrial group, it is one of the least thought about regarding industrial coal and energy policy decision making. It has specific needs – needs which are significantly different from those of the other major industrial sectors. These differences must be understood if any energy policy promoting coal will benefit the users.

The Textile Mill Product group (SIC 22) includes those businesses involved in the production of fibers, yarns, fabrics of any type, knit apparel, yarn based rugs and carpets, and processing of any fabrics other than plastics. The Leather and Leather Products group (SIC 31) includes any business engaged in the preparation and finishing of hides and skins and production of finished goods made from these or similar materials. Apparel and Other Textile Products group (SIC 23) is involved in the production of clothing and other products by cutting and sewing of purchased fabrics and materials produced by the abovementioned industries plus related material from the plastics and rubber industries. These are the businesses which produce the "taken-for-granted" products like socks, underwear, suits, and shoes – the silent industry very seldom heard from.

There are approximately 14,000 facilities employing 20 or more people that come under the textile industry grouping. Of these, 3,400 are in the Textile Mill Industry where almost all the coal is consumed in approximately 110 plants. Most of these businesses are located in the northeast and southeast sections of the United States, especially in the North and South Carolina area. For the most part, it is a small town industry. In many of these towns, the textile mill is the major industry where many of the town's people have worked for 20, 30, or 40 years. The plants are small by general industry standards, usually employing from 50 to maybe as high as 300 people. Except for a few modern facilities, the basic technology used is much the same as that used in the 1950s and 1960s.

The textile industry is an American industry in the broadest sense of the word. There is and has always been intense competition within the United States for the U.S. market. As a result, for most companies, there has never been enough profit to invest in new energy-related equipment. The increased burden of government regulations, investor demand for short-term profits, and high U.S. labor costs have increased the opportunity for international competition to enter the U.S. market and capture significant portions of it. There is no room for added costs or capital spending which do not generate revenues and yield less than a 2-year payback. With foreign competition, the industry is barely holding its own, and the slightest cost increases can generate significant business losses. What funds are available are being invested in modern, high-speed, high-tech looms to maintain a competitive position.

In the 1930s and 1940s, the textile industry was primarily fueled with coal. However, in the 1970s with the passage of the Clean Air Act and the low capital cost of the packaged oil- and gas-fired boilers, there was no choice but to replace an aging population of low efficiency, labor-intensive 40- and 50-year-old coal-fired boilers with cheap gas and oil fired systems.

TABLE 10
Relative Rates and Cost of Energy Utilization in the Textile Industry

	Electric	Residual	Distillate	Natural Gas	Coal	LPG	Other
Trillion Btu	105	21	9	107	38	3	8
Percent of Total	36	7	3	37	13	1	3
1989 Dollars Per Million Btu	15.07	2.19	3.90	2.94	1.61	4.77	UND
Annual Fuel Bill–1989 Dollars (millions), Consumption	1,582	46	35	315	61	14	UND
Equivalent Coal Tons (1000 Short Tons)		954	409	4,861	1733	136	363

ENERGY OVERVIEW

The textile industry is a small energy user when compared to major industrial companies. For the grouping considered herein, there is a total consumption of 292 trillion Btu. This is about 1.7 percent of the total industry energy consumption of 17,522 trillion Btu for the same period. Of the 292 trillion Btu, 291 trillion Btu, or about 99.7 percent was used for heat, power, or electric generation. Coal accounted for 38 trillion Btu, or about 13 percent, of the energy used as fuel in this group of industries.

As a comparison of the fuels used for the production of heat, power, and electricity within this industry, Table 10 presents a breakdown of energy use rates, by fuel, with the relative costs in dollars per million Btu.

Oil and natural gas are the primary fuels used. There is little data available from the industry itself which can be used to track current energy consumption and cost as they affect the potential of coal use within the industry. Based upon observations over the last 2 years, the lower natural gas prices may have shifted the total energy consumption picture more toward natural gas use and away from coal. The potential market for coal would be as a replacement for the oil and gas fuels currently used. This could generate a total market for coal on the order of about 8 million tons per year.

IMPEDIMENTS TO COAL USE

From the consumption figures presented, it is evident they follow the basic small mill described previously. Because of the small size of most of the facilities, the energy requirements are too small to justify any economies of scale for equipment, transportation, or environmental considerations when burning coal. At this size, the boilers are normally small, stoker–fired systems where a higher cost, specifically sized coal is required for operation.

The availability of stoker–sized coal impedes the use of coal in the small size units. Many of the primary coal suppliers to the industrial stoker market have gone to new, modern mining methods using continuous mining machines which produce less stoker coal. Since this is normally of better quality than the fine coal produced along with it, more of the stoker coal is being needed to improve the quality for the utility product to meet environmental regulations. New technologies are going to be needed to compensate for this trend in the availability of stoker coal.

The smaller facility is hindered by the initial capital investment for coal burning equipment in relation to the money available and the cash flow and payback requirements needed to operate the business. The larger facilities, those with energy consumption greater than 70 to 100 million Btu per hour steam demands, are the companies primarily responsible for most of the coal burning in the industry. Here the energy requirements are conducive to and support conventional coal burning equipment with reasonable paybacks as a percentage of the revenues generated for that facility. In the last 10 years, only one boiler company has developed a practical and economic piece of equipment applicable to the smaller systems. This is the CNB boiler. Because of the size and requirements of the market, there is no incentive for equipment manufacturers to address this need.

The small industry boilers are designed to emit much fewer particulate emissions (on a percentage basis) and nitrogen oxide than the larger industrial and utility units. These particulate emissions are of a much coarser nature than those from other type systems. Normally, these boilers use the best portion of the coal product; in many cases, the lowest sulfur coal from a coal seam. Requirements to decrease the emissions to levels below the equipment capabilities associated with the small sized units has placed a significant application cost burden on the industry. For the most part, this will prevent the application of coal to all but the largest facilities. Further, the uncertainties of new proposed regulations mandating extensive emission control for particulates, continuous emission monitoring and unrealistically low sulfur emissions has all but eliminated coal as a viable option. There is no tolerance in the industry for any increased costs, especially added extra capital costs without increased production or productivity.

INCENTIVES TO INCREASE COAL USE

The only incentive to increase the use of coal in the textile industry is its lower cost. However, the total application cost of coal must be considered. In this industry, the impediments increase the application cost to a point where, in many cases, the differential cost of using coal is lost. Considering the capital availability within the industry, the industry is not in a position to be able to fund its own energy research and development. Other than for the large facility, for all practical purposes, there are no incentives to increase coal use in this industry.

Use of heat energy in the textile industry is mainly through industry steam boilers at lower steam pressures. This industry, therefore, would be susceptible to cogeneration which could serve as a justification for coal use instead of other fuels.

USE OF CLEAN COAL TECHNOLOGIES

Most clean coal technologies are aimed toward large scale removal of sulfur and nitrogen oxides from coal to produce a cleaner environment. These technologies, for the most part, deal with either front-end fine coal cleaning or expensive back-end removal technologies. Small units need coarse, specially sized coal and cannot afford costly back-end systems. The current new technologies being funded will have little or no effect on the abilities of the textile industry to use coal in the future.

Of all the energy technologies considered today, three may have some impact on the use of coal in this industry. These are micronized coal (the Microfuel and TAS systems) with fine coal cleaning like AFT's flotation cell, the TRW Slagging Combustor, and the natural gas industry's coal and gas co-firing technology. These may have a potential benefit if design, complexity, and application costs can be controlled to maintain a positive total cost differential at the small unit sizes.

CLEAN COAL TECHNOLOGY DEVELOPMENT

As previously mentioned, there is no incentive for equipment manufacturers to develop technologies to meet the needs of this industry. If the textile industry is to increase its use of coal, research into small size systems will have to be undertaken and promoted by someone other than the textile industry. Considering the fact that coal could replace natural gas and oil, these fuel lobbies will definitely hinder any intrusion by the coal industry either directly or indirectly through environmental regulations thereby raising the application cost of coal.

CONCLUSIONS

The textile industry is typically made up of small producing facilities located in small towns in the northeast and southeast sections of the United States.

If consideration is given to the requirements of the small unit and textile industry needs, micronized coal, the slagging combustor, and coal and gas co-firing may be applicable to this industry.

IMPEDIMENTS

There are no economies of scale to minimize the effects of capital and application costs on the coal system.

Intense competition from within the United States and from foreign companies make capital investment in coal energy systems almost nonexistent.

Any increase in fuel cost or application cost can produce significant business losses for the small companies within the industry.

There is no incentive for equipment manufacturers to develop new technologies for this industry.

Current and proposed regulations will all but eliminate coal from further consideration within this industry.

RECOMMENDATIONS

The Secretary of Energy should encourage a high-level of research and development activity into small size combustion systems.

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Chapter X

Refining and Chemical Industries

INTRODUCTION

The refining and chemical industries are both processing industries. However, since they differ in their energy use, this chapter will discuss each separately. Conclusions, impediments, and recommendations for both industries will be presented.

PROCESS INDUSTRIES

Refining Industry

The refining industry is a large consumer of energy; however, a refinery tends to run in energy balance. In many cases more than 70 percent of a refinery's energy needs may be supplied by refining gas.

Table 11 (page 58) presents refinery energy use in the Organization for Economic Cooperation and Development (OECD) and selected industrial countries, including the indicated use of coal in selected years[1]. Refinery energy sources are remarkably constant across industrial countries, with oil and electricity providing all refinery energy in most industrial countries. Only six OECD countries use natural gas for refinery energy. Natural gas represents over 10 percent of refinery energy in four industrial countries, including the United States and Canada.

Coal is unimportant in refineries at present and may have no role at all in refinery energy. The OECD data show only 2 of its 24 member countries with any coal as inputs to refinery uses, the United States and West Germany. A German specialist informed the American Petroleum Institute that no coal is used as an energy source in German refineries. It was suggested that the coal shown in OECD data may have been the raw material for experimental coal-to-oil plants, which have been withdrawn from service. By adding the 1,000 short tons per day used at Rhur Chemie in a coal gasification plant, one will be close to the reported number.

In the United States, the only refinery use of coal is at a lubricating oil refinery in West Virginia.

In 1985–1987, SFA Pacific, Inc., performed a study[2], funded by the Department of Energy, on the possibilities of expanding coal use in several energy-intensive industries, including petroleum refining. The 1985 report[3] says, "Only a small amount of coal has traditionally been used in the oil refining industry." This basically confirms the data in Table 11.

Significant use of coal in United States refineries apparently would depend on a favorable conjunction of several factors. Refinery operations would have to evolve in a way that increased the demand for purchased energy by using more energy per unit of product without a corresponding increase in usable by-products. Nonetheless, even in a complex refinery, more than 70 percent of fuel requirements may be satisfied by refinery gas. For coal to be considered for the excess, the attractiveness of coal for refinery use in economic and environmental terms would have to improve.

Oil is readily available at refineries and requires no special facilities. In addition, most oil used as fuel in refineries represents by-products with limited sales opportunities, such as "refinery gas" and petroleum coke. In contrast, coal requires dedicated handling facilities and storage areas and, in most cases, must be purchased from outside and transported long distances. Coal often has environmental, real or perceived, disadvantages which have particular importance considering the air quality problems in many areas where refineries are located. These environmental problems can be overcome by utilizing clean coal technologies.

TABLE 11
Refinery Energy Sources in OECD Countries[1]
(million tons oil equivalent)

		Oil	Gas	Electricity	Coal	Total
1973	United States	29.79	25.50	2.22	--	57.51
	Canada	5.17	--	0.24	--	5.41
	Germany	9.84	--	0.55	--	10.38
	Japan	17.19	--	0.42	--	17.61
	Other OECD	38.95	0.22	1.10	--	40.28
	Total OECD	100.94	25.72	4.53	--	131.19
1978	United States	49.62	18.93	2.45	--	71.00
	Canada	4.77	--	0.31	--	5.08
	Germany	9.89	--	0.40	0.15	10.44
	Japan	25.04	--	0.48	--	25.53
	Other OECD	39.06	0.49	1.28	--	40.83
	Total OECD	128.38	19.42	4.92	0.15	152.88
1986	United States	39.99	13.89	2.92	0.13	56.93
	Canada	4.76	1.87	0.39	--	7.02
	Germany	5.01	0.32	0.46	0.67	6.45
	Japan	9.76	--	0.43	--	10.19
	Other OECD	28.14	0.78	1.21	--	30.13
	Total OECD	87.66	16.86	5.41	0.80	110.72

Notes:
1. The 24 OECD nations are Australia, Austria, Belgium, Canada, Denmark, Finland, France, West Germany, Greece, Iceland, Ireland, Italy, Japan, Luxembourg, the Netherlands, New Zealand, Norway, Portugal, Spain, Sweden, Switzerland, Turkey, United Kingdom, and United States.
2. This table is based on "end use" energy. This concept does not include indirect energy use in the form of conversion and distribution losses. To calculate total primary energy needed to support an activity, it would be necessary to include such items as electric power generation and transmission losses, energy used in operating natural gas pipelines, and similar items. In particular, primary energy in electricity is about 2.7 times the indicated figures.
3. OECD data are provided by the individual countries, and so may not be strictly comparable. The data in this table are "residuals," i.e., the difference between inputs and outputs, so any errors or inconsistencies in the data would be magnified. Methodology changes from year to year, making detailed comparisons over time more difficult.

SFA Pacific's work envisioned significant opportunities for the use of coal in refinery boilers during the 1990s, but these conclusions were hedged with many qualifications. The most favorable conditions involved substantial increases of oil and gas prices, relative to coal; an increase in a refinery's per unit energy needs; and commercial development of new coal technologies as well as availability of offsite space for coal facilities and rail or barge transportation at individual refineries.

SFA's 1985 report[3] asserted, "Coal will almost certainly work its way into oil refining. The main uncertainty is when." Five years have passed, and the prospects for coal use do not appear any closer. (At Idemitsu Oil Refineries in Japan, coal is being used in refinery boilers with an annual consumption of about 680,000 tons per year.) Oil prices have fallen rather than risen. However, new coal technologies have been developed and can be used. Economics will determine their installation. The refining industry has recovered from its depressed state, but for a number of reasons there is little prospect of major grassroots refinery construction in the United States.

Refinery energy requirements have been boosted by low–gravity, high–sulfur crudes, but continued improvements in efficiency have mitigated this rise. Furthermore, there are indications that the more severe processing could result in additional by–products, particularly petroleum coke. This coke makes an excellent feedstock for a clean coal technology such as gasification.

On balance, there is little reason to believe that the current situation, limited use of coal in refineries, is likely to change in the coming decade. What might happen beyond the turn of the century is a matter that can be impacted by many unpredictable economic and technological changes. In the future, a changing crude slate will probably result in an increasing need for hydrogen. Depending on the ultimate slate of products and their value, this could be derived from coal. A more likely source for the hydrogen is the use of a clean coal technology such as gasification to gasify petroleum coke, the bottom of the barrel as a hydrogen and/or energy source. Indeed such a gasification plant has been announced in Delaware by Delmarva Power, Star Enterprises, Mission Energy, and Texaco Syngas.

In addition to being a source of energy and of hydrogen, coal also has the long-term potential of being a source of feedstock derived from direct or indirect liquefaction of coal. Direct liquefaction has not been scaled to sizes sufficient for commercial use. A large-scale indirect liquefaction plant has been in operation at Sasol in South Africa for a number of years. In addition, the co-processing of coal and heavy petroleum liquids is a potentially promising technique. These technologies are not now economical given the present price of crude oil. In the future, however, they may become so; additional research and development appear to be warranted.

Chemical Industry

The chemical industry is a major user of coal as a fuel. The energy consumption data given in Table 12 show that coal and coke constitute approximately 16 percent of the total chemical industry fuel excluding electricity. Using the data in Table 12 and from the Department of Energy[4], it can be seen that the chemical industry uses 16 percent of the coal consumed by all of industry excluding coke plants. Coal has played an important part in the chemical industry's energy base and is expected to continue.

Certainly, 14.898 million tons of coal per year is not insignificant. Of course, the one quadrillion Btu of electricity used by the industry also can be obtained from coal. The location of industrial facilities and the utilization of natural gas and natural gas liquids as feedstocks has an inherent impact on fuel selection. Chemical plants located in gas producing areas which utilize gas and gas liquids for feedstocks would tend to utilize gas for steam generation and process heat and conversely for coal. Expanded use of coal as a source of steam and feedstock can come through the use of coal gasification processes. This selection then becomes economically driven.

TABLE 12

Chemical Industry Energy Use, 1988

Total Fuels and Electricity (Electricity @ 10,000 Btu/kWh)	2.923 quadrillion Btu
Total Fuels excluding Electricity	1.912 quadrillion Btu
Coal and Coke as Fuel	0.297 quadrillion Btu
Equivalent Tons of Coal and Coke (Tons @ 24MM Btu/ton)	12.375 million tons
Coal and Coke as Percent of Total Fuels and Electricity	10.2 percent
Coal and Coke as Percent of Total Fuels excluding Electricity	15.5 percent
(Based on CMA Member Survey)	

Unlike the refining industry, the chemical industry can use coal as a raw material. For many years, the organics from coke sources were collected and used. With competitive sources from petroleum as well as emissions and other constraints such as technical separation, this area is not likely to expand.

Today there are three plants manufacturing chemicals from coal as a raw material. These are the Tennessee Eastman Plant in Kingsport, Tennessee, manufacturing acetic anhydride from coal via synthesis gas; Ube Industries in Japan, manufacturing ammonia from coal; and the Rhur Chemie Plant in Oberhousen, West Germany, manufacturing oxo-alcohols from coal.

The competing cost of natural gas as a feedstock for the manufacture of ammonia as well as imported ammonia appear to constrain the use of coal as a raw material for these purposes. The choice of feedstock in the future will be based upon economic and environmental considerations. Between now and the year 2000, there does not appear to be any significant impact in the use of coal for chemical raw material.

Additional research directed to the manufacture of chemicals from coal through synthesis gas should lead to other commercial applications of coal as a raw material. These applications, however, may not be commercialized until after the year 2000. The Tennessee Eastman Plant is an example of starting with coal to produce a final product that has now resulted in a base-load plant operation in the manufacture of acetic anhydride by developing the appropriate catalyst to manufacture a product from the synthesis gas derived from coal. Additional research and development in this area will probably continue to expand the market for coal.

One area which has increased potential for coal utilization is in cogeneration. Here the coal burning facility would provide steam to a process as well as electricity to the utility grid or to the industrial facility. Such facilities can prove economical in certain locations even with the required emissions controls. They can be built and operated in such a way as to maintain reliability of the steam supply to the process. When this is coupled to the preparation of a raw material (syngas [CO and H2] as a raw material), the chemical company has the potential, through gasification, for steam, electricity, and a raw material. The potential for this means of coal utilization should be expanded. Today, natural gas is the primary fuel for cogeneration in the chemical industry.

There are impediments to the increased use of coal at this time. These include the energy price differential versus natural gas and environmental restrictions. Installation of scrubbers on critical services such as steam generators creates reliability concerns. The increased operating cost of boilers equipped with scrubbers or fluidized bed boilers and the potential reliability effects are a concern which can enter into the decision regarding fuel selection for new equipment. Increased cogeneration can be inhibited by a lack of access to the grid, and technology may not be in place to economically convert syngas to commercial chemicals.

Cogasification of waste material with coal is one area which may enable coal to: become a more significant provider of electricity and/or energy, become a raw material to chemical plants, or allow it to be used more significantly as an energy source of fuel in chemical plants.

The Cool Water Plant in Daggett, California, is expected to come back on line in 1992, using a mixture of sewage sludge and coal to generate electric power. Tipping fees available for eliminating the waste can go a long way in terms of making a coal plant economical in today's low priced gas environment. The future raw material base then becomes a significant, secure source. The Federal Government should encourage continued use of this waste with coal as a viable raw material/energy source available to the industry.

CONCLUSIONS

In the foreseeable future, there will be no significant increase in the use of coal in the petroleum and chemical industries.

Environmental and economic reasons are the greatest constraint on expanded coal use in refinery and chemical operations. These are of particular concern for an industry that exceeds all others in expenditures for environmental control.

Additional development of direct and indirect coal liquefaction technology has the potential to expand the use of coal in refineries by making it an attractive feedstock for the production of transportation fuels.

Additional development of technology to manufacture chemicals from syngas derived from coal has the potential to expand the use of coal in the chemical industry.

Cogeneration can increase the use of coal in the process industries.

IMPEDIMENTS

Impediments to the use of coal in the refining and chemical industries are the energy price differential versus natural gas and environmental constraints, equipment reliability concerns, increased operating cost of boilers equipped with scrubbers, and the lack of access to the grid.

RECOMMENDATIONS

The Department of Energy should continue to support and expand the development of technology for the conversion of coal into liquids and coal into gas.

The Department of Energy should continue to support and expand the research in chemicals derived from synthesis gas from coal.

The Secretary of Energy should encourage Federal and State Governments to ensure that cogenerators have access to transmission lines and power markets.

The Secretary of Energy should encourage the redefining of a cogenerator as one who not only produces electricity, but produces useful co-products, such as chemicals; uses energy as mechanical energy; or is an emissions reductions facility[5].

The Secretary of Energy should encourage the expanded use of clean coal technology in industry through industrial liaison programs.

The Secretary of Energy should appoint an industry advisory committee, which should include members representing the chemical and petroleum refining industries, to advise on the research and development needs of the industry to provide for more coal use.

The Department of Energy should continue its efforts to improve the image of coal in the eyes of the public.

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Letter from Thomas Parker, Jr., Chemical Manufacturers Association to W. R. Siegart, dated January 2, 1990.

ACKNOWLEDGEMENTS

This chapter was prepared by W. R. Siegart, PhD, Senior Staff Consultant, Alternate Energy and Resources Department, Texaco, Inc., with the assistance of the American Petroleum Institute and the Chemical Manufacturers Association.

Appendix A

Industrial Sector Energy Data Used in This Report

This appendix presents Industrial Sector energy data which is used and referenced throughout this report.

Total Primary Consumption of Energy for All Purposes by Census Region, Industry, Group, and Selected Industries, 1985.

Source: U.S. Department of Energy, Energy Information Administration, Manufacturing Energy Consumption Survey: Consumption of Energy, 1985 (DOE/EIA-0512-85) 1988.

Manufacturing Energy Consumption for Heat and Power, by Type of Fuel and Industry Group: 1985.

Source: Statistical Abstract of the United States, 1989, 109th Edition, U.S. Department of Commerce, Bureau of the Census.

Installed Nonutility Generation Capacity by Sector - 1987.

Source: Edison Electric Institute, 1987 Capacity and Generation of Non-Utility Sources of Energy.

Nonutility Power Generating Capacity - 1988.

Source: U.S. Department of Energy. Energy Information Administration, Annual Energy Outlook 1990: With Projections to 2000, (DOE/EIA-0383) 1990.

Table A1

Total Primary Consumption of Energy for All Purposes by Census Region, Industry Group, and Selected Industries, 1985
Part 1. (Estimates in Btu or Physical Units)

SIC Code(a)	Industry Groups and Industry	Total (trillion Btu)	Net Electricity(b) (million kWh)	Residual Fuel Oil (1000 bbls)	Distillate Fuel Oil (1000 bbls)	Natural Gas (billion cu ft)	LPG (million gallons)	Coal (1000 short tons)	Coke & Breeze (1000 short tons)	Other(c) (trillion Btu)
20	Food and Kindred Products	949	44,417	6,290	4,362	464	89	5,571	122	121
21	Tobacco Manufactures	19	1,225	308	55	3	1	407	0	*
22	Textile Mill Products	248	25,552	2,858	929	89	24	1,631	0	8
23	Apparel and Other Textile Products	31	4,030	165	372	11	4	70	0	*
24	Lumber and Wood Products	325	13,753	W	3,976	24	W	W	0	224
25	Furniture and Fixtures	48	4,220	145	342	18	8	89	0	9
26	Paper and Allied Products	2,211	51,948	24,727	2,048	393	56	14,015	0	1,146
2621	Paper Mills, Except Building Paper	997	29,012	12,567	1,054	153	24	8,315	0	469
2631	Paperboard Mills	770	9,471	6,829	230	129	5	4,626	0	458
27	Printing and Publishing	76	11,184	93	256	31	11	36	0	3
28	Chemicals and Allied Products	3,567	119,448	16,499	4,409	1,627	8,433	14,957	533	280
2819	Industrial Inorganic Chemicals	312	32,857	1,248	541	122	4	2,007	533	5
2821	Plastics Materials and Resins	573	11,907	863	258	166	3,247	1,281	0	46
2869	Industrial Organic Chemicals	1,115	16,524	3,440	819	511	3,749	4,248	0	87
2873	Nitrogenous Fertilizers	479	3,956	W	27	449	W	0	0	W
29	Petroleum and Coal Products	5,123	33,254	18,586	3,187	695	754	339	0	4,110
2911	Petroleum Refining(d)	5,019	31,910	15,731	752	668	430	336	0	4,073
30	Rubber and Misc. Plastics Products	213	25,784	1,729	737	94	29	328	0	3
31	Leather and Leather Products	13	1,053	378	201	4	2	32	0	*
32	Stone, Clay, and Glass Products	895	30,755	1,496	6,924	374	48	14,635	267	20
3241	Cement, Hydraulic	317	9,886	202	658	16	1	11,571	W	W
33	Primary Metal Industries	2,626	140,476	6,405	2,304	672	68	41,676	9,286	33
3312	Blast Furnaces and Steel Mills	1,869	38,995	5,458	988	400	5	39,888	7,243	14
3334	Primary Aluminum	248	61,648	W	52	22	8	19	W	8
34	Fabricated Metal Products	302	26,804	801	1,742	172	48	329	44	6
35	Machinery, Except Electrical	240	28,623	1,150	1,326	102	36	741	24	3
36	Electric and Electronic Equipment	211	30,884	984	578	80	16	373	22	3
37	Transportation Equipment	321	32,767	2,630	1,629	124	30	1,860	37	11
38	Instruments and Related Projects	73	7,570	W	196	20	Q	W	0	1
39	Misc. Manufacturing Industries	31	31,190	312	168	14	4	48	0	Q
	Total	**17,522**	**636,937**	**87,008**	**35,739**	**5,012**	**9,399**	**97,981**	**10,336**	**5,982**

Table A1 (Cont)

Notes:

a See Appendices A and D for descriptions of the Standard Industrial Classification system.

b Net Electricity is obtained by summing purchases, transfers in, and generation from noncombustible renewable resources, minus quantities sold and transferred out. It does not include electricity inputs from onsite cogeneration or generation from combustible fuels because that energy has already been included as generating fuel (for example, coal).

c Other includes net steam (the sum of purchases, generation from renewables, and net transfers), and other energy that respondents indicated was used to produce heat and power or as feedstock/raw material inputs. See also footnote "d".

d For the petroleum refining industry only, the feedstocks and raw material inputs for the production of nonenergy products (i.e., asphalt, waxes, lubricants, and solvents) are included in the "other" column, regardless of type of energy. The remaining columns for the petroleum refining industry include only energy that was consumed for the production of heat and power. The "other" column also includes net steam and other energy that respondents indicated was used in the production of heat and power. Those inputs and feedstocks that were converted to other energy products (e.g., crude oil converted to residual and distillate fuel oils) are excluded. See Appendix A for more information.

* Estimate less than 0.5 rounded to zero

W = Withheld to avoid disclosing data for individual establishments. Data are included in higher level totals.

Q = Withheld because relative standard error is greater than or equal to 50 percent. Data are included in higher level totals.

NA = Not available. Data are included in higher level totals.

Totals may not equal sum of components because of independent rounding.

The derived estimates presented in this table are for the primary consumption of energy for heat and power and as feedstocks or raw material inputs. Primary consumption is defined as the consumption of the energy that was originally produced offsite or was produced onsite from input materials not classified as an energy. Examples of the latter are hydrogen produced from the electrolysis of brine; the output of captive (onsite) mines or wells; woodchips, bark, and woodwaste from wood purchased as a raw material input; and waste materials such as wastepaper and packing materials. Primary consumption excludes quantities of energy that are produced from other energy inputs and therefore avoids double-counting.

Sources:

Energy Information Administration, Office of Energy Markets and End Use, Energy End Use Division, Form EIA-846(F), 1985 Manufacturing Energy Consumption Survey.

Office of Oil and Gas, Petroleum Supply Division, Form E1A-810, Monthly Refinery Report for 1985.

Table A2

ENERGY

NO. 940. MANUFACTURING ENERGY CONSUMPTION FOR HEAT AND POWER, BY TYPE OF FUEL AND INDUSTRY GROUP: 1985

(In trillions of Btu. Based on the Manufacturing Energy Consumption Survey; therefore subject to sampling variability)

SIC[1] Code	Industry	Total Consumption	Net Electricity[2]	Fuel Oil[3]	Natural Gas	Coal & Coke	Other
(X)	**Total**	**13,747.9**	**2,286.5**	**705.2**	**4,617.7**	**1,980.3**	**4,158.2**
20	Food and kindred	954.3	165.8	65.1	458.9	131.7	132.9
21	Tobacco products	19.8	4.6	2.3	3.4	9.4	.1
22	Textile mill products	248.1	88.1	21.3	91.2	38.0	9.7
23	Apparel and other textile products	32.4	15.3	2.9	12.5	1.4	.4
24	Lumber and wood products	348.9	55.1	23.4	31.4	(D)	(D)
25	Furniture and fixtures	48.6	15.2	2.7	19.6	2.1	9.1
26	Paper and allied products	2,355.6	183.6	166.9	379.7	322.5	1,302.9
27	Printing and publishing	98.6	52.5	2.4	40.6	(D)	(D)
28	Chemicals and allied products	2,460.5	445.2	100.3	1,180.9	336.4	397.7
29	Petroleum and coal products	2,426.3	120.3	134.9	690.7	7.3	1,472.9
30	Rubber and misc. plastic products	220.8	90.7	15.2	102.0	8.1	4.8
31	Leather and leather products	13.4	4.3	3.3	4.5	.9	.4
32	Stone, clay, and glass products	927.6	116.3	33.1	397.0	349.0	32.3
33	Primary metal industries	2,362.2	458.7	53.2	669.2	660.6	520.5
34	Fabricated metal products	296.2	91.2	16.7	171.6	8.7	8.0
35	Machinery, except electrical	277.6	114.2	14.6	113.7	30.6	4.5
36	Electric and electronic equipment	223.7	110.1	10.4	91.4	8.6	3.3
37	Transportation equipment	322.2	115.0	25.7	120.7	43.8	17.0
38	Instruments and related products	79.7	29.2	8.1	23.6	(D)	(D)
39	Miscellaneous manufacturing	31.3	11.4	2.6	15.4	1.3	.7

Notes:

- D Figure withheld to avoid disclosure.
- X Not applicable.
- 1 Standard Industrial Classification; see text, Section 13.
- 2 Net electricity is obtained by aggregating purchases, transfers in, and generation from noncombustible renewable resources minus quantities sold and transferred out.
- 3 Includes distillate and residual.

Source:

U.S. Energy Information Administration, *Monthly Energy Review*, January 1987.

Table A3
Installed Nonutility Generation Capacity By Sector 1987

Sector	Capacity MW	Percent
Chemicals	7,465	25
Lumber, Wood Products, Paper	6,645	22
Oil, Gas, Refining, Coal	3,576	12
Metal Mining and Metal Manufacturing	2,491	8.3
Other Industrial	2,302	7.7
Other Nonindustrial	7,536	25
Total	**30,015**	**100**

Source:
Edison Electric Institute, 1987 Capacity and Generation of Non-Utility Sources of Energy

Table A-4
Nonutility Power Generating Capacity 1988

Fuel	Capacity MW	Percent
Coal	5,400	17.2
Natural Gas	12,200	38.9
Other Fossil[1]	4,000	12.7
Renewal Sources/Other[2]	9,800	31.2
Total	**31,400**	**100**

Notes:

1. Includes petroleum coke, waste heat, blast furnace gas, coke oven gas, and anthracite culm.
2. Includes hydroelectric, biomass, geothermal, wood, non-fossil waste, solar, wind, and pumped/other storage.

Source:

U.S. Department of Energy, Energy Information Administration, Annual Energy Outlook 1990: With Projections to 2000, (DOE/EIA-0383) 1990, Table A7, p. 46.

Appendix B

Pulp and Paper Industry

STONE & WEBSTER ENGINEERING CORPORATION

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ADDRESS ALL CORRESPONDENCE TO P.O. BOX 2325, BOSTON, MA 02107

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RICHLAND, WA
RICHMOND, VA
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TAMPA
WASHINGTON D.C.

April 6, 1990

Mr. Joseph J. M. Plante
Vice President and Senior Manager of Projects
Stone & Webster Engineering Corporation
245 Summer Street
Boston, MA 02110

THE NATIONAL COAL COUNCIL (NCC)
ADDENDUM REPORT - INDUSTRIAL USE
OF COAL AND CLEAN COAL TECHNOLOGY

Dear Joe:

On behalf of J. G. Thompson, Westvaco Corporation, and myself, I am pleased to submit the enclosed report on the Pulp and Paper Industry. This report describes, among other things, the pulping process and mill types; discusses production levels and capacities; presents energy trends and prospects for increased coal use in the industry; and presents impediments to coal use. It is our understanding that this report will be incorporated into the subject report as an appendix.

Very truly yours,

Percy L. Nelson

Percy L. Nelson
Vice President
Pulp & Paper and Industrial

CC: JGThompson

Enclosure

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INTRODUCTION

Status of Pulp and Paper Industry in North America

North America is the most significant pulp and paper producing region in the world, accounting for approximately 50 percent of worldwide pulp making capacity and 40 percent of worldwide paper and paperboard capacity. It appears that this position will not be relinquished soon, since the pulp and paper producing areas have access, for the most part, to abundant supplies of the resources required for continued development of the industry. Principal resources required on a readily accessible basis would include the following.

- Woodlands and forests to produce the necessary supply of fiber.
- An adequate supply of purchased energy (both fuel and electric power) to supplement the energy available from self-generated fuels from pulping operations.
- A trained labor force to include the necessary management, engineering, and operating personnel.
- Large quantities of clean, fresh water.
- Access to rail, highway, and/or shipping facilities for incoming raw materials and supplies and shipment of the mill output of pulp and/or paper.

Ranking of the Pulp and Paper Industry in the United States

Table 1 indicates the Department of Commerce figures for the value of shipments made by United States industries for the calendar year 1987, including those made by the pulp and paper industry.

TABLE 1
U.S. Paper Industry Value of Shipments Ranked With Other Industries - 1987[1]
($ billion)

Nondurable Goods Industries	
Food, kindred products	325.0
Tobacco products	19.9
Textile mill products	57.5
Paper and allied products	110.3
Chemicals and allied products	212.7
Petroleum and coal products	124.5
Rubber and plastics products	80.5
All other	196.2
Total Nondurable Goods	**1,126.6**
Durable Goods Industries	
Stone, clay, and glass products	62.1
Primary metals	117.1
Fabricated metal products	135.0
Machinery, excluding electrical	216.6
Electrical machinery	210.7
Transportation equipment	323.0
Instruments and related products	66.8
All other	132.2
Total Durable Goods	**1,263.5**
Total Manufactured Goods	**2,390.1**

Table 1 shows that the pulp and paper industry's shipments were valued at $110.3 billion in 1987. On this basis, the industry ranked as the ninth largest in the country behind the following industries listed in declining order:

	1987 Shipments *($ billion)*
Food and kindred products	325.0
Transportation equipment	323.0
Machinery, excluding electrical	216.6
Chemical and allied products	212.7
Electrical machinery	210.7
Fabricated metal products	135.0
Petroleum and coal products	124.5
Primary metals	117.1

In 1987, shipments in the pulp and paper industry represented 9.79 percent of the value of all nondurable goods shipped, and 4.61 percent of the value of all manufactured goods shipped. Table 1 does not show that shipments in the pulp and paper industry for 1987 were up 12.7 percent from the previous year, the largest gain of any industry. Shipments in 1988 were up about 6.5 percent above the 1987 level.

Total Coal Usage in the Pulp and Paper Industry

In 1988, the pulp and paper industry used an estimated 13,412,000 tons of coal. This represents about 32 percent of all purchased energy, both fuel and electric power, used by the industry. It also represents about 14 percent of all energy used by the industry, including both purchased energy and self-generated and residue fuels.

In 1988, the energy supplied by coal to the industry was about equal to that supplied by natural gas, but was about 85 percent greater than that supplied by residual fuel oil.

DEFINITION OF PULPING PROCESSES

Sources of Fiber

Wood is the principal source of fiber for papermaking in the industry. A great variety of species is used, both hardwoods and softwoods.

Pulp is produced from other fiber sources, namely textile fibers, flax, bagasse, and straw, for producing specialty papers. However, the mills using fibers from these sources are few in number by comparison and their output is generally small, particularly in the United States. On a total production basis and an energy consumption basis, the effects of not addressing the mills using these special fiber sources will be insignificant.

Pulping Methods

One of two basic methods is used in the production of wood pulp.

Mechanical Pulping – This pulping method primarily uses a softwood supply to produce a high yield from the wood furnish (normally in the order of 90 percent plus) to give a comparatively low quality pulp. Pulp furnish for producing newsprint is normally in the order of 80 percent mechanical pulp. Mechanical pulping consumes large blocks of power but uses little, if any, energy in the form of steam. Therefore, cheap sources of electric power or hydro-mechanical power are essential if mechanical pulp is to be produced economically.

In 1988, about 9.7 percent of total wood pulp production in the United States was produced by mechanical pulping methods. The only self-generated fuel produced from mechanical pulping would be the bark and wood refuse generated as a by-product of processing the wood supply.

Mechanical pulp is produced by one of two generic procedures.

Stone Groundwood Process – debarked roundwood is pressed against a rotating grindstone and ground into mechanically produced pulp.

Refiner Mechanical Pulping Process – wood chips are mechanically reduced to pulp between the rotating plates of a disc refiner. There are several variations such as Thermo-Mechanical Pulp and Chemi-Thermo-Mechanical Pulp.

Chemical Pulping – This pulping method involves the steaming and cooking of wood chips under pressure in a digester vessel in the presence of a cooking liquor solution of certain chemicals in order to separate the fiber in the wood from the lignin material. Compared to mechanical pulping, chemical pulping produces a higher quality pulp at a lower yield, consumes substantial quantities of energy in the form of process steam, and uses significantly less power. The various types of chemical pulping are generally identified and designated by the chemistry of the cooking liquor involved.

Alkaline (Kraft) Pulping – the wood chips are cooked in an alkaline solution consisting basically of $NaOH$, NaS, and $NaCO$. In 1988, over 78 percent of all wood pulp produced in the United States (including mechanical pulp) was produced using kraft pulping technology. This pulping method lends itself to the production of large quantities of pulp in any given installation, and is employed by most of the large chemical pulp producers in the country. The process can be applied equally well to both softwood and hardwood furnish. Spent pulping liquors separated from the wood fibers after the digester cook provide the greatest source of self-generated fuel in the industry as the liquors are fired in black recovery boilers, where the inorganic chemicals are reclaimed and steam is generated as a byproduct.

Sulphite Pulping – the wood chips are cooked in an acid solution consisting of sulphite or bisulphite salts of magnesium, sodium, or ammonium. In 1988, only about 2.5 percent of all wood pulp produced in the United States was produced by all the various sulphite processes. In general, these processes produce less self-generated fuel in the spent pulping liquors than the kraft pulping process.

Dissolving Pulp – produced using either a modified kraft or sulphite process to produce a chemical cellulose for conversion into such products as rayon, cellophane, and cellulose acetate. In 1988, only about 2.2 percent of all wood pulp produced in the United States was dissolving pulp.

Semi-Chemical Pulp – the introduction of chemicals during mechanical pulping, a modification of mechanical pulping. In 1988, about 7.1 percent of all wood pulp in the United States consisted of semi-chemical pulp.

Secondary Fiber (Recycled Paper) – Use of recycled paper is increasing as a source of secondary fiber to supplement the use of virgin wood pulp fibers in certain grades of paper. At present, recycled waste paper is supplying approximately 25 percent of the total fiber furnish for United States paper and paperboard production, amounting to an annual use in excess of 20,000,000 short tons of wastepaper. The use of secondary fibers has been increasing, and some years in the future may approach 40 percent of total fiber furnish.

Recycled wastepaper is used as a lower grade alternative to virgin wood pulp in such papers as newsprint, folding cartons, construction paper and board products, and others. Pulping wastepaper is significantly easier than pulping wood and uses substantially less energy.

BASIC DESIGNATION OF MILL TYPES

Basically, pulp and paper mills can be divided into three separate categories with some variations in certain instances.

Market Pulp Mills – Those mills which produce and ship pulp, usually in dried and baled form, for sale on the open market or for use in a remote paper mill belonging to their own organization. By definition, market pulp mills do not have paper machines for producing paper from the pulp they produce. Since pulp mills are basically processing raw wood into fiber, they are more likely to have a larger portion of their energy supplied by fuels generated as by-products of the pulping process than other types of mills.

Straight Paper Mills – Those mills which obtain pulp supplies from a remote source or by purchase on the open market. These mills contain only the paper machines and auxiliary systems required to produce the sheets of paper from the pulp supplied. A paper mill generally has to purchase all of its fuel requirements since it creates no by-product fuels from its process operations.

Integrated Pulp and Paper Mills – Those mills which include both a pulp mill for producing the necessary pulp in slush form (without drying and baling) and the necessary paper mill to use this pulp, all in one plant on the same site. For an integrated mill, the generation of by-product fuels and the requirements for purchased fuels are a composite of the separate equivalent items for market pulp mills and separate paper mills.

In some cases, mills are only partly integrated, supplying their paper machines partly with pulp produced onsite and partly with purchased pulp. Typically, many newsprint mills supply their paper machines with mechanical pulp produced onsite and supplemented with purchased chemical pulp. In other cases, a mill may produce more pulp than its integrated paper machine can use and will sell the excess as market pulp.

LOCATIONS OF MAJOR PULP AND PAPER MILLS IN THE UNITED STATES AND CANADA

A map showing the location of every pulp, paper, paperboard, and construction board mill in the United States and Canada is available from Miller Freeman Publications. This map is based on data from the 1988 edition of Lockwood-Post's Pulp & Paper Directory[2]. Table 2 presents the number of pulp, paper, and board mills in the United States by region and by state[3].

An analysis of the data shown on the Miller Freeman Publications' map and the data in Table 2 would indicate that:

- The south has 157 pulp mills out of a United States total of 358, thereby comprising about 44 percent of the total number, but turns out almost 68 percent of the total annual production.
- The south has 173 paper mills out of a United States total of 604, thereby comprising about 29 percent of the total number, but turns out almost 53 percent of the total annual production.
- Mills in the south can be and are served by the major bituminous coal fields of Alabama, Kentucky, West Virginia, and Virginia. No other region has coal supplies so readily accessible.
- On the average, mills in the south tend to be larger in capacity than those in other regions. Coal burning in general is more readily suited to larger installations.
- It is not surprising that the south already uses more total tonnage of coal for its purchased fossil fuel requirements than all other regions of the country combined. This is undoubtedly due in part to the greater pulp and paper tonnage produced as well as it proximity to the coal sources.

ANNUAL PRODUCTION LEVELS AND CAPACITY IN THE UNITED STATES

Production and Capacity Statistics

Recent and historical production rates and manufacturing capacities for pulp and paper in the United States are presented in Tables 3 through 7.

From the production and capacity data shown in these tables it can be seen that:

- Both the total production rates and total manufacturing capacity for pulp and paper have, for the most part, risen steadily over the last 25 to 30 years.
- Rates of production increase for particular grades of paper have been generally upward, but the individual rates of increase have been more erratic than the overall rates.
- Typically, pulp mills and paper mills operate 24 hours per day, 7 days per week, for anywhere from 350 to 360 days per year, which accounts for the high operating rates as a percent of manufacturing capacity.
- From all present indications it would appear that production rates will continue to increase into the foreseeable future. This will require an increasing contribution from fossil fuels, some of which will presumably be supplied by coal.

SELF-GENERATED AND RESIDUE FUELS - PULP MILLS ONLY

Essentially, all of the self-generated and residue fuels are produced by the pulping operations in which the wood supply is processed into pulp fibers prior to the papermaking operations. The quantities of these fuels will vary substantially depending upon the wood species used, the pulping process used, the pulp yield obtained from the wood, and certain other factors. The greater the amount of energy obtained from these self-generated and residue fuels in any given mill, the lower the requirement for supplemental fossil fuels will be, including possibly coal.

TABLE 2
Number of Pulp, Paper, and Board Mills in U.S., by Region[3]
*(Number of mill sites)**

Western Region

State	Paper/ Board Mills	Pulp Mills
Alaska	—	2
Arizona	2	5
California	33	13
Colorado	1	—
Idaho	2	1
Montana	1	1
New Mexico	1	—
Oregon	17	21
Washington	19	24
Total	76	67

Midwestern Region

State	Paper/ Board Mills	Pulp Mills
Illinois	11	2
Indiana	12	2
Iowa	1	1
Kansas	2	—
Michigan	37	11
Minnesota	12	11
Missouri	4	1
Ohio	32	11
Wisconsin	48	36
Total	159	75

Northeastern Region

State	Paper/ Board Mills	Pulp Mills
Connecticut	10	1
Maine	20	22
Massachusetts	38	5
New Hampshire	14	2
New Jersey	17	3
New York	53	16
Pennsylvania	37	8
Vermont	7	2
Total	196	59

Southern Region

State	Paper/ Board Mills	Pulp Mills
Alabama	18	21
Arkansas	9	9
Delaware	4	1
Florida	11	11
Georgia	21	20
Kentucky	5	3
Louisiana	13	19
Maryland	4	2
Mississippi	11	9
North Carolina	18	13
Oklahoma	7	6
South Carolina	11	11
Tennessee	13	11
Texas	12	10
Virginia	14	11
West Virginia	2	—
Total	173	157

United States Total

Paper/Board Mills	604
Pulp Mills	358

1987 Production Capacity**

Region	Paper/Board Short Tons	Paper/Board % of Total	Pulp Short Tons	Pulp % of Total
Northeast	11,438,000	14.63	4,792,000	7.83
Midwest	14,004,000	17.91	4,571,000	7.47
South	41,155,000	52.64	41,376,000	67.64
West	11,588,000	14.82	10,433,000	17.06
Total	78,185,000	100.00	61,172,000	100.00

Notes:
* Includes mills manufacturing paper and/or paperboard, regardless of the number of paper machines and regardless of whether or not one or more pulp mills are located at the site.
** American Paper Institute. Excludes construction paper and board and wood pulp for this grade.

These by-product fuels produced by the wood pulping process would include the following.

Spent Pulping Liquors are created in the digester cooking process using chemical pulping procedures. Spent pulping liquors are naturally not produced by mechanical pulping. They are normally incinerated in so-called recovery boilers for three purposes.

1. To dispose of the liquors and other organic materials separated from the wood fibers by the particular chemical cooking process.

2. To reclaim the inorganic chemicals in the spent liquor for reuse in the pulping process. The degree of chemical reclamation will vary with the pulping process used.

TABLE 3
U.S. Wood Pulp Production By Major Grades, 1982–1988[4]
(000 Short Tons)

	1988	1987	1986	1985	1984	1983	1982
WOOD PULP							
Bleached Sulfite	1,365	1,269	1,275	1,364	1,359	1,306	1,242
Unbleached Sulfite	195	171	164	196	259	310	345
Total Sulfite	**1,560**	**1,440**	**1,439**	**1,560**	**1,618**	**1,616**	**1,587**
Bleached & Semi-Bleached Sulfate	26,302	25,411	24,158	22,626	22,350	21,107	19,721
Unbleached Sulfate	21,681	21,442	20,481	19,510	20,721	19,590	18,170
Total White Pulp (bleached sulfite + bleached & semi-bleached sulfate)	27,667	26,680	25,433	23,990	23,709	22,413	20,963
Total Chemical Paper-Grade (total sulfite + bleached & semi-bleached sulfate + unbleached sulfate)	49,543	48,293	46,078	43,696	44,689	42,313	39,478
Semi-Chemical	4,357	4,246	4,191	4,026	4,069	3,812	3,700
Mechanical	5,943	5,702	5,476	5,251	5,506	5,067	5,064
Total Paper-Grade	**59,843**	**58,241**	**55,745**	**52,973**	**54,264**	**51,192**	**48,242**
Dissolving/Special Alpha	1,367	1,312	1,257	1,174	1,206	1,261	1,092
Total Wood Pulp	61,210	59,553	57,002	54,147	55,470	52,453	49,334
MARKET PULP							
Chemical Paper-Grade	7,200	6,806	6,316	5,613	5,680	5,255	4,643
Groundwood, other	0	0	5	15	15	12	1
Dissolving/Special Alpha	1,365	1,308	1,251	1,172	1,204	1,260	1,089
Total Market Pulp	8,565	8,114	7,572	6,800	6,899	6,527	5,733
OPERATING RATES (%)							
Total White Pulp	100.9	99.1	97.5	95.6	99.6	98.8	94.7
Total Paper-Grade	97.7	97.7	95.5	88.9	92.0	88.9	83.7
Dissolving/Special Alpha	97.6	94.5	89.8	80.7	81.1	82.7	68.0

3. To generate, as a byproduct of the above two operations, a portion of the steam required for the mill operations.

Spent liquors from kraft pulping generally will produce more steam per ton of pulp produced than comparable sulphite liquors, and will permit recovery of a larger percentage of the inorganic chemicals in the liquor. Combustion of spent pulping liquors provides the largest single source of energy to the pulp and paper industry.

Onsite Bark and Wood Refuse is a by-product of the woodyard and woodroom operation in all pulp mills, for both chemical and mechanical pulping operations, in which the bark is removed from the roundwood prior to pulping. The quantity, properties, and nature of the bark fuel will vary primarily with the wood species. Mills receiving their wood supply in the form of chips supplied from remote satellite woodyards may have no bark fuel available.

Onsite wood refuse fuel would normally come from sources such as cull wood in the wood supply, trimmings, fines from the classifying chip screens, and possibly knots rejected from the pulping operations.

TABLE 4
U.S. Paper and Board Production By Major Grade, 1984–88[5]

	1988	1987	1986	1985	1984	1988/87	1987/86	1986/85	1985/84	1984/83
			(000 Short Tons)					*(Percent Change)*		
PAPER										
Newsprint	5,982	5,842	5,630	5,428	5,539	2.4	3.8	3.7	–2.0	7.2
Printing/writing	21,793	20,778	19,668	18,423	18,420	4.9	5.6	6.8	0.0	6.1
Uncoated groundwood(s)	1,624	1,498	1,540	1,521	1,565	8.4	–2.7	1.2	–2.8	2.2
Coated paper(s)	7,359	6,860	6,263	5,875	6,249	7.3	9.5	6.6	–6.0	9.3
Uncoated free–sheet(s)	11,277	10,966	10,410	9,690	9,152	2.8	5.3	7.4	5.9	4.9
Thin paper	217	240	271	262	303	–9.6	–11.4	3.4	–13.5	3.8
Cotton fiber(s)	167	163	152	144	147	2.5	7.2	5.6	–2.0	10.5
Bleached bristol(s)	1,150	1,052	1,033	970	1,003	9.3	1.8	6.5	–3.3	3.7
Tissue paper	5,476	5,301	5,095	4,941	4,941	3.3	4.0	3.1	0.0	3.2
Packaging & industrial converting(s)	5,199	5,074	5,117	5,204	5,586	2.5	–0.8	–1.7	–6.8	1.7
Unbleached kraft paper(s)	3,038	3,081	3,303	3,403	3,684	–1.4	–6.7	–2.9	–7.6	0.5
Other paper	2,162	1,993	1,814	1,801	1,902	8.5	9.9	0.7	–5.3	4.0
Total Paper	38,450	36,995	35,510	34,036	34,466	3.9	4.2	4.3	–1.2	5.0
PAPERBOARD										
Unbleached kraft linerboard	17,897	17,683	16,402	15,183	16,037	1.2	7.8	8.0	–5.3	6.9
Other unbleached kraft board	1,244	1,215	1,287	1,184	1,149	2.4	–5.6	8.7	3.0	2.5
Semi–chemical paperboard	5,666	5,540	5,376	5,088	5,169	2.3	3.1	5.7	–1.6	9.3
Solid bleached	4,511	4,406	4,222	3,948	4,048	2.4	4.4	6.9	–2.5	3.1
Recycled	8,789	8,601	8,092	7,630	7,637	2.2	6.3	6.1	–0.1	3.2
Total Paperboard	38,107	37,445	35,379	33,034	34,039	1.8	5.8	7.1	–3.0	5.8
Total Paper & Paperboard	76,557	74,440	70,889	67,070	68,505	2.8	5.0	5.7	–2.1	5.4
CONSTRUCTION & WET MACHINE	NA	1,600	1,600	1,700	1,800	–	–	–5.9	–5.6	–
Total Paper & Paperboard	NA	76,040	72,489	68,770	70,305	–	4.9	5.4	–2.2	5.2

Notes:
(s) = Shipments
NA = Not Available
Data may not add to totals because of rounding.

Since the bark and wood refuse must be disposed of in some manner, burning of these fuels also could be considered to be a disposal operation which produces steam as a by-product.

Hogged Fuel is bark and wood fuel received at a mill from offsite sources and reduced in particle size by chipping or hogging. Hogged fuel can consist of the following or any combination thereof: bark and wood refuse produced by remote satellite woodyards; sawmill wood refuse, including sawdust, chips, slabs, and bark; forest residuals from logging operations, including limbs and tops from the trees; actual harvesting of undesired species of wood; and discarded and scrap lumber from construction sites.

In some cases, the hogged fuel may be purchased to supplement the onsite residue fuels; in other cases the mill may own the offsite facilities. In either case, the delivered cost of the hogged fuel will be critically affected by the distance from the source to the mill site.

Partially Dewatered Sludge from the mill effluent clarifier is frequently burned in conjunction with the bark and wood refuse fuel. For the most part, this may be considered to be a disposal operation in order to minimize the use of a landfill for disposal. Given the water content of most sludge material and the inerts in the sludge solids, the net energy obtained from sludge burning is normally negligible.

TABLE 5

Historical U.S. Paper and Board Production, Capacity, and Operating Rates, 1960–88[6]

(000 Short Tons)

	Production				Capacity		Operating Rate
Year	Paper	Paperboard	Total paper/ board	Change	Total paper/ board[1]	Change	Total paper/ board
1988	38,450	38,107	76,557	2.8	80,315	2.7	95.3
1987	36,995	37,445	74,440	5.0	78,186	3.2	95.2
1986	35,510	35,379	70,889	5.9	75,777	2.0	93.5
1985	34,036	32,922	66,958	-2.2	74,301	1.6	90.1
1984	34,466	34,002	69,468	5.4	73.098	2.8	93.7
1983	32,816	32,145	64,961	9.6	71,126	1.5	91.3
1982	30,252	29,044	59,296	-4.5	70,086	2.8	84.6
1981	30,901	31,208	62,109	1.7	68,172	2.7	91.1
1980	30,116	30,926	61,042	0.0	66,368	2.7	92.0
1979	29,666	31,404	61,070	4.3	64,615	2.4	94.5
1978	28,320	30,252	58,572	3.4	63,091	1.8	92.8
1977	27,721	28,935	56,656	3.0	62,004	1.1	91.4
1976	26,577	28,415	54,992	14.6	61,307	1.9	89.7
1975	23,260	24,737	47,997	-13.9	60,140	1.0	79.8
1974	26,863	29,894	55,757	-1.0	59,527	2.3	93.7
1973	26,797	29,550	56,347	4.7	58,164	4.1	96.9
1972	25,359	28,484	53,843	8.2	55,873	3.2	96.4
1971	23,722	26,019	49,741	2.1	54,136	1.6	91.9
1970	23,351	25,367	48,718	2.2	53,260	0.3	91.5
1969	23,449	26,362	49,811	5.8	53,094	3.8	93.8
1968	22,181	24,890	47,071	7.6	51,147	4.7	92.0
1967	20,926	22,819	43,745	0.4	48,850	4.8	89.5
1966	20,725	23,179	43,904	8.4	46,608	7.1	94.2
1965	19,157	21,332	40,489	6.4	43,535	4.6	93.0
1964	18,112	19,954	38,066	6.0	41,623	3.7	91.5
1963	17,320	18,594	35,914	4.4	40,143	3.4	89.5
1962	16,560	17,847	34,407	5.7	38,810	1.3	88.7
1961	15,821	16,727	32,548	4.3	38,299	4.0	85.0
1960	15,295	15,926	31,221	15.4	36,840	3.1	84.7
Average annual change		1980-88		2.6		2.4	
		1970-79		2.3		2.0	
		1960-69		6.4		4.0	

Note:
1. Excludes hardpressed board, construction paper and board, and wet machine board.

ENERGY TRENDS IN THE PULP AND PAPER INDUSTRY

The general trends in both the use and supply of energy to the pulp and paper industry can be observed from data available for the years 1972 and 1988. Presumably future trends will continue in the same direction, but the rates of change may be slower.

Overall Energy Trends

Energy Usage – Table 8 indicates, for the years 1972 and 1988, the energy used in the pulp and paper industry both on a total basis and on an average basis per ton of production of pulp and paper. A further breakdown is presented to show the energy furnished by fossil fuels and purchased energy and that energy which is self-generated and supplied by residue fuels.

TABLE 6
U.S. Capacity Integrated to Wood Pulp[7]
(000 Short Tons)

	1987 Tons	1987 Percent	1982 Tons	1982 Percent	1976 Tons	1976 Percent
PAPER						
Newsprint	5,493	91.5	5,212	92.2	3,589	89.4
Uncoated groundwood	1,318	79.7	1,515	91.5	1,093	83.5
Coated groundwood	4,008	96.9	3,093	95.4	2,218	96.5
Coated free-sheet	2,436	75.4	1,776	78.1	1,359	71.4
Uncoated free-sheet/cotton fiber	9,058	77.5	7,384	80.3	4,837	64.8
Thin	74	25.5	106	28.7	57	15.9
Bristols	981	90.9	946	88.5	1,092	93.7
Packaging/industrial converting	4,048	73.7	4,887	80.4	5,071	81.8
Tissue	2,266	41.2	2,606	50.8	2,043	45.4
Total	**29,682**	**75.9**	**27,525**	**79.4**	**21,359**	**73.1**
PAPERBOARD						
Unbleached kraft	19,421	100.0	17,402	100.0	14,568	100.0
Solid bleached	4,733	100.0	4,121	100.0	3,998	100.0
Semi-chemical	5,576	98.1	5,207	100.0	4,758	100.0
Recycled	368	4.0	346	4.0	513	5.8
Total	**30,098**	**77.0**	**27,076**	**76.4**	**23,837**	**74.3**
Total Paper & Board	**59,780**	**76.5**	**54,601**	**77.9**	**45,196**	**73.7**

TABLE 7
U.S. Mill Distribution for Paper/Board and Wood Pulp[8]

Mill capacity range (000 tpy)	Paper and Paperboard: Number of Mills 1987	Number of Mills 1980	Annual Capacity (% share) 1987	Annual Capacity (% share) 1980	Woodpulp: Number of Mills 1987	Number of Mills 1980	Annual Capacity (% share) 1987	Annual Capacity (% share) 1980
0-25	137	205	2.2	3.7	13	30	0.3	0.8
26-50	89	115	4.1	6.0	16	29	1.0	2.0
51-75	69	70	5.4	6.2	16	19	1.6	2.2
76-100	38	42	4.2	5.2	12	17	1.7	2.8
101-125	27	43	3.8	6.9	13	12	2.4	2.5
126-150	26	16	4.4	3.2	8	9	1.7	2.7
151-175	8	15	1.6	3.7	10	14	2.6	4.2
176-200	21	20	4.9	5.6	9	10	2.8	3.8
201-250	31	23	8.7	7.7	20	19	7.0	7.5
251-300	20	13	7.9	5.0	15	17	6.5	8.0
301-350	12	15	5.0	6.9	9	7	4.7	4.7
351-400	8	18	3.7	9.5	14	13	8.5	8.8
401-450	16	12	8.6	7.2	10	13	6.9	9.9
451-500	11	8	6.5	5.3	14	14	10.7	12.0
Over 500	35	20	30.0	18.0	38	25	41.6	28.1
Total	548	635	100.0	100.0	217	248	100.0	100.0

TABLE 8
Total Energy and Energy per Ton for 1972 and 1988[9]

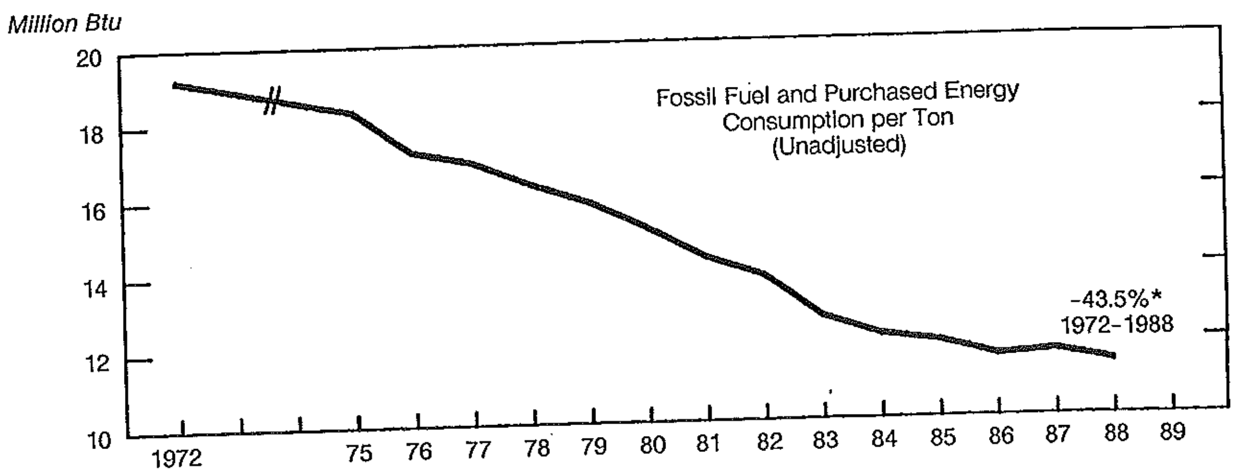
	Fossil Fuel & Purchased Energy	Self-Generated & Residue Fuels	Total Energy
1988 Energy Consumption (billion Btu)	1,011,963	1,360,547	2,372,510
Total Production (thousand ton)	76,557	76,557	76,557
Energy Use/Ton (millions Btu)	13.2	17.8	31.0
1972 Energy Consumption (billion Btu)	1,245,505	847,074	2,092,579
Total Production (thousand ton)	53,843	53,843	53,843
Energy Use/Ton (millions Btu)	23.1	15.7	38.8

The trend for fossil fuel and purchased energy per ton of pulp and paper production for the years from 1972 to 1988 is shown on Figure 1.

Energy Supply – Table 9 indicates the sources of fuel and energy from which the pulp and paper industry met its needs in 1988, contrasted with corresponding data for the year 1972, the year before the Arab oil embargo. Consumption figures are presented in percent of total energy and fuel usage.

The trend for self-generated energy in percent of total energy used between 1972 and 1988 is shown on Figure 2.

FIGURE 1 U.S. Pulp, Paper, and Paperboard Industry[10]



August 1989

Note:
* On an adjusted basis. Adjustments made for process changes between the base year and current year which affect energy efficiencies.

TABLE 9
Fuel Sources – 1988 Versus 1972[10]

Purchased	1988 (%)	1972 (%)	Self-Generated	1988 (%)	1972 (%)
Purchased Electricity	6.6	4.4	Wood Residues	11.1	2.0
Coal	13.9	10.7	Bark	5.2	4.5
Residual Fuel Oil	7.5	21.2	Spent Pulping Liquors	39.2	33.3
Distillate Fuel Oil	0.4	1.0	Self-Generated Hydropower	0.5	0.4
Natural Gas	14.0	21.1	Other	0.5	0.1
Other	1.1	1.3			
Total	43.5	59.7		56.5	40.3

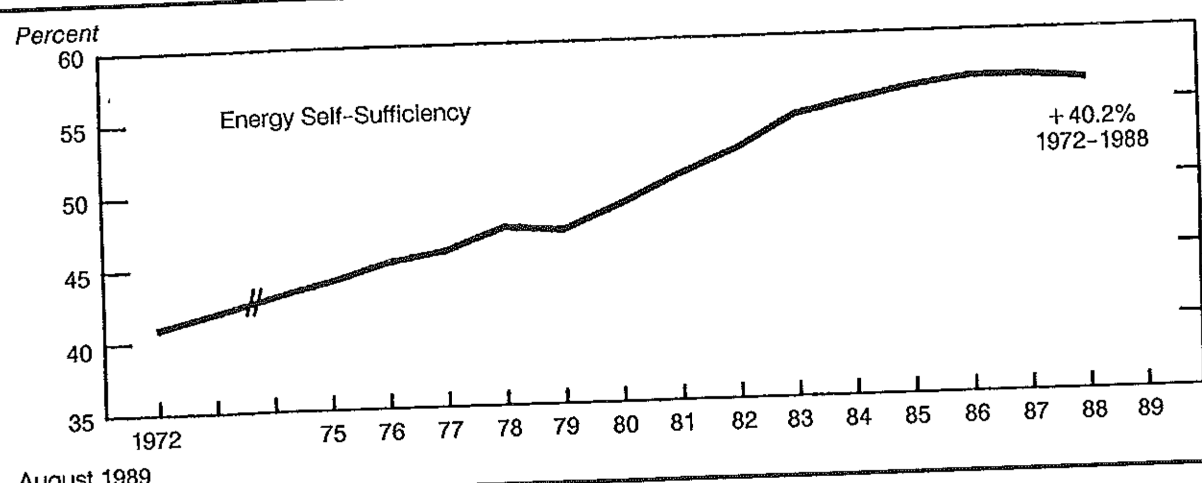
Steam Load Trends – Table 8 shows the total energy use per ton of production declining from 32.7 million Btu per ton in 1972 to a value of 26.5 million Btu per ton in 1988, equivalent to a per unit decrease of about 19 percent. The actual decrease in the per unit steam usage will exceed this figure due to an offsetting increase in electric power used.

The decrease in steam used per ton has been realized through increased operating efficiencies designed into new mills and improvements made to the process in remodelling existing mills. The significant price increases in fossil fuels, oil in particular, brought about by the Arab oil embargo starting in 1973, provided a powerful impetus and economic justification for these improvements. Those improvements which were the easiest to implement and which involved the greatest savings have most likely already been made. Therefore, it is to be expected that reductions in steam usage per ton will continue due to still further increases in the efficient use of steam in the mills but perhaps at a slower rate of improvement.

Typical of the process changes being made to reduce the use of energy in the form of steam would be:

- Improved dewatering of the sheet of paper at the wet end of the machine by mechanical means in order to reduce the amount of water that must be removed by steam in the dryers.
- Improved reclamation of heat from air exhausted from the paper machine dryer hoods using heat exchangers to heat the incoming air.
- Use of hot water that would otherwise be rejected to the mill sewer without cooling to supply heat to the pulp and papermaking processes that originally would have been provided by live steam.

FIGURE 2 U.S. Pulp, Paper, and Paperboard Industry[10]



- Use of digester–blow heat recovery systems to reclaim heat from flash steam formerly blown to atmosphere at the completion of the pulp cooking cycle.

Electric Power Load Trends – Running in the opposite direction from the trend for steam usage, the use of electric power in the mills tends to increase every year both in total and in per ton of production of pulp and paper.

This is due to a combination of:

- The increasing complexity of the pulping and papermaking processes, which typically might require the installation of additional motor–driven equipment such as stock refiners, pulp cleaners, pulp washers, stages of bleaching, expansion of finishing and converting areas, and numerous other items.
- More stringent environmental regulations regarding discharge of effluent from the mill sewers requiring, at present, the installation of primary clarification and secondary treatment and, in some cases, still further treatment.
- More stringent environmental regulations regarding air pollution, which would require the application of larger and more efficient electrostatic precipitators, baghouses, and flue gas scrubbers in the power plant and chemical recovery areas, and scrubbers or incineration systems for various vent gas streams from the pulp mills.

The American Paper Institute figures for the calendar year 1988 indicate the following total usage of electric power for the industry.

Total In-Plant Electric Generation	=	50,721 x 10^6 kWh/yr
Total Purchased Electric Energy	=	+ 47,125 x 10^6
Energy Sold	=	- 7,086 x 10^6
Net Electric Energy Used	=	90,760 x 10^6 kWh/yr

Assuming an average operating period of 350 days per year industry–wide, this figure for net electric energy used translates into a normal industry electric power usage in excess of 10,800,000 kW.

It can be expected that the per unit use of electric energy in kWh/ton of production will continue to increase, given the ever increasing complexity of the pulping and papermaking process and the ongoing demands for increased environmental controls.

Analysis of Data

From the energy data shown and the trends in energy usage demonstrated, it can be concluded that, based upon the projected annual increase in pulp and paper production, an increase in the total annual use of fossil fuels will be required, thereby providing the potential for increased use of coal. Working in the opposite direction, reductions in the steam usage per ton of production will tend to reduce the overall use of fossil fuels, but probably not enough to offset the increased use due to higher production levels.

Steam Generation and Fuel Supply

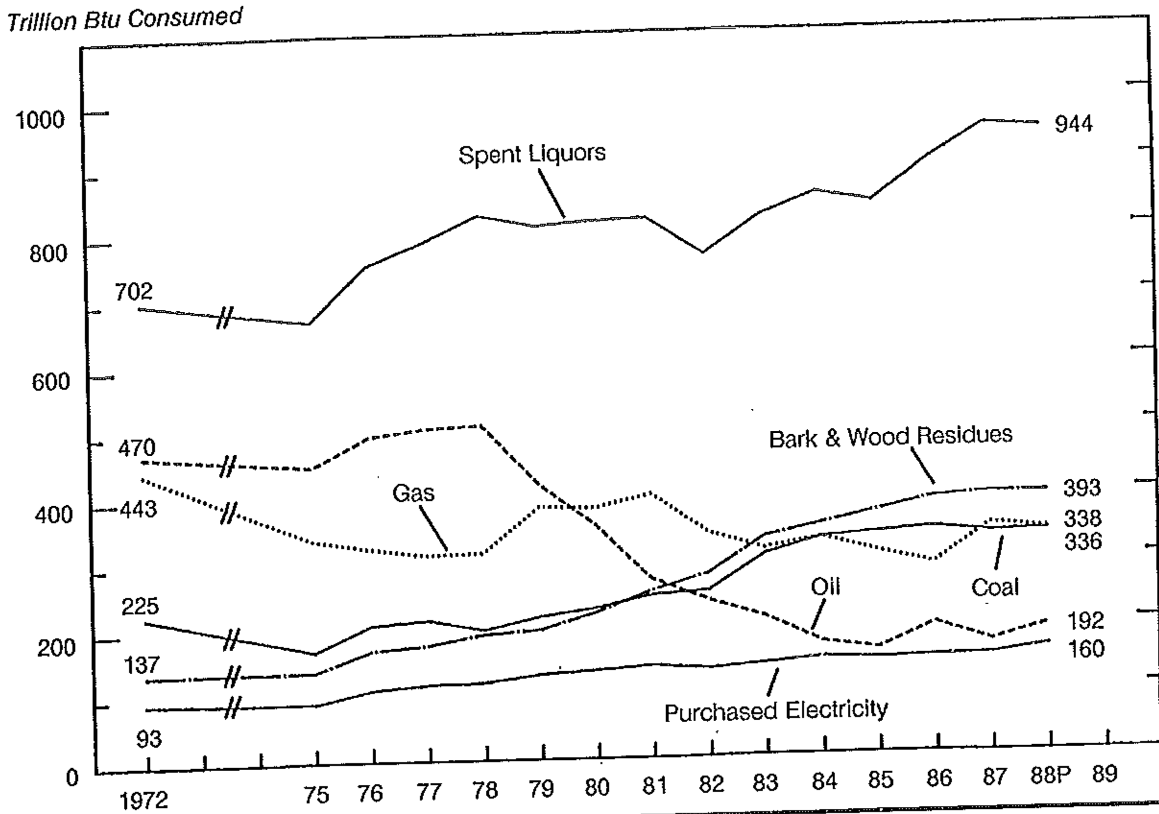
The trends for the total supply of energy industry–wide for all fuels consumed and for purchased electricity for the years between 1972 and 1988 are shown on Figure 3. The initial impetus for these trends was provided by the increase in the cost of fossil fuels following the Arab oil embargo in 1973. Individual trends in the consumption of each of the individual fuels are plotted on Figure 3.

Spent Pulping Liquor – For spent pulping liquors the trend curve shows that:

- The total amount of energy obtained from spent pulping liquors has increased fairly steadily.
- Spent pulping liquor is the largest single source of energy for the industry when compared to each of the other sources.
- Spent pulping liquors provided a greater percentage of the total energy mix in 1988 than they did in 1972. This is due not only to the steadily improving efficiencies of the liquor burning recovery boilers in the chemical pulping industry, but also to the declining energy requirements per ton of production throughout the industry.

Bark and Wood Refuse Fuel and Hogged Fuel – The curve on Figure 3 also shows the combined energy supplied by both onsite bark and wood refuse fuel and by hogged fuel from offsite sources. For those fuels, the trend curve indicates that:

FIGURE 3 Pulp, Paper, and Paperboard Industry Changing Fuel Mix, 1972–1988[10]



- The total amount of energy obtained from these wood fuels has increased steadily between 1972 and 1988, and has, in fact, increased at a percentage rate greater than other fuel. Presumably this increase in energy for wood fuel is the result of improved efficiency of the boilers in which the wood fuel is burned, an increase in the quantity of onsite bark and wood refuse fuel more or less in proportion to the increase in pulp production, and a substantial increase in the use of hogged fuel obtained from offsite.

- Total bark and wood residue fuels have progressed from last place in 1972 to second place in 1988 in the total amount of energy supplied to the industry.

Fossil Fuels – In fossil fuels, the trend curves from 1972 to 1988 show that:

- The use of oil has declined substantially so that oil provides less total energy to the industry than either gas or coal.

- The use of natural gas has declined but not to the extent that the use of oil has declined.

- The use of coal has increased substantially to the point where the energy supplied by coal is about equal to that supplied by gas.

- The total energy supplied in 1988 by oil, gas, and coal combined was less than the total amount supplied by these fuels in 1972, and was less than the energy supplied by spent pulping liquors alone in 1988.

Analysis of Data

From the data shown on the trend curves for the various fuels on Figure 3, it can be concluded that:

- The thrust throughout the pulp and paper industry has been and will continue to be to minimize the use of all fossil fuels in the pulp mills.

- As a corollary, the pulp mills will be designed and operated to maximize the percentage of their energy obtained from spent pulping liquors and bark and wood residue fuels.

- It is likely that offsite hogged fuel will provide the greater future increase in energy per ton supplied to pulp mills since its supply is not a function of pulp production at the mill. There is already at least one market pulp mill in the south which does not use fossil fuels in normal operation; its entire energy supply is obtained from kraft black liquor, bark and wood refuse fuel, and hogged fuel.
- For the most part, nonintegrated paper mills will have to continue to rely solely on the use of fossil fuels.
- Any major interruption in the supply of imported oil will shift these trend lines more strongly toward the use of self-generated and residue fuels and the use of coal.

Plant Thermal Cycles and Generation of Electric Power

Typical Power Plant Thermal Cycles – Typically, process and heating steam is supplied to the pulping and papermaking areas of a mill at two process steam pressure levels – on the order of 150 psig and 50 psig. In a typical plant thermal cycle, steam will be produced by the boilers at power generating steam pressure levels anywhere from 400 psig to 1500 psig, introduced to steam turbine-generator units, and extracted or exhausted at the process pressure levels where the latent heat in the steam is still available for process uses. This dual use of steam, in which the steam is first passed through steam turbines for power generation and then sent to the mill process areas to supply heat energy, is defined by the pulp and paper industry as cogeneration. Plant thermal cycles involving steam turbine-generator units producing only cogenerated electric power operate with a turbine-generator heat rate in the order of 3600 Btu/kWh. Cogeneration is the most efficient method of converting thermal energy into electrical energy.

Trend in Power Generating Steam Pressure Levels – Since the trend in most mills is toward less steam use and more electric power use per ton of production, the goal in cogeneration is to produce more electric power from a smaller flow of steam. This is accomplished by designing for increasing levels of high pressure steam to the steam inlets of the turbine-generator units. Plants which a few years ago might have been designed for high pressure steam levels of 600 or 900 psig might now be designed for 1250 or even 1500 psig.

Quantities of Electric Power Generated – For the years 1982 to 1988, Table 10 indicates the total in-plant generation for the industry, the electric power sold to utilities, and the amount of power produced by cogeneration.

Analysis of Data

From the data shown on Table 10, it is evident that:

- Over half of the net electrical energy used by the industry in 1988 was generated in-plant.
- In the period from 1982 to 1988, the amount of electrical energy generated in-plant increased by 48 percent.
- During 1988, cogenerated electric power represented 86 percent of total in-plant generation compared to 81 percent in 1982.
- Electric power sold to utilities rose from 2 percent of the 1982 in-plant generation to 14 percent in 1988.
- Since the supply of self-generated, in-plant electric power does not alter the supply of self-generated and residue fuels, the additional energy required for in-plant generation of power must be supplied by fossil fuels. This represents a potential for the use of coal.

INDUSTRY-WIDE ESTIMATED FUEL AND ENERGY USE

Table 11 provides data for the pulp and paper industry for the entire United States for the full years 1988, 1987, and 1972. A detailed breakdown is given for Total Purchased Fossil Fuel and Energy and for Total Self-Generated and Residue Fuels.

TABLE 10
Quantities of Electric Power Generated[11]
(including hydroelectric)

Report Period	Total In-Plant Electric Generation (million kWh)	Electricity Sold to Utilities[1] (million kWh)		Electricity Cogenerated[2] (million kWh)	
			% of Col.1		% of Col.1
Total Year - 1982	34,243.0	668.3	2.0	27,843.6	81.3
Total Year - 1983	37,527.4	1,182.7	3.2	30,464.2	81.2
Total Year - 1984	40,043.7	2,493.2	6.2	33,780.2	84.4
Total Year - 1985	40,165.5	2,855.9	7.1	35,363.0	88.0
Total Year - 1986	45,883.0	4,517.5	9.8	40,691.5	88.7
Total Year - 1987	48,633.7	6,891.1R	14.2	41,779.2	85.9
Total Year - 1988	50,720.6	7,085.8	14.0	43,720.4	86.2

Notes:
R Revised
1. Including sales of gross electricity solid to public and private utilities.
2. Electricity generated by qualifying cogenerated facilities as defined by FERC in 18 CFR Section 292.205.

Analysis of United States Data

The 1988 fuel and energy use figures shown in Table 11 show that:

- Self-generated and residue fuels provided 56.5 percent of the total energy used by the industry compared to 43.5 percent for all purchased fossil fuels and energy.
- Spent pulping liquors provided 39.2 percent of the total energy used, making this energy source the largest single contributor to the total requirements. The industry derived more total energy from spent pulping liquors than from coal, oil, and gas combined.
- Together bark and hogged fuel provided 16.3 percent of the total energy used, thereby providing more energy than any one of the fossil fuels – coal, oil or gas. This makes bark and hogged fuel the second largest contributor to the overall energy package, after spent pulping liquors.
- Coal provided 13.9 percent of the total energy requirements, about equal to the 14.0 percent obtained from natural gas, and almost double the 7.5 percent figure for residual oil.
- The total estimated tonnage for the coal used was 13,412,000 tons. If the assumptions are made that all oil and gas could be replaced with coal and that self-generated and residue fuels would make no further inroads on the use of fossil fuels, then presumably the annual use of coal could be increased to a level of approximately 35,000,000 tons per year based upon 1988 production levels for pulp and paper.

Table 11 compares the fuel and energy use figures for 1972 (the year before the Arab oil embargo) with the corresponding figures for 1988.

- In 1972, self-generated and residue fuels provided only 40.3 percent of the total energy used by the industry compared to 59.7 percent for all purchased fossil fuels and energy.
- Total energy supplied by self-generation and residue fuels increased over this 17-year period, from 847,074 billion Btu to 1,360,547 billion Btu, for a net increase of about 61 percent in total energy furnished.

TABLE 11
U.S. Pulp, Paper, & Paperboard Industry Estimated Fuel & Energy Use
Full Years – 1988, 1987, 1972[12]

Source	Units	1988* Estimated Use	1988* Billion Btu	1988* % of Total+	1987* Estimated Use	1987* Billion Btu	1987* % of Total+	1972* Estimated Use	1972* Billion Btu	1972* % of Total+
Purchased Electricity	MM kWh	47,125.1	160,297.8	6.6	43,468.5	147,838.8	6.1	27,559.5	93,698.4	4.4
Purchased Steam	MM lb	19,199.7	21,180.9	.9	14,081.1	17,364.0	.7	19,548.3	22,613.0	1.1
Coal	M ton	13,412.0	335,513.7	13.9	13,432.0	335,087.0	13.9	9,033.6	224,737.1	10.7
Residual Fuel Oil	M 42 gal. bbl	28,849.3	181,527.3	7.5	25,393.4	159,818.4	6.6	71,121.2	447,381.5	21.2
Distillate Fuel Oil	M 42 gal. bbl	1,748.5	10,437.5	.4	1,423.6	8,499.8	.4	3,698.9	22,020.9	1.0
Liquid Propane Gas	M gal.	29,281.6	2,689.3	.1	29,806.6	2,737.3	.1	28,566.8	2,628.9	.1
Natural Gas	MM cf	331,948.7	338,080.0	14.0	338,602.4	345,437.7	14.4	435,459.9	443,916.3	21.1
Other Purchased Energy			2,258.0	.1		24,823.7	1.0		1,634.0	.1
Energy Sold			(–40,021.2)			(–35,386.5)			(–13,125.0)	
Total Purchased Fossil Fuel & Energy			1,011,963.3	43.5		1,006,220.2	43.2		1,245,505.1	59.7
Hogged Fuel (50% Moisture Content)	M ton	31,904.6	267,033.9	11.1	30,961.7	258,089.4	10.7	5,191.2	42,103.2	2.0
Bark (50% Moisture Content)	M ton	14,592.4	125,823.8	5.2	16,779.3	134,869.3	5.6	10,348.2	94,428.9	4.5
Spent Liquor (Solids)	M ton	76,659.8	944,298.3	39.2	76,918.4	949,556.5	39.6	55,175.5	698,393.4	33.3
Self-Generated Hydroelectric Power	MM kWh	3,365.1	11,446.5	.5	3,448.0	11,662.2	.5	2,696.4	9,171.3	.4
Other Self-Generated Energy			11,944.6	.5		10,177.4	.4		2,977.4	.1
Total Self-Generated & Residue Fuels			1,360,547.1	56.5		1,364,354.8	56.8		847,074.2	40.3
Total Energy			2,372,510.4	100.0		2,370,575.0	100.0		2,092,579.3	100.0

Notes:
* – Based on a sample of 92.9% total dried pulp, paper, and paperboard production for 1988, 91.3% for 1987, and 90.1% for 1972.
\+ – Determined by using "Total Energy" + "Energy Sold" as a denominator.

- In 1972, spent pulping liquors provided 33.3 percent of the total energy used by the industry compared to 39.2 percent in 1988. Over this 17–year period, the total energy supplied by spent pulping liquors increased from 698,393 billion Btu to 944,298 billion Btu, for a net increase of about 35 percent.
- In 1972, bark and hogged fuel provided 6.5 percent of the total energy used by the industry compared to 16.3 percent in 1988. Over this 17–year period, the total energy supplied by bark and hogged fuel increased from 136,532 billion Btu to 392,858 billion Btu, for a net increase of 188 percent. The use of hogged fuel made a much larger contribution to this increase than the use of onsite bark.
- In 1972, coal provided 10.7 percent of the total energy compared to 13.9 percent 1988. Total energy from coal increased from 224,737 billion Btu to 335,514 billion Btu, an increase of about 49 percent.
- In 1972, natural gas provided 21.1 percent of total energy compared to 14.0 percent in 1989. Total energy from natural gas actually decreased from 443,916 billion Btu to 338,080 billion Btu; a decrease of about 24 percent in total energy supplied.
- In 1972, residual fuel oil provided 21.2 percent of total energy compared to 7.5 percent in 1988. Total energy from residual fuel oil actually decreased from 447,382 billion Btu to 181,527 billion Btu, a decrease of almost 60 percent.

These figures indicate that in the industry use of fossil fuels, the use of coal is on the rise and the use of natural gas and residual oil is declining.

Between 1972 and 1988, the industry output of pulp, paper, and paperboard increased by more than 42 percent.

Regional United States Data

Table 12, Estimated Fuel and Energy Use by Region for 1988, provides the subject data broken down into separate fuel and energy use data for six regions of the United States. The regions listed are:

- *New England* – includes Maine, New Hampshire, Vermont, Massachusetts, Connecticut, and Rhode Island
- *Middle Atlantic* – includes New York, Pennsylvania, and New Jersey
- *North Central* – includes Wisconsin, Michigan, Illinois, Indiana, Ohio, North Dakota, South Dakota, Minnesota, Nebraska, Iowa, Kansas, and Missouri
- *South Atlantic* – includes Delaware, Maryland, West Virginia, Virginia, North Carolina, South Carolina, Georgia, and Florida
- *South Central* – includes Kentucky, Tennessee, Mississippi, Alabama, Oklahoma, Arkansas, Texas, and Louisiana
- *Mountain and Pacific* – includes Washington, Oregon, California, Nevada, Idaho, Montana, Wyoming, Utah, Arizona, New Mexico, and Colorado

For each region, a detailed breakdown is given both for Total Purchased Fossil Fuel and Energy and for Total Self-Generated and Residue Fuels on the same basis as the corresponding data for the entire United States presented in Table 12.

Analysis of Regional Data

From the 1988 fuel and energy use figures shown in Table 12, it can be seen that:

- Over 73 percent of the total energy derived from spent pulping liquors occurs in the South Atlantic and South Central regions combined. This is the region which turns out approximately 68 percent of the total pulp production in the United States.
- Approximately 68 percent of the total energy derived from the combination of bark and hogged fuel also occurred in the South Atlantic and South Central regions combined, which again reflects the predominance of pulping capacity in the areas.
- Of the total energy derived from coal nationwide it can be calculated from the tabulated data that:

  1. Approximately 40 percent is consumed in the South Atlantic and South Central regions combined, reflecting the large percentage of the total pulp and paper production capacity in the area as well as proximity to major coal fields.
  2. Very little coal is burned in New England, due possibly to its distance from major coal fields and the relatively small size of many of the mills in the area.
  3. A significant portion of coal used is consumed in the North Central area due to its proximity to major coal fields.

- Of the total energy derived from residual oil nationwide it can be calculated from the tabulated data that:

  1. The industry in New England uses almost 31 percent of the total oil used in the industry nationwide in spite of the fact that the area produces on the order of 10 percent of the total production of pulp and paper. This is surely the result of easy bulk oil delivery along the seacoast plus the distance to major coal fields. Only the South Atlantic region used more total oil.
  2. Although the South Atlantic region uses almost 35 percent of residual oil used by the industry, this amounts to only about 26 percent of the total energy supplied by fossil fuels in the region (coal being by far the largest contributor).

- Of the total energy derived from natural gas in the industry, it can be calculated from the tabulated data that approximately 51 percent is

TABLE 12

U.S. Pulp, Paper, & Paperboard Industry Estimated Fuel & Energy Use by Region*

Full Year 1988[12]

		New England			Middle Atlantic			North Central			South Atlantic			South Central			Mountain & Pacific		
Source	Units	Estimated Use	Billion Btu	% of Total+	Estimated Use	Billion Btu	% of Total+	Estimated Use	Billion Btu	% of Total+	Estimated Use	Billion Btu	% of Total+	Estimated Use	Billion Btu	% of Total+	Estimated Use	Billion Btu	% of Total+
Purchased Electricity	MM kWh	3,248.6	11,052.9	7.0	3,659.5	12,460.4	11.9	7,679.1	26,11[illegible]9	9.3	7,991.3	27,176.7	3.8	10,999.7	37,421.1	4.7	13,546.9	46,073.9	13.0
Purchased Steam	MM lb	2,490.4	3,126.0	2.0	.0	.0	.0	7,475.9	8,157.4	2.9	D	D	D	D	D	D	4,790.0	5,130.5	1.4
Coal	M ton	176.0	4,594.1	2.9	1,041.5	26,443.2	25.3	4,172.8	102,359.5	36.6	5,341.9	137,070.9	19.2	D	D	D	D	D	D
Residual Fuel Oil	M 42 gal. bbl	8,913.2	56,183.8	35.4	3,403.6	21,292.9	20.4	1,470.1	9,260.6	3.3	10,018.3	62,870.0	8.8	2,184.7	13,770.8	1.7	2,859.4	18,149.2	5.1
Distillate Fuel Oil	M 42 gal. bbl	96.9	581.9	.4	105.4	625.2	.6	136.1	806.2	.3	976.6	5,830.6	.8	304.6	1,827.7	.2	128.9	765.9	.2
Liquid Propane Gas	M gal.	9,368.9	861.7	.5	6,724.7	618.4	.6	2,849.7	261.4	.1	D	D	D	4,973.2	456.5	.1	D	D	D
Natural Gas	MM cf	2,952.4	3,021.5	1.9	14,202.0	14,589.3	14.0	55,175.7	56,207.1	20.1	30,232.5	30,841.4	4.3	167,066.6	169,513.4	21.2	62,318.6	63,907.3	18.1
Other Purchased Energy			52.1	Negl.		35.5	Negl.		54.1	Negl.		506.6	.1		1,059.1	.1		550.6	.2
Energy Sold			(3,419.3)			(–1,112.3)			(–5,583.2)			(–10,991.4)			(–5,408.4)			(–13,506.6)	
Total Purchased Fossil Fuel & Energy			76,054.7	50.1		74,952.6	72.8		197,635.9	72.6		253,615.1	37.0		278,891.7	35.5		130,813.3	40.8
Hogged Fuel (50% Moisture Content)	M ton	3,056.6	24,481.1	15.4	396.2	3,220.7	3.1	2,082.4	17,174.5	6.1	8,771.1	75,513.1	10.6	10,801.0	91,028.0	11.4	6,797.3	55,616.5	15.7
Bark 50% Moisture Content)	M ton	D	D	D	272.5	2,386.7	2.3	1,297.8	11,193.7	4.0	4,516.8	38,646.7	5.4	7,070.9	61,602.1	7.7	D	D	D
Spent Liquor (Solids)	M ton	3,342.3	41,999.7	26.4	1,496.1	18,370.3	17.6	3,638.5	46,626.0	16.5	27,016.9	331,714.5	46.4	29,739.7	359,280.0	44.9	11,426.3	147,307.8	41.6
Self-Generated Hydroelectric Power	MM kWh	1,435.3	4,881.2	3.1	149.9	509.7	.5	399.3	1,358.2	.5	D	D	D	D	D	D	183.2	622.7	.2
Other Self-Generated Energy			D	D		3,884.4	3.7		846.8	.3		D	D		D	D		1,789.4	.5
Total Self-Generated & Residue Fuels			79,318.6	49.9		28,371.8	27.2		76,199.2	27.4		450,778.1	63.0		516,280.3	64.5		209,599.1	59.2
Total Energy			155,373.3	100.0		103,324.4	100.0		273,835.1	100.0		704,393.2	100.0		795,172.0	100.0		340,412.4	100.0

Notes:

* – Based on a sample of 92.9% total dried pulp, paper, and paperboard production.
\+ – Determined by using "Total Energy" + "Energy Sold" as a denominator.
D – Withheld to avoid disclosure of individual data (included in total).
Negl. – Negligible.

consumed in the South Central region, amounting to slightly more than the amount of gas used by all other regions combined. This would be due naturally to the region's proximity to the major gas fields in Louisiana, Texas, and Oklahoma, and the accessibility of major gas transmission line to the mills.

PROSPECTS FOR INCREASED USE OF COAL

Conclusions

The following conclusions could be drawn from the data and information presented herein for the pulp and paper industry.

Industry Demand for Fossil Fuels – In spite of the industry thrust to minimize the use of fossil fuels by economizing on the use of energy in the mills and by increasing the amount of energy from self-generated and residue fuels, there will always be a demand for fossil fuels in the industry. The total use of fossil fuels should increase, driven by a continuing rate of expansion in the production of pulp and paper which will more than offset the economies in energy use per ton of production.

Industry Demand for Coal – The use of coal in the industry has increased steadily from 1972 to 1988, both in total quantity and as a percentage of the total energy consumption, while the reverse has been true for both residual fuel oil and natural gas. It is expected that this trend will continue, driven by market forces and by the availability of oil and gas.

Dependability of Supply of Fossil Fuels – Given the limited reserves and dwindling domestic production of oil and natural gas plus the reliance on imported oil for somewhere near one-half of the country's petroleum requirements, there has to be some question regarding the adequacy and reliability of the supply of oil. Any interruption in the supply of imported oil increases the demand for natural gas and exacerbates the problems of adequate pipeline capacity for delivery. With coal, the supply is abundant. Problems in obtaining coal would be associated with mining production and transportation, the solutions for which would be within the domestic jurisdiction and control of the United States.

Long-Term Availability of Fossil Fuels – In the future, coal will be the dominant fossil fuel. There may be a few decades or more remaining in the domestic reserves for oil and gas, but the domestic reserves for coal appear to be adequate for the next several hundred years. In years to come, most mills may have to rely on coal or coal derivatives in some form for their fossil fuel supply.

Relative Price Structure of Competing Fossil Fuels – In areas where steam is already cheaper to produce with coal than with oil or gas and where the boilers are designed and equipped to burn the available coal, in all likelihood coal is already being used. In other areas, a changing price structure which produces a competitive advantage will take place when shortages of oil and natural gas occur at the same time.

Mill Classification versus Potential for Coal Usage – The demand for fossil fuels overall and the potential demand for coal in particular will be greatest in those mills which do not have a source of self-generated and residue fuels. A market pulp mill which produces all its energy from self-generated and residue fuels is not a potential customer for coal. Some of the older and less energy-efficient market pulp mills will indeed require some fossil fuel.

On the other hand, nonintegrated paper mills must use purchased fossil fuels for their entire fuel supply. Integrated pulp and paper mills generally will fall between market pulp mills and nonintegrated paper mills in the percentage of energy produced by fossil fuels.

Impediments

Relative Price Structure – Coal generally will not be used where its delivered price produces steam at a higher cost than oil or natural gas. This is the greatest single impediment to increased coal use in the pulp and paper industry.

Mill Location Relative to Coal Source – For mills located in a remote area a great distance from the coal fields, conversion to coal firing would probably be implemented only as a last resort.

Availability of Rail Delivery Facilities – Coal is a bulk commodity well suited for rail shipment, particularly where large quantities of coal and long distance shipping are involved. However, over the past decade, railroads have been engaged in the sale or abandonment of short lines, branches, and sidings in order to improve profitability. As an example, CSX Corporation, a major coal hauling railroad in the east, states in its 1989 Annual Report that the corporation went from a high of 80,000 employees in 1980 to 37,700 employees in 1989, and from a system of 30,000 route-miles in 1980 to one of 19,700 route-miles in 1989, all during a period of generally rising revenues. Wherever this policy prevents delivery of coal directly into a particular mill property, it can only increase the delivered cost of coal to that mill and reduce the chances that the mill will use coal.

Capital Costs Required for Coal Burning – Whether a coal burning plant is installed new or from the conversion of existing boilers, the required capital cost is substantially greater than that required for a comparable oil or gas fired installation. This presents a major obstacle to the use of coal.

Environmental Restrictions – Compliance with environmental regulations governing air pollution is more difficult with coal than with oil or gas, given the levels of emission for fly ash particulates, SO_2, NOx, CO, volatile organic compounds, and trace elements of other components generated by coal firing. Recently, the New Source Performance Standards for coal-fired boilers have been made so restrictive that the environmental permitting of new coal-fired boilers has become most difficult, almost to the point of being impossible. Such regulations may well be the greatest obstacle (after price) to the increased use of coal in the pulp and paper industry.

Landfill Availability – With available landfill sites at a premium, the disposal of bottom ash and fly ash from coal firing is becoming more difficult and more costly. Residue from SO_2 removal systems merely adds to the volume of material that must be sent to the landfill site.

Fugitive Coal Dust – In mills producing a high brightness bleached pulp or white papers, it is necessary to keep fugitive coal dust out of the product. Fugitive dust from coal storage piles, coal unloading and handling operations, coal bunkers, and coal firing operations must be controlled.

Boiler Availability versus New Coal Burning Technology – It is customary for most boilers in the pulp and paper industry to operate on-line 24 hours per day between 350 and 360 days per year. Failure to achieve this level of availability will usually result in lost production and reduced revenues, since few mills are willing to invest in standby boiler capacity. The most recent trend in the design of coal fired boilers in industrial sizes normally used by the pulp and paper industry seems to favor the solids circulating fluidized bed (CFB) boiler design. Many of the recent installations have had a poor history of reliability and availability due to problems with erosion in the gas passages, refractory maintenance, and the like. However, it appears that CFB boilers will continue to be used for coal firing due to their inherent advantages in limiting SO_2 and NOx emissions, and also due to the more readily disposable nature of the discharged ash. Inadequate availability for pulp and paper requirements using the present generation of CFB boilers is a real impediment to the increased use of coal. Improvements in design and operation must be implemented to provide the required reliability.

Recommendations

Competitive Pricing – Pursue coal sales and increased coal usage in areas where coal already enjoys a competitive advantage over oil and natural gas. Competitive pricing is the key to increased usage of coal. Every effort should be made to minimize the cost of coal at the mine mouth through modern mining techniques and to minimize transportation costs by competitive bidding, optimized routing, or the use of unit trains where possible. Coal is most likely to be competitive in mills located near major coal fields.

Costs for Competing Oil and Natural Gas – For areas and mills where coal is not presently used, determine the price structure for all fossil fuels and be prepared to move in with coal as soon as the price structure changes in its favor.

Coal Quality – The quality of coal across the country is not constant. A higher quality coal could be defined as one with a lower content of ash, sulphur, and moisture; a higher ash fusion temperature; and a higher heating value. If a higher quality coal can be offered to a customer, he will be faced with fewer operating problems in his firing equipment, furnace and boiler, and ash collection and disposal.

Type of Mills to Consider for Coal Use – Pursue coal sales and increased coal use particularly in mills with a significant need for fossil fuels. This would include the larger mills and those which do not generate most of their energy from self-generated and residue fuels.

Boiler Design – Mills containing multi-fuel boilers already designed to burn coal are more likely to convert to coal firing than mills that must install new boilers to make the conversion.

Environmental Regulations – Some states are more reasonable than others in environmental permitting procedures and implementation of the various regulations. It is suggested that coal sales might be pursued first in those states which appear to be more reasonable in their attitude toward environmental matters.

Rail Access – It is probable that any mill of significance will have an adequate rail siding suitable for adaption for rail car deliveries of coal. Any substantial quantities of coal that must be delivered over any great distance will require rail delivery. Marketing efforts for coal should first be directed at those mills with suitable rail access and facilities.

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Appendix C

Description of The National Coal Council

Recognizing the valuable contribution of the industry advice provided over the years to the Executive Branch by the National Petroleum Council and the extremely critical importance of the role of coal to America and the world's energy mix for the future, the idea of a similar advisory group for the coal industry was put forward in 1984 by the White House Conference on Coal. The opportunity for the coal industry to have an objective window into the Executive Branch drew overwhelming support.

In the fall of 1984, The National Coal Council was chartered and in April 1985, the Council became fully operational. This action was based on the conviction that such an industry advisory council could make a vital contribution to America's energy security by providing information that could help shape policies leading to the increased production and use of coal and, in turn, decreased dependence on other, less abundant, more costly, and less secure sources of energy.

The Council is chartered by the Secretary of Energy under the Federal Advisory Committee Act. The purpose of The National Coal Council is solely to advise, inform, and make recommendations to the Secretary of Energy with respect to any matter relating to coal or the coal industry that he may request.

The National Coal Council does not engage in any of the usual trade association activities. It specifically does not engage in lobbying efforts. The Council does not represent any one segment of the coal or coal-related industry nor the views of any one particular part of the country. It is instead to be a broad, objective advisory group whose approach is national in scope. Matters which the Secretary of Energy would like to have considered by the Council are submitted as a request in the form of a letter outlining the nature and scope of the study. The request is then referred to the Coal Policy Committee which makes a recommendation to the Council. The Council reserves the right to decide whether or not it will consider any matter referred to it.

The first major studies undertaken by the National Coal Council at the request of the Secretary of Energy were presented to the Secretary in the summer of 1986, barely one year after the startup of the Council. These reports covered *Coal Conversion, Clean Coal Technologies, and Interstate Transmission of Electricity.*

An additional study, completed in 1986, was originated by the Council members and authorized by the Secretary. This report dealt with *New Source Performance Standards for Industrial Boilers.*

Since 1986, the Council has prepared reports on four studies sanctioned by the Secretary of Energy. The following reports have been presented to the Secretary:

In 1987
- *Coal Reserve Data Base*
- *International Competitiveness of U.S. Coal and Coal Technologies.*

In 1988
- *The Use of Coal in the Industrial, Commercial, Residential and Transportation Sectors*
- *Innovative Clean Coal Technology Deployment*

Two additional studies are planned for completion in mid-1990. They are:

Industrial Use of Coal and Clean Coal Technology - Addendum Report

The Long-Range Role of Coal in the Future Energy Strategy of the United States.

Members of The National Coal Council are appointed by the Secretary of Energy and represent all segments of coal interests and geographical disbursement. The National Coal Council is headed by a Chairman and a Vice-Chairman who are elected by the Council. The Council is supported entirely by voluntary contributions from its members.

Appendix D

The National Coal Council Membership Roster – 1990

CHAIRMAN

MR. WILLIAM CARR*
President
Mining Division
Jim Walter Resources, Inc.

VICE CHAIRMAN

MR. W. CARTER GRINSTEAD, JR.*
Vice President
Exxon Coal & Minerals Company

CHAIRMAN – NATIONAL COAL COUNCIL COAL POLICY COMMITTEE

DR. IRVING LEIBSON
Executive Consultant
Marketing and Technology
Bechtel Group, Inc.

MEMBERS

DR. SY ALI
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Industrial Engine Technology
Allison Gas Turbine Division
General Motors Corporation

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Baird and Baird

MR. GEORGE M. BARBERICH
Executive Vice President,
Comptroller, & Chief Financial Officer
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MR. DANIEL BEAM*
Commercial Fuels, Inc.

MR. EDDIE BECK
Manager
Bowling Green Municipal Utilities

MR. THOMAS J. BELVILLE*
President
Belville Mining Company, Inc.

MR. WILLIAM W. BERRY*
Chief Executive Officer
Dominion Resources

MR. GEORGE M. BIGG
President
Simms Fork Associates, Inc.

MR. H. L. BILHARTZ, JR.
President
ARCO Coal Company

MR. GERALD BLACKMORE*
G. Blackmore, Inc.

DR. SANDRA BLACKSTONE*
Professor – College of Law
University of Denver

MR. THOMAS H. BRAND, JR.*
Brocksen & Brand, Inc.

MR. J. ROBERT BRAY*
Executive Director
Virginia Port Authority

MR. WILLIAM T. BRIGHT*
Chairman of the Board
Land Use Corporation

DR. ROBERT W. BROCKSEN*
Executive Director
Living Lakes, Inc.

MR. BOBBY R. BROWN*
Chairman/Chief Executive Officer
Consolidation Coal Company

**Denotes Member of the Coal Policy Committee*

MR. DONALD P. BROWN
President
Cyprus Coal Company

MR. THOMAS BROWN*
Representative
Eastern Conference Teamsters

DR. DONALD CARLTON*
President
Radian Corporation

THE HONORABLE GARREY CARRUTHERS*
Governor of New Mexico

MR. FRED CLAYTON
President
Shand Mining, Inc.

MR. WILFRED CONNELL
Vice President
Illinois Power Company

MR. ROBERT P. COOPER*
Vice President
Land Acquisition & Environmental Affairs
Farrell-Cooper Mining Company

MR. JOSEPH W. CRAFT, III*
President
MAPCO Coal, Inc.

MR. A. W. DAHLBERG*
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Georgia Power Company

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MR. GARRY DRUMMOND*
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Drummond Company, Inc.

MR. JOHN DWYER
President
North Dakota Lignite Council

THE HONORABLE GEORGE EVANS*
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Kentucky Energy Cabinet

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Chairman/Chief Executive Officer
Fairchild International

MR. JOSEPH FARRELL*
Chairman–Coal Group
The Pittston Company

MR. JERRY FARRINGTON*
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Appendix E

The National Coal Council Study Group for the Industrial Use of Coal and Clean Coal Technology – Addendum Report

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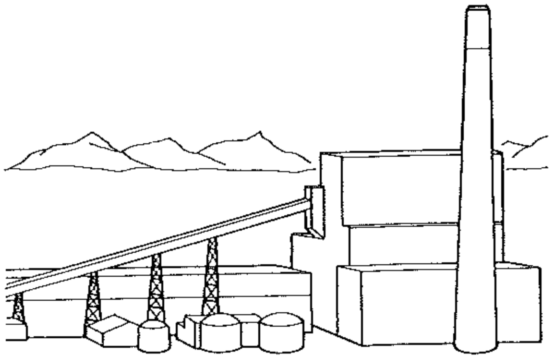

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