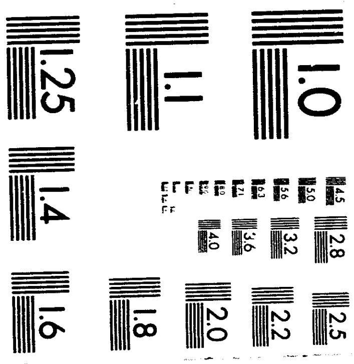
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DOE/EIA-M064

NEMS Industrial Module Documentation Report

January 1994

Office of Integrated Analysis and Forecasting
Energy Information Administration
U.S. Department of Energy
Washington, DC

This report was prepared by the Energy Information Administration, the independent statistical agency within the Department of Energy. The information contained herein should not be construed as advocating or reflecting any policy position of the Department of Energy or any other organization.

Table of Contents

1. Introduction

Purpose of this Report

This report documents the objectives, analytical approach, and development of the National Energy Modeling System (NEMS) Industrial Demand Model. The report catalogues and describes model assumptions, computational methodology, parameter estimation techniques, and mouel source code.

This document serves three purposes. First, it is a reference document providing a detailed description of the NEMS Industrial Model for model analysts, users, and the public. Second, this report meets the legal requirement of the Energy Information Administration (EIA) to provide adequate documentation in support of its statistical and forecast reports (*Public Law 93-275, section 57(b)(1)*). Third, it facilitates continuity in model development by providing documentation from which energy analysts can undertake model enhancements, data updates, and parameter refinements as future projects.

Model Summary

The NEMS Industrial Demand Model is a dynamic accounting model, bringing together the disparate industries and uses of energy in those industries, and putting them together in an understandable and cohesive framework. The Industrial Model generates mid-term (up to the year 2010) forecasts of industrial sector energy demand as a component of the NEMS integrated forecasting system. From the NEMS system, the Industrial Model receives fuel prices, employment data, and the value of output of industrial activity. Based on the values of these variables, the Industrial Model passes back to the NEMS system estimates of consumption by fuel types.

The NEMS Industrial Model estimates energy consumption by energy source (fuels and feedstocks) for 26 manufacturing and 6 nonmanufacturing industries. The manufacturing industries are further subdivided into the energy-intensive manufacturing industries and non-energy-intensive manufacturing industries. The energy-intensive industries are modeled through the use of a detailed process flow accounting procedure, whereas the non-energy-intensive, as well as the nonmanufacturing industries, are modeled through econometrically based equations. The industrial model forecasts energy consumption at the nine Census division levels; energy consumption at the Census division level is allocated by using State Energy Data System (SEDS) data and the shares remain constant.

Each industry is modeled as three separate but interrelated components consisting of the process/assembly component (PA), the buildings component (BLD), and the boiler/steam/cogeneration component (BSC). The BSC component satisfies steam demand from the PA and BLD components. In some industries, the PA component produces byproducts that are consumed in the BSC component. For the energy-intensive industries, the PA component is broken down into the major production processes or end uses.

Archival Media

As of this writing, the model has not been officially archived. The model will be archived on IBM 3090 mainframe magnetic tape storage as part of the National Energy Modeling System production runs used to generate the Annual Energy Outlook 1994.

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Organization of this Report

Chapter 2 of this report discusses the purpose of the NEMS Industrial Demand Model, detailing its objectives, input and output quantities, and the relationship of the Industrial Model to the other modules of the NEMS system. Chapter 3 of the report describes the rationale behind the Industrial Model design, providing insights into further assumptions utilized in the model development process to this point. Chapter 3 also reviews alternative industrial sector modeling methodologies drawn from existing literature. Chapter 4 details the model structure. The first section in the chapter provides a flow diagram of the model. The second section provides a description of the principal model subroutines, including the key computations performed and equations solved in each subroutine.

The Appendices to this report provide supporting documentation for the Industrial Model. Appendix A lists and defines the input data used to generate parameter estimates and endogenous forecasts from the Industrial Model, along with the parameter estimates and the outputs of most relevance to the NEMS system and the model evaluation process. A table referencing the equation(s) in which each variable appears is also provided in Appendix A. Appendix B contains a mathematical description of the algorithms used in the Industrial Model, including model equations and variable transformations. Appendix C is a bibliography of reference materials used in the development process. Appendix D consists of a model abstract. Appendix E lists the input data and estimation methods for deriving the input data.

2. Model Purpose

Model Objectives

The NEMS Industrial Demand Model was designed to forecast industrial energy consumption by fuel type and Standard Industrial Classification (SIC). The Industrial Model generates mid-term (up to the year 2010) forecasts of industrial sector energy demand as a component of the NEMS integrated forecasting system. From the NEMS system, the Industrial Model receives fuel prices, employment data, and the value of output for industrial activity. All dollar values are expressed in 1987 dollars. Based on the values of these variables, the Industrial Model passes back to the NEMS system estimates of fuel consumption for seventeen main fuels (including feedstocks and renewables) for each of 32 SIC industry groups. The Industrial Model forecasts energy consumption at the four Census region levels; energy consumption is allocated to the Census division level based on SEDS data, with the shares remaining constant.

The NEMS Industrial Model is an annual energy forecasting model; as such, it does not model seasonal variations in fuel demand or fuel prices, for example. The model was designed primarily for use in applications such as the Annual Energy Outlook and other applications that examine mid-term energy-economy interactions.

The model can also be used to examine various policy, environmental, and regulatory initiatives. For example, energy consumption per dollar of output is, in part, a function of energy prices. Therefore, the effect on industrial energy consumption of policies that change relative fuel prices can be analyzed endogenously in the model. Currently, industrial carbon emissions are explicitly accounted for in the model as a function of fuel consumption.

To a lesser extent, the Industrial Model can endogenously analyze specific technology programs or energy standards regulations. The model distinguishes among the energy-intensive manufacturing industries, the non-energy-intensive manufacturing industries, and the non-manufacturing industries. The unit energy consumption in the non-energy-intensive industries is modeled econometrically as a function of relative fuel price ratios and an autonomous trend. Consequently, the Industrial Model does not currently have the capability to model detailed technologies or processes for these industries.

A process flow approach, represented by their major production processes or end uses, is used to model the energy-intensive industries. This approach provides considerable detail about how energy is consumed in that particular industry. Even using this approach, however, the process flows are modeled at a high degree of aggregation. Therefore, technologies or processes at the same level of aggregation as the model can be endogenously analyzed by changing the relevant unit energy consumption values for those technologies or processes. For example, the model can analyze changes at the level of a blast furnace or a pulping process. To model technologies or processes at a lower level of aggregation, off-line analysis can be performed, and the results incorporated into the model through the use of engineering judgment.

Relationship between the Industrial Model and Other NEMS Models

Table 1 shows the Industrial Model inputs from and outputs to other NEMS modules. Note that all inter-module interactions must pass through the system module.

Table 1. Interaction With Other NEMS Modules

INPUTS	From Module
Controlling information (iteration count, present year, number of years to be modeled, convergence switch, etc.	System
Electricity prices	Electricity Market Module
Natural gas prices	Natural gas supply
Steam coal prices Metallurgical coal prices	Coal supply
Distillate oil prices Residual oil prices LPG prices Motor gasoline prices Petrochemical feedstock prices Asphalt and road oil prices Other petroleum prices	Petroleum Market Module
Value of output Employment	Macro

INPUTS	From Module

Refinery consumption of:
  Natural gas
  Steam coal
  Distillate oil
  Residual oil
  LPG
  Still gas
  Petroleum coke
  Other petroleum
Refinery consumption of fuels to cogenerate electricity:
  Natural gas
  Steam coal
  Residual oil
  Biomass
Refinery electricity consumption:
  Purchased electricity
  Cogenerated electricity
  Electricity sold to the grid
Refinery consumption of renewables
	Petroleum Market Module

Table 1. Interaction with Other NEMS Modules, cont.

OUTPUTS	To Module
Industrial consumption of: Purchased electricity Natural gas Steam coal Metallurgical coal Net coal coke imports Distillate oil Residual oil LPG Motor gasoline Kerosene Petrochemical feedstocks Still gas Petroleum coke Other petroleum	Supply Modules
Consumption of renewables: Biomass Hydropower Solar/wind/geothermal/etc.	System
Nonutility generation: Cogeneration of electricity Electricity sales to the grid and own use	Electricity Market Module
Carbon emissions	System

3. Model Rationale

Theoretical Approach

Introduction

The NEMS Industrial Model can best be characterized as a dynamic accounting model, because its architecture attempts to bring together the disparate industries and uses of energy in those industries, and put them together in an understandable and cohesive framework. This explicit understanding of the current uses of energy in the industrial sector is used as the framework from which to base the dynamics of the model.

One of the overriding characteristics in the industrial sector is the extensiveness and the heterogeneity of industries, products, equipment, technologies, processes, and energy uses. Adding to this heterogeneity is that the industrial sector as defined at EIA includes not only manufacturing, but also agriculture, mining, and construction. These disparate industries range widely from highly energy-intensive activities to non-energy-intensive activities. Industries are modeled at a disaggregate level so that changes in composition of the products produced will not significantly offset accounting of energy consumption. Other industrial modeling approaches have either lumped together these very different activities across industries or users, or they have been so disaggregate as to require extensive resources for data development and for running the model.

Modeling Approach

There are a number of considerations that have been taken into account in building the industrial model. These considerations have been identified largely through experience with the current and previous EIA models and with various EIA analyses, through communication and association with other modelers and analysts, and through literature review. The primary considerations are listed below.

- The industrial model incorporates three major industry categories, consisting of energy-intensive manufacturing industries, non-energy-intensive manufacturing industries, and nonmanufacturing industries. The level and type of modeling and the attention to detail is different for each. Manufacturing disaggregation is at least at the 2-digit SIC level, with some further disaggregation of the more energy-intensive industries.

- Each industry is modeled as three separate but interrelated components, consisting of boilers/steam/cogeneration (BSC), buildings (BLD) and process/assembly (PA) activities.

- The model uses a vintaged capital stock accounting framework that models energy use in new additions to the stock and in the existing stock. The existing stock is retired based on retirement rates for each industry.

- The energy-intensive industries are modeled with a structure that explicitly describes the major process flows or major consuming uses in the industry.

- Technology penetration at the level of major processes in each energy-intensive industry is based upon engineering judgment. A second relationship provides additional energy conservation due to the effect of changes in energy prices.

- The model structure accommodates several industrial sector activities including: fuel switching, cogeneration, renewables consumption, recycling, byproduct consumption, and carbon emissions. The principal model calculations are performed at the four Census region levels and aggregated to a national total.

- The implementation of the model is being phased, beginning with the basic accounting structure and with relatively simple behavioral relationships. Features and enhancements will be added over time, as needed or appropriate for specific analyses.

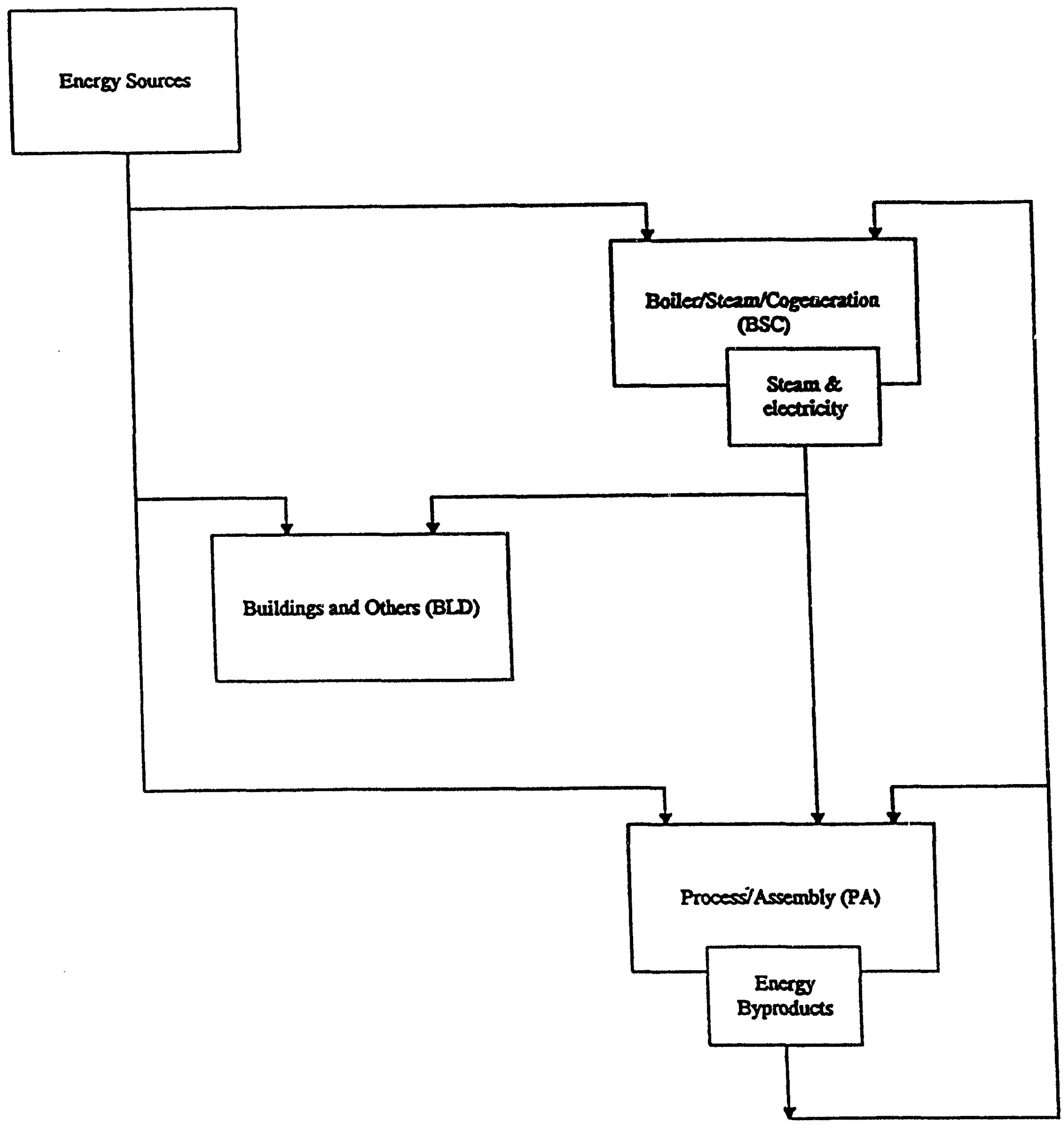
Fundamental Assumptions

The industrial sector consists of a wide variety of heterogeneous industries. The Industrial Model classifies these industries into three groups by Standard Industrial Classification (SIC) - energy-intensive industries, non-energy-intensive industries, and non-manufacturing industries. There are eight energy-intensive manufacturing industries modeled; seven of them are modeled in the industrial model. They are as follows: food and kindred products (SIC 20); paper and allied products (SIC 26); bulk chemicals (SIC's 281, 282, 286, and 287); glass and glass products (SIC's 321, 322, and 323); hydraulic cement (SIC 324); blast furnaces and basic steel products (primarily SIC's 331, 332, etc.); and primary aluminum (primarily SIC's 3334, 3341, 3353, 3354, 3355, etc.). Petroleum refining (SIC 2911) is modeled in detail in a separate module of NEMS, and the projected energy consumption is included in the manufacturing total. The forecast for Oil and Gas (SIC 1311) lease and plant and cogeneration consumption are exogenous to the Industrial model, but endogenous to the NEMS modeling system.

Each industry is modeled as three separate but interrelated components consisting of the process/assembly component (PA), the buildings component (BLD) and the boiler/steam/cogeneration component (BSC). (See Figure 1). The BSC component satisfies the steam demand from the PA and BLD components. For the energy-intensive industries, the PA component is broken down into the major production processes or end uses.

Figure 1. Industrial Model Components

The flow of energy among the three industrial model components follows the arrows.



Energy consumption in the NEMS Industrial Model is primarily a function of the level of industrial economic activity. Industrial economic activity in the NEMS system is measured by the dollar value of output produced by each SIC industry group. The value of output for the Industrial Model by SIC is provided by the NEMS MACRO Module. As the level of industrial economic activity increases, the amount of energy consumed to produce the relevant industrial products typically increases at a slower rate.

The amount of energy consumption reported by the Industrial Model is also a function of vintage of the capital stock that produces the output. It is assumed that new vintage stock will consist of state-of-the-art technologies that are relatively more energy efficient than the average efficiency of the existing capital stock. Consequently, the amount of energy required to produce a unit of output using new capital stock is less than that required by the existing capital stock. The energy intensity of the new capital stock relative to 1990 capital stock is reflected in the parameter of the Technology Possibility Curve estimated for each of the energy-intensive industries. These curves are based on engineering judgment of the likely future path of energy intensity changes.

The energy intensity of the existing capital stock also is assumed to decrease over time, but not as rapidly as new capital stock. The decline is due to retrofitting and replacement of equipment due to normal wear and tear. The net effect is that over time the amount of energy required to produce a unit of output declines. Although total energy consumption in the industrial sector is projected to increase, overall energy intensity is projected to decrease.

Energy consumption in buildings is assumed to grow at the same rate as employment in that industry. Energy consumption in the BSC is assumed to be a function of the steam and electricity requirements of the other two components.

Industry Disaggregation

Table 2 identifies the industry groups to be modeled in the industrial sector along with their Standard Industrial Classification[1] (SIC) code coverage. These industry groups have been chosen for a variety of reasons. The primary consideration is the distinction between energy-intensive industry groups (or large energy consuming industry groups) and non-energy-intensive industry groups. The energy-intensive industries are modeled in more detail, with aggregate process flows. The industry categories are also to be as consistent as possible with the categories which are available from the Manufacturing Energy Consumption Survey (MECS).[2] Table 2 identifies 6 nonmanufacturing industries and 26 manufacturing industries. Within the manufacturing industries, the seven most energy-intensive industries are modeled in greater detail in the Industrial Demand Model. Refining (SIC 2911), also an energy-intensive industry, is modeled elsewhere in NEMS.

Energy Sources Modeled

The NEMS Industrial Model estimates energy consumption for the 32 SIC industries by energy source (fuels and feedstocks) for 17 energy types. The major energy sources (fuels) modeled in the Industrial Model are:

- Electricity
- Natural Gas

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[1]The Standard Industrial Classification (SIC) codes have been modified at various points in time, leading to occasional difficulties with tracking specific industries over time. In general this is not a problem, but does lead to some difficulties with matching some databases, including the National Energy Accounts.

[2]All the two digit industries can be made consistent with the published tables in MECS, but the published MECS tables do not have subcategories (below 2 digit) that add up to their industry total. Moreover, in cases where there are subcategories, MECS uses a fairly specific 4-digit industry which is typically at a lower level of detail than that which is desired for the industrial model. This makes for some difficulty with coordination. There can be coordination at the 2-digit level.

Table 2. Industry Categories for the EIA Industrial Model[a]

	Level of Modeling
Nonmanufacturing Industries	
Agricultural Production - Crops (SIC 01)	Aggregate
Other Agriculture including Livestock (SIC 02, 07, 08, 09)	Aggregate
Coal Mining (SIC 11, 12)	Aggregate
Oil and Gas Mining (SIC 13)	Part External
Metal and Other Non-metallic Mining (SIC 10, 14)	Aggregate
Construction (SIC 15, 16, 17)	Aggregate
Manufacturing Industries	
Food and Kindred Products (SIC 20)	Detailed
Tobacco Products (SIC 21)	Aggregate
Textile Mill Products (SIC 22)	Aggregate
Apparel and Other Textile Products (SIC 23)	Aggregate
Lumber and Wood Products (SIC 24)	Aggregate
Furniture and Fixtures (SIC 25)	Aggregate
Paper and Allied Industries (SIC 26)	Detailed
Printing and Publishing (SIC 27)	Aggregate
Chemicals and Allied Products (SIC 28)	–
Bulk Chemicals (SIC 281, 282, 286, and 287)	Detailed
Other Chemicals and Allied Products (SIC 283, 284, 285, 289)	Aggregate
Petroleum and Coal Products (SIC 29)	–
Petroleum Refining (SIC 2911)	External
Asphalt, Coal and Miscellaneous Products (SIC 295, 299)	Aggregate
Rubber and Miscellaneous Plastic Products (SIC 30)	Aggregate
Leather and Leather Products (SIC 31)	Aggregate
Stone, Clay and Glass Products (SIC 32)	–
Glass and Glass Products (SIC 321, 322, 323)	Detailed
Cement, Hydraulic (SIC 324)	Detailed
Other Stone and Clay Products (SIC 325, 326, 327, 328, 329)	Aggregate
Primary Metals Industries (SIC 33)	–
Blast Furnace & Basic Steel Products (primarily SIC 331, 332, etc.)	Detailed
Primary Aluminum (primarily SIC 3334, 3341, 3353, 3354, 3355, etc.)	Detailed
Other Primary Metals Products (SIC 333-336, 339, with above exceptions)	Aggregate
Fabricated Metal Products (SIC 34)	Aggregate
Industrial Machinery and Equipment (SIC 35)	Aggregate
Electronic & Other Electric Equipment (SIC 36)	Aggregate
Transportation Equipment (SIC 37)	Aggregate
Instruments and Related Products (SIC 38)	Aggregate
Miscellaneous Manufacturing Industries (SIC 39)	Aggregate

[a]Not all possible SIC numbers are used in the SIC classification scheme. For example, there is no SIC 03, 04, 05 or 06. There are also difficulties with the definition of some of the categories for use in the industrial model. For example, the most difficult category is primary aluminum. It is defined in the SIC classification as a four-digit industry under primary metals, but this represents only part of what is generally understood to be the aluminum industry. This four-digit code does not represent the manufacture of alumina from bauxite which is a significant energy consumer. The alumina activity is in the chemical industry under SIC 2819.

- Steam Coal
- Distillate Oil
- Residual Oil
- LPG for heat and power
- Other Petroleum
- Renewables
- Motor Gasoline

Other energy sources that are used in specific industries are also modeled:

- Natural Gas Feedstock
- Coking Coal (including net imports)
- LPG Feedstock
- Petrochemical Feedstocks
- Asphalt and Road Oil
- Still Gas
- Petroleum Coke
- Other Petroleum Feedstocks

In the model, byproduct fuels are always consumed before purchased fuels.

Key Computations

The key computations of the Industrial Model are the Unit Energy Consumption (UEC) estimates made for each SIC industry group. UEC is defined as the amount of energy required to produce one dollar's worth of output. The overall modeling approach posits a *putty/clay* process of investment to determining UEC's. This means that before a piece of equipment or industrial process is installed, the factor inputs may be freely variable. Thus, the combination of energy and other factor inputs will be chosen to minimize costs (for a given output level) based on the current price expectations. However, after installation the capital has become clay, and factor proportions cannot be changed without additional investment. This characterization of the industrial expansion process leads to the notion that the existing capital stock has limited variation of input ratios of energy versus other factors, but when new capital is added the input ratios are freely variable. Distinguishing between the characteristics of the process when new capital equipment is put into place and the characteristics of the process with existing capital equipment is done with a vintage-based accounting procedure.

The modeling approach incorporates technical change in the production process to achieve lower energy intensity. Autonomous technical change can be envisioned as a learning-by-doing process for existing technology. As experience is gained with a technology, the costs of production decline. Autonomous technical change is the most important source of technical change in the industrial sector. The reason is that few industrial innovations are adopted solely because of their energy consumption characteristics; industrial innovations are adopted for a combination of factors, many of which are hard to quantify. These factors include process changes to improve product quality, changes made to improve productivity, or changes made in response to the competitive environment. These strategic decisions are not readily amenable to economic or engineering modeling at the level of disaggregation in the Industrial Model (For example, see [67]).

Modeling the changes to UEC is one of the main features of the Industrial Model. The methodology for performing the estimation differs, however, both among the components of the model and between the energy-intensive and non-energy-intensive industries. The following sections describe the methodology for each of the components in more detail.

Buildings Component UEC

Buildings are estimated to account for 3 percent of energy consumption in manufacturing industries [30]. (In non-manufacturing industries, building energy consumption is assumed to be negligible.) This estimate is based on a combination of an ISTUM model run and a study on industrial building energy use prepared by Hagler-Bailly [49]. In reality, however, there is very little actual data on which to base accurate estimates. Consequently, the modeling approach is a parsimonious one. Energy consumption in industrial buildings is assumed to grow at the same rate as employment in that industry. This assumption appears to be reasonable since lighting and HVAC are used primarily for the convenience of humans rather than machines.

Estimates of 1990 manufacturing sector (SIC 20-39) building UEC's are presented in Table E-1 in Appendix E. The subroutines and equations used to forecast industrial buildings energy consumption are shown on page B-4 in Appendix B.

Process and Assembly Component UEC

The process and assembly component accounted for the largest share of direct energy consumption for heat and power in 1990 - 54 percent. Of the total, natural gas accounts for 33 percent, electricity for 29 percent, and byproducts 20 percent of the total [30].

Estimation of the PA component UEC's differs according to whether the industry is an energy-intensive industry or a non-energy-intensive industry. UEC's for the non-energy-intensive industries are estimated using econometric techniques. For the energy-intensive industries, the econometric estimates are replaced by engineering data relating energy consumption to the product flow through the process steps in each industry. In addition, engineering judgment is also used to characterize autonomous change in the energy-intensive industries through the use of Technology Possibility Curves. Each of these methods is discussed in the following sections. The subroutines and equations for the PA component begin on page B-5 in Appendix B.

Non-Energy-Intensive Industry UEC Estimation

The formulation to estimate UEC's for the non-energy-intensive industries incorporates price-induced energy intensity changes and autonomous efficiency trends in a single economically motivated equation. The resulting equation shows that the change in UEC results from a combination of autonomous and price-induced technical change. One process operates on the existing stock (or technology). It is expected that small but measurable efficiency gains can be obtained even with the existing technology. The other process operates through the incorporation of new technology and current price expectations in the production process.

The price-induced technical change can be represented as a function of price changes.[3] The autonomous change is somewhat more problematical. However, one may argue that as equipment using the current technology undergoes maintenance and refurbishing that the tendency is to incorporate the latest version of the equipment being replaced. Usually, the latest versions consume energy somewhat differently. The autonomous trend can be represented as a function of cumulative output from existing technology. The resulting equation takes the following form:

$$\frac{UEC_{f,t}}{UEC_{f,1958}} = \alpha \left(\frac{P_{f,t}}{P_{f,1958}}\right)^{\beta_f} * \left(\frac{\sum_{i=1958}^{t-1} Q_i}{Q_{1958}}\right)^{\beta_2} \qquad (1)$$

[3]A similar formulation is found in [87].

where:

$UEC_{f,t}$	=	Unit energy consumption for fuel *f* in year *t*,
$UEC_{f,1958}$	=	Unit energy consumption for fuel *f* in year 1958,
$P_{f,t}$	=	Price of fuel *f* in year *t*, in 1987 dollars,
$P_{f,1958}$	=	Price of fuel *f* in year 1958, in 1987 dollars,
Q_{1958}	=	Output in year 1958, in 1987 dollars,
Q_i	=	Output in year i.

The α parameter captures the effects of influences on the UEC that are not specified in the model.

In double log form, this formulation leads to estimated elasticities as follows:

$$LN\left(\frac{UEC_{f,t}}{UEC_{f,1958}}\right) = LN\ \alpha + \beta_f\ LN\left(\frac{P_{f,t}}{P_{f,1958}}\right) + \beta_2\ LN\left(\frac{\sum_{i=1958}^{t-1} Q_i}{Q_{1958}}\right) + \epsilon \qquad (2)$$

The estimated β_f and β_2 would then represent the UEC elasticity for price-induced and autonomous change, respectively. The β_f are expected to be less than zero, but β_2 may be positive or negative. Similar UEC elasticities are estimated for natural gas, petroleum products, and coal. The baseline (1988) PA component UEC values for the non-manufacturing and the non-energy-intensive manufacturing industries are given in Appendix E Table E-2.A. and Table E-2.B., respectively. The regression parameter estimates (β_f and β_2) that are used in the model to modify the baseline UEC values and the statistical properties of these estimators are given in Table E-15 in Appendix E. In Table E-15, β_2 is identified by RCUMOUT. Obviously, not all variables appear in each equation. The consumption, output, and price input data for the regressions can be found in Appendix E Tables E-22A through E-22D.

Energy-Intensive Industry UEC Estimation

For the seven most energy-intensive industries, energy consumption for the PA component is modeled according to the process flows in that industry. The industries are food and kindred products, paper and allied products, blast furnaces and basic steel products, primary aluminum, bulk chemicals, hydraulic cement, and glass and glass products industries. (Petroleum refining is also a major energy consuming industry but it is being modeled elsewhere in NEMS.)

To derive energy use estimates for the process steps, the production process for each industry was first decomposed into its major steps, and then the engineering and product flow relationships among the steps were specified. The process steps for the seven industries were analyzed according to one of the following methodologies:

Methodology 1. Developing a process flowsheet and estimates of energy use by process step. This was applicable to a number of industries where the process flows could be fairly well defined for a single broad product line by unit process step (blast furnace and basic steel products, primary aluminum, hydraulic cement, glass and glass products, and paper and allied products).

Methodology 2. Developing end use estimates by generic process units as a percent of total use in the PA component. This was especially applicable where the diversity of end products and unit process is extremely large (food and kindred products, and bulk chemicals).

In both methodologies, major components of end use are identified by process for various energy sources:

- Fuels;
- Electricity (valued at 3412.0 Btu/Kwh);
- Steam; and
- Non-fuel energy sources.

The following sections present a more detailed discussion of the process steps and unit energy consumption estimates for each of the energy-intensive industries. The data tables showing the estimates are presented in Appendix E, and are referenced in the text as appropriate. The process steps are model inputs with the variable name *INDSTEPNAME*, and are also listed on page A-59 of this report.

Food and Kindred Products (SIC 20)

The food and kindred products industry is the largest (with the exception of transportation, SIC 37) of the twenty manufacturing industry sectors with regard to the value of annual shipments. The energy use profile has been divided into the nine sectors according to the food industry's 3-digit SICs: SIC 201, Meat Products; SIC 202, Dairy Products; SIC 203, Preserved Fruits and Vegetables; SIC 204, Grain Mill Products; SIC 205, Bakery Products; SIC 206, Sugar and Confectionery Products; SIC 207, Fats and Oils; SIC 208, Beverages; and SIC 209, Miscellaneous Foods and Kindred Products.

The 1992 Arthur D. Little supplement to "Energy Use for Industry" served as a basis for the 1988 values. Since the ADL supplement was based on 1985 data, the values were estimated for 1988 by multiplying by a ratio of 1988 MECS data to 1985 MECS data. The portion of "other electricity" reported in the ADL supplement (January 1992) which can be attributed to the BLD component was subtracted using proportions from EIA 1988 data. The UEC for the PA component of the food and kindred products industry is expressed in terms of trillion Btu per billion dollars of output.

The food and kindred products industry consumed approximately 996 trillion Btus of energy in 1988 [43]. Energy use in the food and kindred products industry for the PA Component was estimated on the basis of end-use in four major categories:

- Steam or hot water;
- Direct fuel used in a process such as in grain drying or directly fired ovens;
- Electrical energy used in refrigeration; and
- Other electric energy.

Figure 2 portrays the PA component's end-use energy flow for the food and kindred products industry. The UEC's estimated for this industry are provided in Table E-3, Appendix E. Note that the steam/hot water use shown in the table represents the energy content of steam that is used in the industry sub-sector (i.e., boiler losses and efficiencies are not included in these tables). The dominant end-use was steam (and hot water), which accounted for 57 percent of the total energy consumption. Direct fuel use made up about 21 percent. Electric energy was primarily used for motors, pumps and drives, contributing 18 percent of the energy consumption and refrigeration accounting for about 4 percent.

Paper and Allied Products (SIC 26)

The paper and allied products industry's principal processes involve the conversion of domestic wood fiber to pulp, and then paper and board to consumer products that are generally targeted at the domestic marketplace. Aside from dried market pulp, which is sold as a commodity product to both domestic and international paper and board manufacturers, the industry produces a full line of paper and board products. Figure 3 illustrates the major process steps for all pulp and paper manufacturing. The wood is prepared by removing the bark and chipping the whole tree into small pieces. Pulping is the process in which the fibrous cellulose in the wood is

Figure 2. Food and Kindred Products Industry End-Use Flow

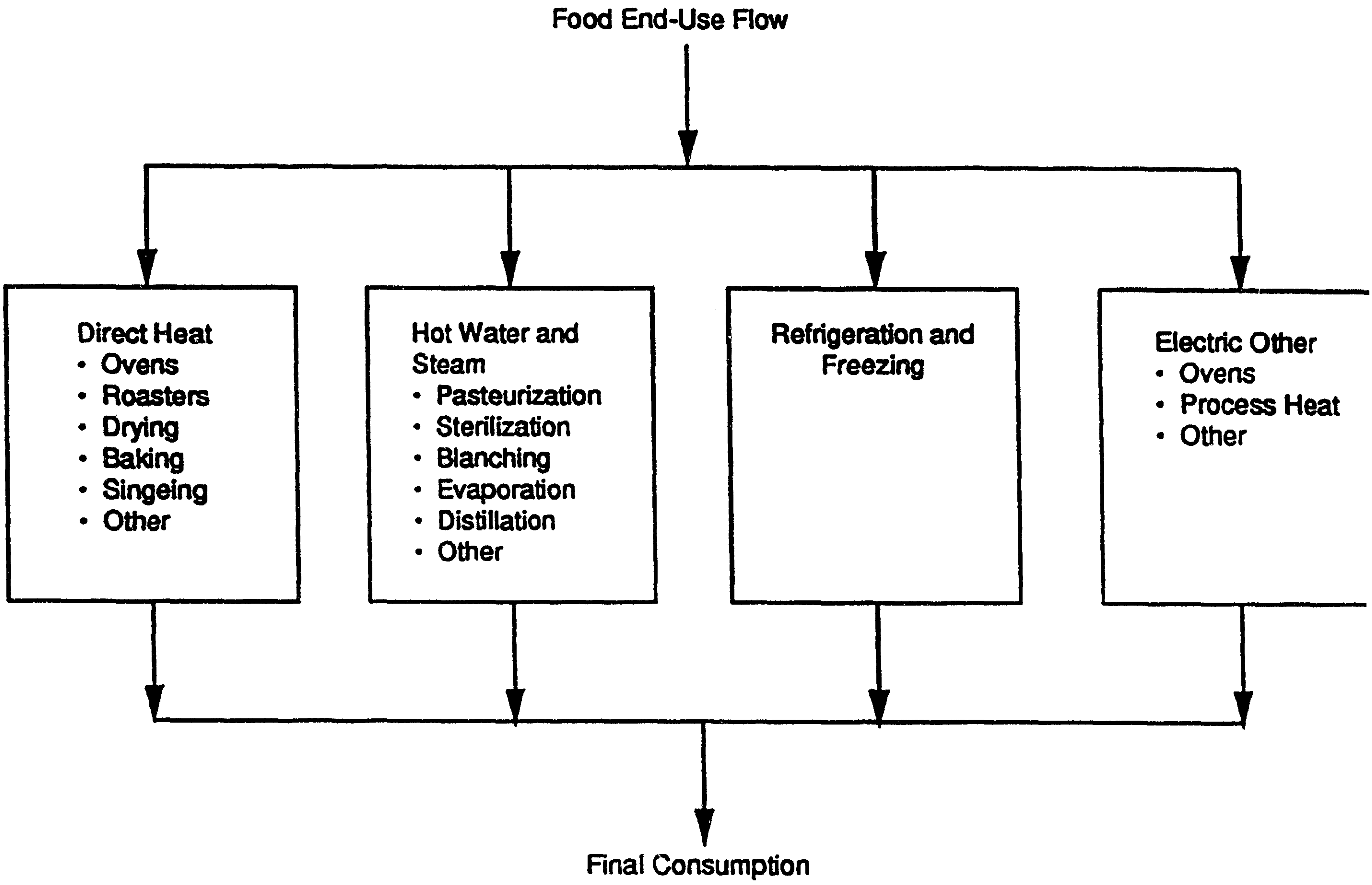
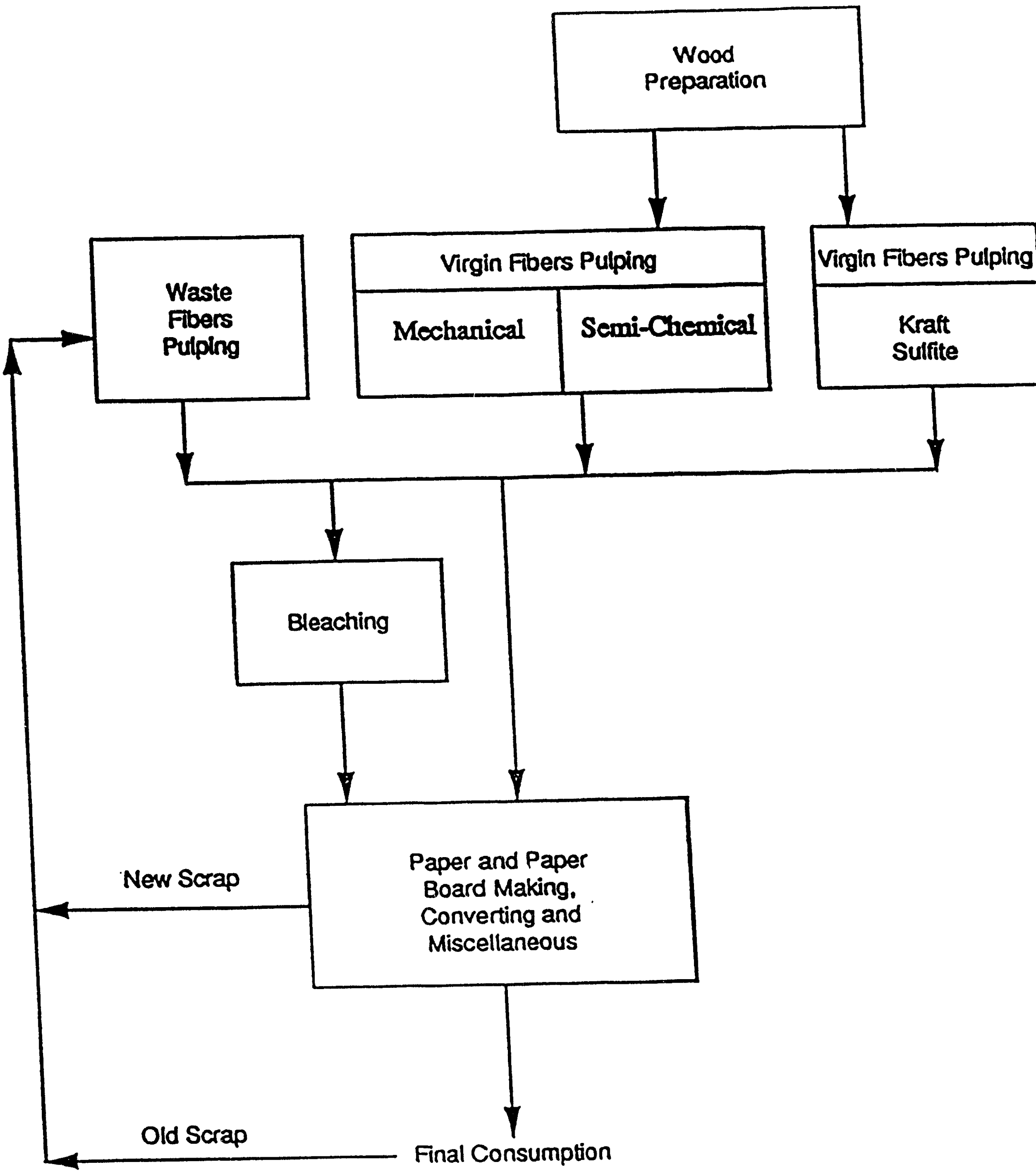


Figure 3. Paper and Allied Products Industry Process Flow



removed from the surrounding lignin. Pulping can be conducted with a chemical process (e.g., Kraft, sulfite) or a mechanical process. (In addition, a semi-chemical process is also available.) The pulping step also includes processes such as drying, liquor evaporation, effluent treatment and miscellaneous auxiliaries. Bleaching is required to produce white paper stock.

Paper and paperboard making takes the pulp from the above processes and makes the final paper and paper board products. The manufacturing operations after pulp production are similar for each of the paper end-products even though they have different desired characteristics imparted by the feedstocks (fibers furnished) and specific processes used, i.e. texture, strength, whiteness. The processes in the paper-making step include papermaking, converting/packaging, coating/redrying, effluent treatment and other miscellaneous processes.

In 1988, a total of 76 million tons of paper and paperboard products were produced. The major paper products include woodfree printing paper, groundwood printing paper, newsprint paper,tissue paper and packaging paper. The major paper board products include kraft paperboard, corrugating medium and recycled paperboard. Of the total 76 million tons of product, 62 percent were produced from kraft chemical process, 5 percent from semi-chemical, 25 percent from waste fibers and 8 percent from mechanical (groundwood). The average unit energy consumption estimated for this industry is slightly over 28 million Btu/ton of final product. The unit energy use estimates for this industry are provided in Table E-4, Appendix E. The largest component of this energy use is in the paper and paper board making process step and kraft pulping step, accounting for 40 percent each. The three types of kraft pulp (bleached, unbleached and market) were combined and presented as a weighted average. Use of recycled paper as the feedstock for the waste fiber pulping step was also taken into account.

Of the four pulping processes, it was assumed in the model that capacity additions would be in the following proportions: kraft pulping - 58.6 percent waste fiber pulping - 36.8 percent; semi-chemical pulping - 2.8 percent; and mechanical pulping - 1.7 percent [31]. The regional distribution for each technology is shown in Table E-17 in Appendix E.

Bulk Chemical Industry (SIC 281, 282, 286, and 287)

The bulk chemical sector is very complex. Industrial inorganics and industrial organics are the basic chemicals, while plastics, agricultural chemicals, and other chemicals are either intermediates or final products. The chemical industry is estimated to consume 21 percent (4.4 quadrillion Btu) of the total energy consumed in the manufacturing sector. This industry also is a major energy feedstock user and a major cogenerator of electricity.

The complexity of the bulk chemical industry, with its wide variety of products and use of energy as both a fuel and feedstock, has led to an end-use modeling approach. The unit energy consumption in the PA component for the bulk chemical industry is shown in Table E-5 in Appendix E. The end-use flow for the industry is shown in Figure 4. From an energy use viewpoint, four 3-digit SIC sectors dominate the bulk chemical industry:

SIC 281, Industrial Inorganic Chemicals;

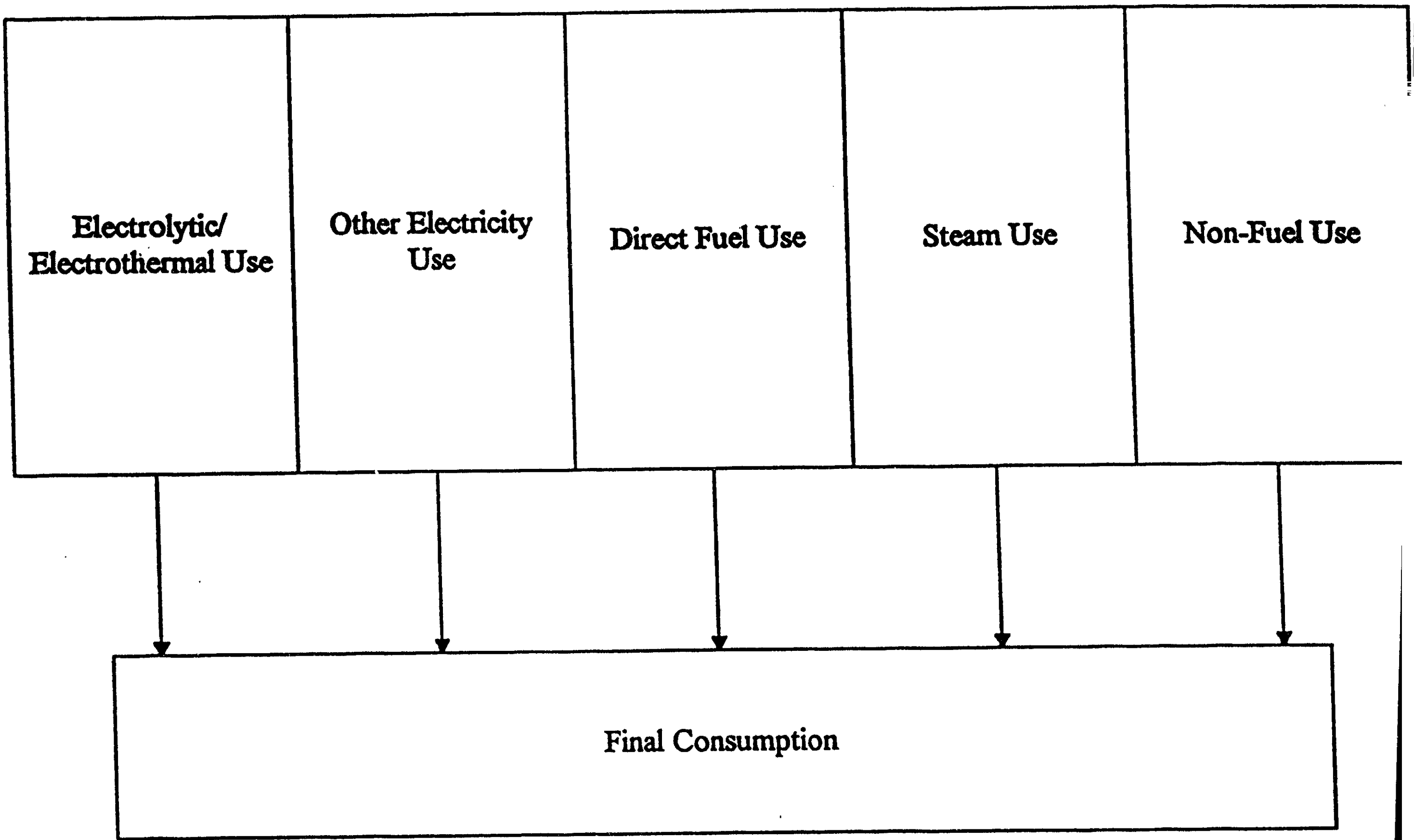
SIC 282, Plastic Materials and Resins;

SIC 286, Industrial Organic Chemicals, which can be produced from a variety of feedstocks; and

SIC 287, Agricultural Chemicals.

Of the 25 top energy consuming chemicals, five were inorganic chemicals. *Chemical and Engineering News* (4/90) listed four of these five substances among the top 50 for production in 1988. One hundred billion pounds of chlorine, sodium hydroxide, sodium carbonate (Trona,) and oxygen were produced in 1988 alone. Sulfuric acid and calcined gypsum were also produced in significant quantities (84.28 and 34.55 billion lbs, respectively) in 1988.

Figure 4. Bulk Chemical Industry End-Use Flow



These five chemicals alone accounted for the use of 507 trillion Btu in 1988, representing 32 percent of the chemical industry being studied. The energy consumption in the bulk chemicals industry was fairly evenly divided between the four major end uses. Steam made up 34 percent, electricity made up 24 percent and electrolytic and direct fuels each contributed 21 percent [31].

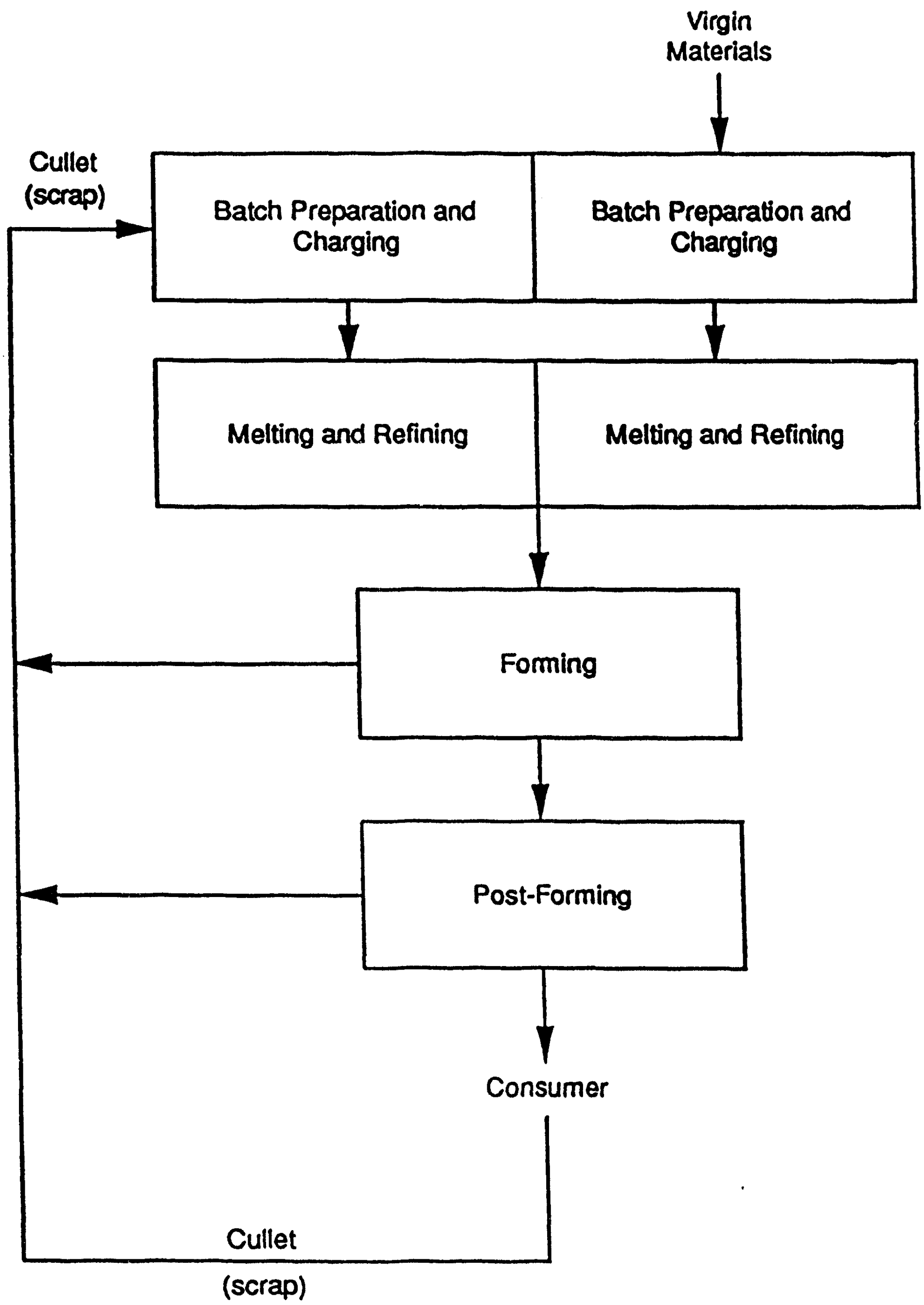
Glass and Glass Products Industry (SIC 321, 322, 323)

The energy use profile has been developed for the total glass and glass products industry, SIC 321, 322, and 323. The glassmaking process contains four process steps: batch preparation, melting/refining, forming and post-forming. Figure 5 provides an overview of the process steps involved in the glass and glass products industry. While scrap (cullet) and virgin materials are shown separately, this is done to separate energy requirements for scrap versus virgin material melting. In reality, glassmakers generally mix cullet with the virgin material.

In 1988, the glass and glass product industry produced approximately 19 million tons of glass products. As noted by the Department of Commerce, this 19 million tons consists of 4.3 million tons of flat glass, 10.8 million tons of container glass, 1.8 million tons of pressed and blown glass, and 2.4 million tons of fiberglass.

The glass and glass product industry consumed approximately 270 trillion Btus of energy in 1988 as identified in the *1988 Manufacturing Consumption Survey*. This accounts for 28 percent of the total energy consumed in the stone, clay and glass industry. The fuel consumed is predominantly for direct fuel use; there is very little steam raising. This direct fuel is used mainly in furnaces for melting. Table E-6 in Appendix E shows the unit energy consumption values for each process step. The unit consumption energy values are presented in MMBtu per ton of process step product.

Figure 5. Glass and Glass Products Industry Process Flow



Hydraulic Cement Industry (SIC 324)

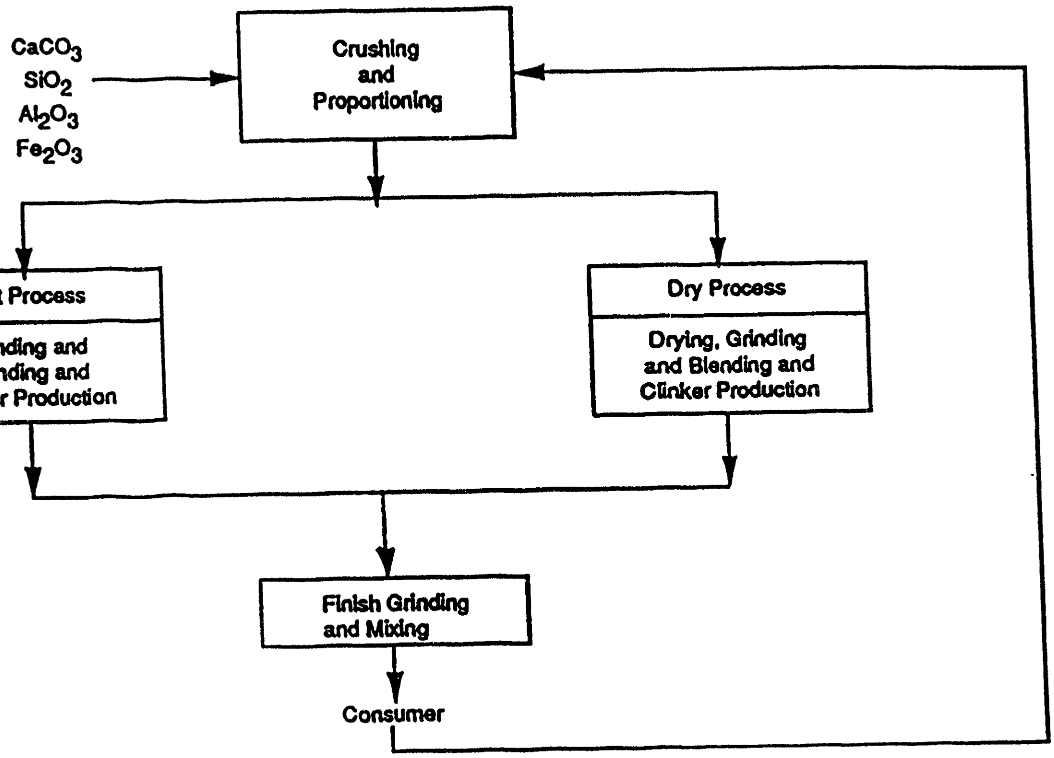
The hydraulic cement industry uses raw materials from quarrying and mining operations which are sent through crushing and grinding mills and then converted to clinker in the clinker producing step. This clinker is then ground to produce cement. The industry produces cement by two major processes: the long-wet process and the dry process. The dry process is less energy-intensive than the wet process. As a result, the long-wet process is obsolescent, and it is projected in the model that all new plants will be based on the dry process. Figure 6 provides an overview of the process steps involved in the hydraulic cement industry.

The Portland Cement Association noted that in 1988 the hydraulic cement industry produced 76.9 million tons of cement, of which 73.3 million or 95 percent was Portland cement with the remaining 3.6 million tons being masonry cement. Since cement is the primary binding ingredient in concrete mixtures, it is used in virtually all types of construction. As a result, the U.S. demand for cement is highly sensitive to the levels of construction activity. The wet process accounted for 34 percent of production, while the dry process accounted for about 60 percent, with the difference being accounted for by imported clinker (6 percent).

The hydraulic cement industry exhibits one of the highest unit energy consumption values (MMBtu/dollar value of output) in the U.S. industrial sector. The industry consumed approximately 454 trillion Btus of energy in 1988 as identified in the *1988 Manufacturing Consumption Survey*. This accounts for 47 percent of the energy consumed in the stone, clay and glass industry. Direct fuel, used in clinker-producing kilns, accounted for 89 percent of the total energy consumption, with the remaining 11 percent attributed to electricity. The electricity consumed is used to operate crushing and grinding equipment, materials handling equipment, machine drives and pumps and fans.

The wet process requires significantly larger amounts of energy which can be largely attributed to fuels used to dry the feed. While wet grinding is known to require less energy than dry

Figure 6. Hydraulic Cement Industry Process Flow



grinding, the entire wet process has longer kilns, requiring greater energy use than the dry process to drive them. Higher air flows, larger pollution control devices, and generally older facilities lead to slightly larger estimated electric energy use for the wet process.

The UEC values for each process in the hydraulic cement industry are shown in Table E-6, Appendix E. As noted previously, it is assumed that all new hydraulic cement capacity will be based on the dry process. The regional distribution of hydraulic cement production processes is presented in Table E-17 in Appendix E.

Blast Furnace and Basic Steel Products Industry (SIC 331, 332, etc.)

The blast furnace and basic steel products industry includes the following six major process steps:

Agglomeration;
Cokemaking;
Iron Making;
Steel Making;
Steelcasting; and
Steelforming.

Steel manufacturing plants can be divided into two major classifications: integrated and non-integrated. The classification is dependent upon the number of the above process steps that are performed in the facility. Integrated plants perform all the process steps, whereas non-integrated plants, in general, perform only the last three steps.

For the Industrial Demand Model, a process flow was developed to classify the above six process steps into the five process steps around which unit energy consumption values were estimated. Figure 7 shows the process flow diagram used for the analysis. The agglomeration step was not considered because it is not part of the SIC 33 (it is part of mining). Iron ore and coal are the basic raw materials which are used to produce iron. A simplified description of a very complex industry is provided below.

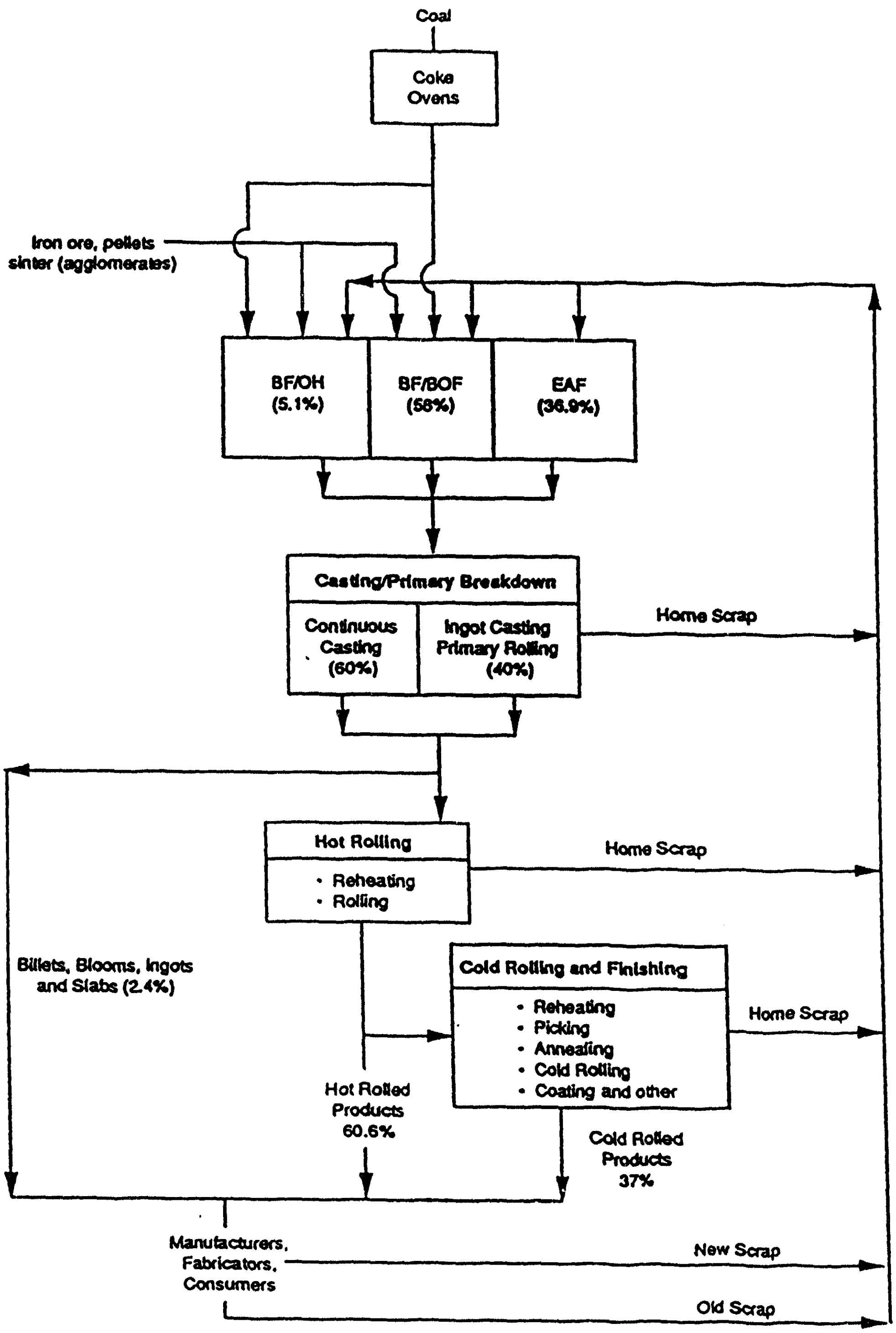
Iron is produced in the Blast Furnace (BF), which is then charged into a Basic Oxygen Furnace (BOF) or Open Hearth (OH) to produce raw steel. The OH now is becoming obsolete; however, it was used to some extent in 1988. The Electric Arc Furnace (EAF) is utilized to produce raw steel from an all steel scrap charge.

The raw steel is cast into ingots, blooms, billets or slabs, some of which are marketed directly (e.g., forging grade billets). The majority is further processed ("hot rolled") into various mill products. Some of these are sold as hot rolled mill products, while some are further cold rolled to impart surface finish or other desirable properties.

In 1988, the U.S. steel industry produced nearly 100 million tons of raw steel utilizing the BF/OH, BF/BOF and the EAF. Taking process yields into account, the total amount of product shipments was approximately 85 million tons. The EAF accounted for 37 percent of the raw steel production, whereas the BF/BOF accounted for 58 percent and the BF/OH for 5 percent. Continuous casting was utilized for 60 percent of the products, and ingot casting for 40 percent. Final consumption was made up of about 2.4 percent ingot, billets, blooms, and slabs, 37 percent cold rolled products, and 60.6 percent hot rolled products.

Table E-8 in Appendix E summarizes UEC estimates by process step and energy type for the blast furnace and basic steel products industry. The largest category for energy use is coal, followed by liquid and gas fuels. Coke ovens and blast furnace also generate a significant amount of byproduct fuels (denoted by a negative number in Table E-8) which are used throughout the steel plant. For the integrated producers, it is assumed in the model that all new

Figure 7. Blast Furnace and Basic Steel Products Industry Process Flow



NOTE: Percentages in boxes indicate market usage of process by estimated tonnage throughputs.

capacity additions will be the blast furnace/basic oxygen furnace technology; open hearth furnaces are obsolete and no new open hearths will be built. The regional distribution of steel-making technologies is presented in Table E-17, Appendix E.

Primary Aluminum Industry (SIC 3334)

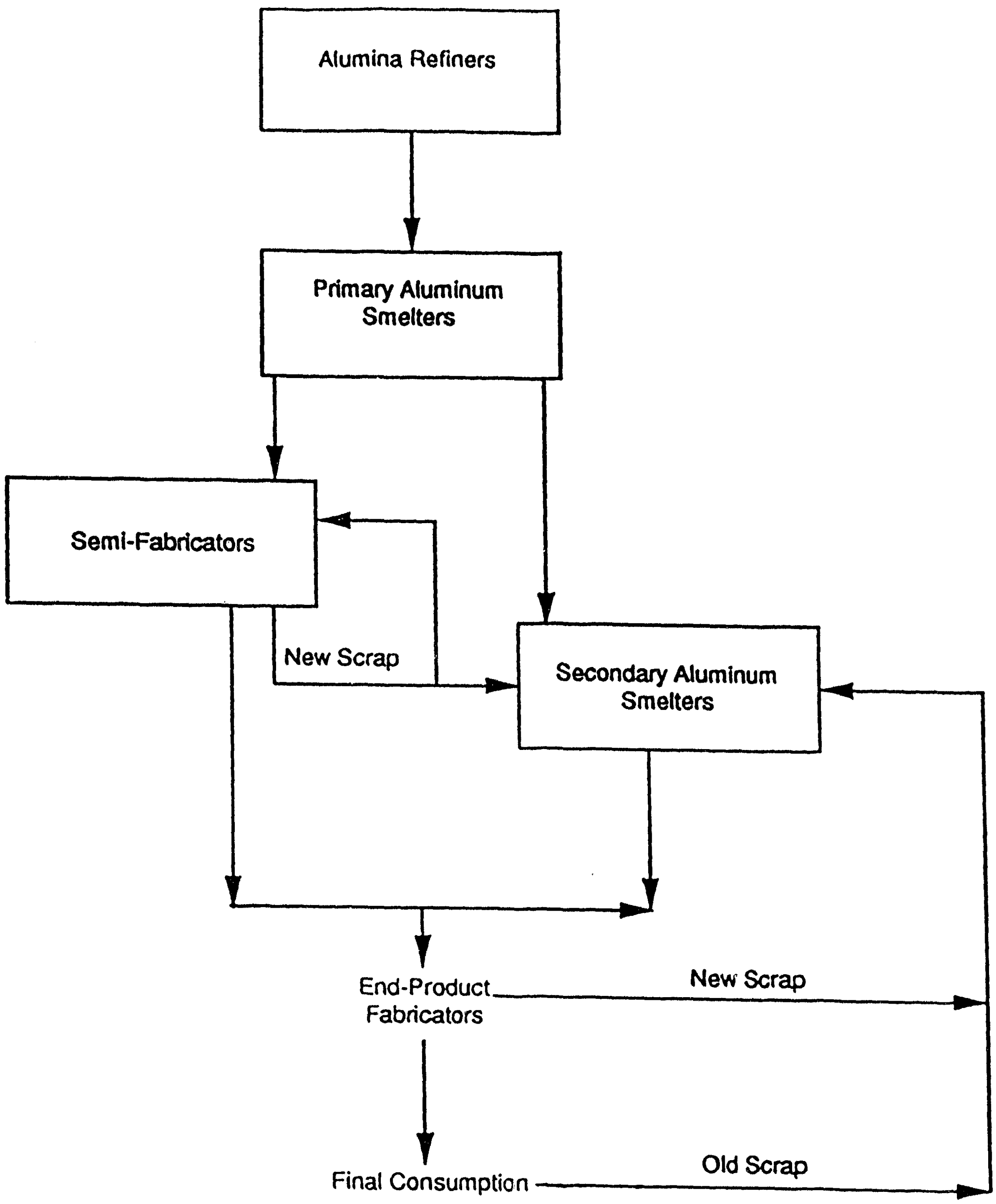
The U.S. primary aluminum industry consist of two majors sectors: the primary aluminum sector, which is largely dependent on imported bauxite and alumina as raw materials; and the secondary sector, which is largely dependent on the collection and processing of aluminum scrap. The primary and secondary aluminum industries generally cater to different markets. Traditionally, the primary industry bought little scrap and supplied wrought products, including sheet, plate and foil. The secondary industry is scrap-based and supplies foundries that produce die, permanent mold, and sand castings. In the past decade, the primary producers have been moving aggressively into recycling aluminum, especially used beverage cans, into wrought products. Figure 8 provides an overview of the process steps involved in the aluminum industry.

The primary aluminum industry modeled in the Industrial Model generally accounts for the energy used in SIC 3334, alumina refineries and primary aluminum smelters. In the future, the following SIC's will also be explicitly accounted for:

SIC 3353: Aluminum sheet, plate, and foil;
SIC 3354: Aluminum extruded products;
SIC 3355: Aluminum rolling and drawing, n.e.c.; and
SIC 3341: Secondary Aluminum.

Domestic aluminum production plus aluminum ingot imports resulted in about 6.6 million tons of semi-fabricated product shipments from U.S. plants. Secondary (scrap-based)

Figure 8. Primary Aluminum Industry Process Flow



operations added another 1.05 million tons. Total shipments were about 7.6 million tons. The primary industry produced approximately 4.3 million tons of aluminum products in 1988.

The UEC estimates developed around the process steps shown in the process flow diagram are presented in Table E-10 in Appendix E. As shown in the table, the alumina smelting process is the most energy-intensive of the four process steps. The primary form of energy used is electricity, which accounts for 58 percent of the total, with fuel accounting for 35 percent and steam accounting for 7 percent. The majority of the fuel for processing alumina and aluminum is used in kilns, furnaces and ovens. The regional distribution of smelters in the primary aluminum Industry is presented in Table E-17 in Appendix E.

Boiler, Steam, Cogeneration Component Share

The boiler, steam, cogeneration (BSC) component consumes energy to meet the steam demands from the other two components and to provide internally generated electricity to the buildings and process and assembly components. The boiler component consumes fuels and renewable energy to produce the steam and, in appropriate situations, cogenerate electricity. The subroutines and equations for the BSC component begin on page B-32 in Appendix B.

The boiler component is estimated to consume 44 percent of total industrial energy consumption. Within the BSC component, natural gas accounts for 35 percent, coal 14 percent, and petroleum products 8 percent. Most of the remainder (38 percent) is accounted for by waste or byproduct consumption. The basis of these estimates is Dun & Bradstreet's Major Industrial Plant Database (MIPD) for 1989. No other data from which to derive estimates exist for the BSC component. Estimates of 1990 BSC component shares are presented in Table E-10 in Appendix E.

The steam demand from the PA and BLD components is passed to the BSC component, which then applies a heat rate and fuel share elasticities to compute the required energy consumption. The heat rate is estimated from MECS and the MIPD. The fuel share elasticities for the BSC component are from [25], and are presented in Table E-11 in Appendix E. The estimates were used for both the energy-intensive and non-energy-intensive industries.

Cogeneration (the generation of electricity and steam) has been a standard practice in the industrial sector for many years. The cogeneration model within the Industrial Model is an econometrically estimated set of recursive equations in log-log form. The first equation relates on-site electricity generation to industrial steam demand. The second equation then relates industrial electricity generation for own use to total electricity generated.

Parameter estimates for the cogeneration model are based on regressions from a panel of pooled time series and cross sectional data. The data source is EIA Form EI-867, consisting of data from approximately 400 cogenerators over the years 1989 to 1991. The regression results are presented in Table E-16, Appendix E.

Technology Possibility Curves and Relative Energy Intensities

Future energy improvements were estimated for old (retrofit) and new processes/plants. The data used to determine the energy savings was obtained from:

- DOE reports;
- DOE memorandum - "Review of Industrial Technologies";
- Selected industry contacts;
- Arthur D. Little, Inc. in-house sources; and
- Other readily available data sources (included in the bibliography).

The energy improvements for old plants as a group consist of gradual improvements due to housekeeping/energy conservation measures, retrofit of selected technologies, and the closure of older facilities leaving the more efficient plants in the "operating pool". The energy savings for old processes/plants were estimated using data available in the above sources and engineering judgment on how much energy conservation savings were reasonably achievable in each industry. The estimated annual energy savings values for energy conservation measures are modest (up to 0.5 percent per year).

The above data sources also were used to estimate the unit energy consumption values for the state-of-the-art (SOA) and advanced technologies. SOA technologies are the latest proven technologies that are available at the time there is a commitment made to build a new plant. These values were then compared to the unit energy consumption values for 1988 to develop a relative energy intensity (REI). Relative energy intensity is defined as ratio of energy use in a new or advanced process compared to 1988 average energy use. Time frame estimates are also provided for when these improvements will take place (see Table E-12, Appendix E).

The savings shown in the appendix for the listed technologies represent savings over "average" 1988 energy use and SOA energy use. The latter increases are due to the gradual commercialization of advanced technologies. Advanced technologies are ones which are still under development and will be available at some time in the future. Where a range is shown for the savings, it was assumed that the lower end of the savings range would start to be realized in the beginning of the time frame, the midpoint of the savings would be realized at the end of the time frame, and the upper end of the savings range would not be realized until 10 or more years after the time frame shown. An energy savings range is most often given when multiple technologies will be becoming available in the future for the same process step or product line. The savings range represents engineering judgment of the most likely achievable savings. In these instances, it is uncertain which specific technologies will be implemented, but it is reasonably certain that at least one of these technologies or a similar technology is likely to be successful. It is also recognized that in some instances thermodynamic limits are being approached which will prevent further significant improvements in energy savings.

The improvements for new plants assumes the plant has been built with the SOA technologies available for that process. SOA technologies are the latest proven technologies that are available at the time there is a commitment made to build the plant. A second and often more important set of substantial improvements are often realized when advanced technologies become available for a certain process. Often one sees a number of technologies being developed and it is difficult to ascertain which specific technologies will be successful. Some judgment is necessary as to the potential for energy savings and the likelihood for such savings to be achieved. All the energy improvement values are based on 1988 energy usage.

Additionally, even SOA technologies and advanced technologies can at times be expected to show improvements once developed as the process is debottlenecked, optimal residence times and temperatures are found, and better energy recovery techniques are installed. Depending on the process, these are factored into the projections as slow improvements ranging from zero to about 0.5 percent/year. However, once a process is installed in a new plant, it is assumed that its energy use per unit of output remains constant. Old plants, however, are assumed to be able to economically justify some retrofits and for other reasons listed above, to show slow improvements over time in their unit energy use. Based on engineering judgment, it is assumed that by 2015, old processes (1988 stock) still operating can achieve up to 50 percent of the energy savings of SOA technology [31]. Thus, if SOA technology has an REI of 0.80, old processes in the year 2015 will have an REI of 0.90.

With a few exceptions (noted as appropriate in Appendix E), it was assumed that the REI for all energy sources decrease in proportion to the total. Thus, if the total REI for a new technology is 0.90, it was assumed that the relative energy intensity for natural gas, oil, coal, or electricity are all 0.9. When the new technology uses a very different energy mix than the existing technology, it is so noted.

The methodology described above was applied by Arthur D. Little , Inc. The initial results for a process step in an industry consist of a scatter of points where the Y-axis is the REI and the X-axis is time from 1990 to 2015. Thus, the scatter might indicate that the REI is 0.9 in 1997, 0.8 in 1999, and 0.5 in 2007. As a convenience for modeling purposes, a least squares line was fitted through these points (using natural logarithms) so that the resulting slope coefficient (i.e., the TPC) could be used rather than a step function. (The TPCs are given in Appendix E. However, since there is no particular meaning to measures of fit for this exercise, they are not given in Appendix E.)

Table E-13 in Appendix E lists the REI's for old and new plants, by process step, for the seven energy-intensive industries. The REI is defined as the ratio of energy use in a new or advanced process compared to the 1988 old plant average energy use which has been normalized to a value of 1.0. The list of SOA and advanced technologies considered in the analysis is presented in Table E-12, Appendix E.

Where the relative amounts of different energy sources changes with time, a separate equation was estimated for each energy source. The procedure for calculating UEC's over time includes establishing the energy sources used as a fraction of the total for each process step, as shown in Table E-14 in Appendix E.

Assumptions

Capital Stock and Vintaging

Industrial energy consumption is affected by increased energy efficiency in new and old plants, the growth rate of the industry, and the retirement rate for old plants. The efficiency changes are captured in the β_i estimated in equation 2, and the rate of growth is given by the

Macroeconomic module. (Retirement rates from the Census Bureau and vintaging information are very sketchy.) At present, the capital stock is grouped into three vintages: old, middle, and new. The old vintage consists of capital in production prior to 1991 and is assumed to retire at a fixed rate each year. Middle vintage capital is that which is added from 1991 through the lag of the forecast year. New production is added in the forecast years when existing production is less than the output forecasted by the NEMS Regional Macroeconomic Model. Capital additions during the forecast horizon are retired in subsequent years at the same rate as the pre-1991 capital stock. The retirement rates used in the Industrial Model for the various industries are listed in Table E-18 in Appendix E.

Renewable Fuels

Renewable fuels are modeled in the same manner as all other fuels in the industrial model. Renewable fuels are modeled both in the PA component and the BSC component. The primary renewable fuels consumed in the industrial sector are pulping liquor, a byproduct of the chemical pulp process in the paper industry, and wood. Hydropower is also modeled in the industrial model, while geothermal, solar thermal, photovoltaic, wind and municipal solid waste are estimated in the NEMS Renewable Energy Module.

Recycling

With projected higher landfill costs, regulatory emphasis on recycling, and potential cost savings, recycling of post-consumer scrap is likely to grow. Projecting such growth, however, is highly dependent on assessing how regulations will be developed, the growth of the economy, and quality related issues dealing with recycled materials. To assess the potential for recycling in the industrial sector, industry experts were canvassed to obtain the best judgment on the future of recycling for the Paper and Allied Products and Blast Furnace and Basic Steel Products industries. The estimates obtained for these industries are shown in Table E-19 in Appendix E.

Legislative Implications

The Energy Policy Act of 1992 (EPACT) and the Clean Air Act Amendments of 1990 (CAA) contain several implications for the industrial model. These implications fall into three categories: coke oven standards, efficiency standards for boilers, furnaces and electric motors, and industrial process technologies. The industrial model assumes the leakage standards for coke oven doors do not reduce the efficiency of producing coke, or increase unit energy consumption. The industrial model uses heat rates of 1.25 (80 percent efficiency) and 1.22 (82 percent efficiency) for gas and oil burners respectively [32]. These efficiencies meet the EPACT standards. The standards for electric motors call for an increase of 10 percent efficiency. The industrial model incorporates a 10 percent savings for SOA motors increasing to 20 percent savings in 2015. Given the time lag in the legislation and the expected lifetime of electric motors, no further adjustments are necessary to meet the EPACT standards for electric motors. The industrial model incorporates the necessary reductions in unit energy consumption for the energy-intensive industries.

Emissions

Industrial emissions are modeled for total carbon. The emissions factors [43] that are utilized to compute the emissions levels are consistent with those used throughout NEMS. The factors are assumed to be constant throughout the forecast horizon. The carbon emission factors used in the model are presented in Table E-20 in Appendix E.

Fuel Switching

In the Industrial Model, seasonal fuel switching is not considered because it is an annual model. Most observable fuel switching is seasonal and is difficult or impossible to detect with annual data. In the BSC component, all natural gas consumption is interruptible, i.e., switchable. Presumably, most of the switching that occurs here is seasonal and unobservable with annual data and prices. Fuel switching is implemented in the model by allowing the share of fuels in existing boilers to shift based on the short-run fuel share elasticities discussed above.

Benchmarking

The 1990 Industrial Model energy demand forecasts are benchmarked to actual 1990 and 1991 State Energy Data System (SEDS) values to ensure that the model forecasts for 1990 coincides with the SEDS consumption data. The benchmark factors are based on the ratio of the SEDS value of consumption for each fuel to the consumption calculated by the model at the census division level. (The average of the benchmark factors for 1990 and 1991 is applied to all future years.) The difference in energy consumption between the benchmarked consumption and forecasted model consumption is accounted for in the "Other Industry" category. Benchmarking is accomplished in Subroutine IBSEDS, described on page 120.

Alternative Approaches

This section discusses the previous EIA industrial model, as well as other industrial modeling approaches that are currently in use or have been recommended for use at EIA.

Previous EIA Industrial Model

The previous EIA industrial model used an econometric approach based on historical patterns of individual fuel and electricity uses in a variety of manufacturing and nonmanufacturing industries [44]. When the model was originally constructed, the time frame of the forecasting was for the next 10 years and provided the appropriate requirements. These requirements consisted primarily of forecasting and not of policy and technology analysis. Subsequently, the forecasting time frame was extended to 20 years and the econometric modeling approach became less appropriate.

The Intermediate Future Forecasting System (IFFS) industrial model estimates the consumption of each fuel or electricity in each of 11 industries independently, by using historical data from the period 1958 through 1985. Each of these energy consumption equations uses independent variables consisting of value of industry output, energy prices, and the lagged (one time period) level of energy consumption. For a relatively short forecast period of time, these equations can perform very well. However, they are lacking in substitution effects, not only in terms of the overall production function and the factor inputs of capital, labor and materials, but also in terms of substitution between various forms of energy. In general, the price estimations did not provide for significant cross price coefficients. In addition, the equations were estimated in log-linear transformations which can cause problems in a long-term forecast. Moreover, the lagged consumption terms can cause accumulating problems if they start going off on the wrong track. One further difficulty with the IFFS model is the insufficient ability of the model to address and assess new policies and/or issues and discrete changes in industry.

The primary advantages of the NEMS model are that:

- The model uses all available data and at the industry specific level as much as possible.

- The model is sensitive in expected directions and degrees to changes in energy prices and to changes in the level of industry output.

- The model equations are directly explainable and understandable and the relationships are straightforward and intuitive.

The model also includes additional algorithms or inputs for nonutility generation of electricity, consumption of renewable energy, and calibration and benchmarking.

Other Approaches to Modeling Industrial Energy Consumption

A variety of models are used to provide energy forecasts of one type or another in the industrial sector. Many of these models are not exclusively industrial models, but rather are macroeconomic models that pay particular attention to energy and to energy consumption sectors. Most industrial sector energy models can be categorized according to certain general characteristics. Several categories are shown in Table 3. These categories identify whether the model is (1) a basic econometric model, (2) an hybrid econometric model with technology and/or process information, (3) an hybrid accounting model with economic relationships and with technology and/or process information, (4) an industry process model with economic relationships, (5) an interindustry and/or macroeconomic model, or (6) an input-output model. The categories are a very rough description of the content of the models and may not be very satisfactory in all cases. Not all these categories are clearly defined and some models may overlap portions of several categories.

Table 3. Other Industrial Energy Models

Basic Econometric

PC-IM (IFFS EIA Model)

PURHAPS Model (Former EIA Model)

INDEPTH Level 1 (EPRI)

Hybrid Econometric

DEMO-PSM

INRAD (Argonne)

LIEF (Marc Ross and Roland Hwang)

Hybrid Accounting

FOSSIL-1 and FOSSIL-2 (AES)

Peck/Bosch/Weyant Vintage Model

Industry Process

INDEPTH Level 2 (EPRI)

ISTUM-1, ISTUM-2 and ISTUM-PC

ICE and IFCAM (EEA)

ORIM (Oak Ridge)

Interindustry/Macroeconomic

Data Resources, Inc. (also Wharton Econometrics)

Hudson/Jorgenson (also Jorgenson/Wilcoxen DGEM)

Input/Output

LIFT (INFORUM at University of Maryland)

Energy Indexes (Short-term analysis)

The hybrid econometric and hybrid accounting types of models are those of most interest for the EIA industrial sector modeling. In most of the cases, the models that are discussed represent only the manufacturing sector part of the industrial sector. There are not many established models that have been created to model energy use in the agriculture, mining and/or construction industries (one notable exception is the ISTUM model).

Each of these models has its own particular approach to modeling industrial energy consumption (several use similar approaches). The approaches used and their advantages and disadvantages are discussed below. It should be kept in mind that the overall objective here is to determine the appropriate approach to be used in the new EIA industrial energy model. To that end, there are a number of unstated criteria and objectives that will be implied in the discussion. In addition, each model is discussed only in terms of what can be learned from it with respect to designing the modeling approach here at EIA.

Energy Intensity Indexes

The most basic approach to modeling industrial energy consumption consists of using an index of energy consumption relative to value of output (an index of energy intensity). This approach can be extended by including prices in the index. This approach can be very useful in the very short term, in a period of time when industry structure, the production function and processes and technologies are fixed. Industry consumption changes at essentially the rate of industry output.

Individual Econometric Energy Equations

On the other hand, over a longer period of time, the relationship between energy consumption and industry output does not remain constant. The changing relationship can be modeled with the use of estimated coefficients. The IFFS industrial model is an example of this approach [44]. In this case, an equation is estimated over historical data, and it identifies a relationship between energy consumption for a single fuel and the value of output in the industry and energy prices. The equation can be specified in a variety of ways and estimated using a number of tools including ordinary least squares, two-stage least squares, or seemingly-unrelated regression. The equation can include a time-trend or lagged endogenous variable to represent technology trends and capital stock adjustments. However, no matter what is done, the equation still represents the circumstances over the historical period and is not necessarily appropriate for a longer-term forecast. It depends upon the extent to which it is assumed that the equation is specified properly, that data are not missing, that the data used in the estimation is good and appropriate, and that the future relationships will remain the same as in the historical period. Moreover, the equation does not capture the production function relationships that economic theory assigns such a high value.

Production Function Based Econometric Models

A wide variety of industrial models are based upon the idea of a production function or its dual, a cost function, and run the gamut from single industry models to economy-wide models. A previous EIA model, PURHAPS, is one example of this type of approach [40]. The PURHAPS model looked at the production function in an implicit manner, modeling the factor share for energy based upon the prices of all the factors, a technology trend and lagged prices of energy.

The production function in these models can be specified in a wide variety of ways, with alternate considerations concerning the relationships among the factor shares. Equation 4 shows the basic form for a production function. The basic relationship is that for a two-factor production function in which the output is a function of inputs of capital and labor. This basic relationship can be extended to other factors of production, such as materials and other variables which may or may not be specified, such as technology.

$$q = f(v_1,...,v_n) \qquad (3)$$

where: q is the production level, and

v_i are factor usages.

The primary idea behind the production function is that production occurs according to some technical production "recipe", in which "factors" of production are brought together to produce output. There are certain engineering relationships among the variables that allow them to be brought together in an efficient manner to produce the product. It is important to note that the production function, as typically explained, is a micro concept. It applies to the technical relationships within the smallest economic units, such as small, well-defined processes. There are often significant problems when the concept is taken to a more aggregate level, such as an aggregate process, a firm, a plant or an industry [50].

The production function provides a technical relationship and the cost function that is the dual to the production function provides the economic relationship. An example of a cost function is shown in equation 5. The economic objective of the firm is to minimize this cost function.

$$TC = P_1 v_1 + \ldots + P_n v_n \tag{4}$$

where: TC is total cost,
P_i are factor prices, and
v_i are factor usages.

Using a variety of mathematical forms, the relationships among the capital, labor, and materials variables in the production function can be specified in various ways with their specific characteristics. There are a variety of standard forms for production functions that have been used at various times throughout the literature (for discussions, see [31], [50], [85]). Some of the more prominent of these major variations include the original Cobb-Douglas, which is a special case of a more general class of production functions, the Constant Elasticity of

Substitution (CES) production functions. Following from these are the Translog [24] and the Generalized Leontief [33].

The total energy equation (the primary equation) in the PURHAPS model (as noted above) is basically a cost function. It assumes that production will be organized in an efficient manner, so that any one factor (energy in this case) can be solved for based upon the relative prices of all the factors of production. This is a common and reasonable assumption. The two major assumptions being made are that the substitution relationships among factor prices remain constant and that the factors are homogeneous enough so that they can be categorized in an aggregate fashion. In practical terms, the assumptions are also being made that the equations properly specify the relationships (missing or misspecified variables), that the coefficients from the historical estimations represent the future and that the exogenous forecasts upon which the forecast is based are good.

The Danish Production Sector Model uses a number of hybrid features [71], including the use of a vintage approach to address the path of adjustment and the modeling of detailed decision making chains (a systems dynamics approach) for each of the factors of production including capital and labor. The model uses a production function approach but uses only capital and labor in the production function (along with a technology time trend) and identifies a type of capital used for energy conservation.

The INDEPTH (Industrial End-Use Planning Methodology) Level 1 models [63] consist of a series of industrial energy models for individual manufacturing industries. For each of the manufacturing industries, alternative standard econometric approaches for modeling energy consumption using a production function are used. The INDEPTH Level 1 models were developed for the Electric Power Research Institute (EPRI) for the use of the EPRI member utilities in assessing the extent and nature of the utilities' industrial electricity demand. For this reason, the models are schematics into which the member utilities can insert the particular details and data of their own industrial demand. In addition, the emphasis of the models is on the modeling of electricity energy demand. In the alternative INDEPTH formulations, the detailed information contained in the firm's production function and explicit cost minimization calculations is summarized by two functions. These are the cost function and the factor demand equations (from the production function). These empirical equations implicitly reflect the decisions that go into equipment choices and production processes as input prices and output demand change. As in econometric models of this type, there is no explicit accounting for the equipment and processes. The relationships are estimated over historical data. The advantages are that the models are rooted in good economic theory and that they can be estimated directly from historical data (although there are some problems with the availability of data). The disadvantages are that the relationships could not be valid too far into the future and that there is no explicit treatment of capital adjustment (vintages) or of technology.

Interindustry and/or Macroeconomic Models

A series of models continue to implement the production function approach but extend the modeling out beyond the boundaries of the industrial sector in order to cover all of the interactions among the entire economy. There are a number of approaches that can be used to do this, but an overriding characteristic is that the models capture some sense of the flows of economic activity from one sector to another. (A "sector" is being used as a general term indicating anything from large entities such as households, government and business, to small entities such as specific industries or types of households.) These can be explicit material flows or accounting for expenditures or payments between sectors.[4] These are not explicitly industrial models, but rather have an industrial sector (or sectors) as parts of the model. Another

[4] These models can range from small, less than 10-equation models, to very large and detailed models with large numbers of sectors with a thousand or more equations. In the context of this paper, however, the emphasis is primarily upon those models which pay some attention to the industrial sector as a distinct entity. Obviously, there is always more detail that can be added to these models, for example regional flows and as economies become more international in scope, international flows.

overriding characteristic is that these models attempt to solve for a economy-wide general economic equilibrium.

There are analogues relating to the sectoral interrelationships and the equilibrium modeling between these models and the IFFS [44]. The IFFS is designed as an energy model, so the sectors consist of energy sectors, rather than overall economic sectors. The interactions between the sectors in IFFS are in terms of energy flows, while that in the macroeconomic and interindustry models are in terms of overall economic activity and/or materials flows (of which energy could be one). Since the overall interest in IFFS is in energy activity, the economy is modeled as a separate sector. In the macroeconomic and interindustry models, there is no real distinction made between the economic sectors and other sectors; it is all one piece and simultaneous. Consequently, the equilibrium in the macroeconomic and interindustry models is theoretically represented as a true, general equilibrium (although it could be imperfectly represented). The equilibrium in IFFS is an approximation to a general equilibrium solution, to the extent that the macroeconomic sector is capturing the interindustry flows that are implied in all the energy sectors. This is a reasonable representation in the mid-term, but as the time horizon extends and industry structure changes in significant ways, there may be some difficulties with its representation as a general equilibrium solution. Because of these overall linkages, it would be difficult to separate the industrial energy sector from the overall macroeconomic or interindustry model in a sensible fashion.[5] There are also difficulties in the other "direction" of trying to use the economic portion of an overall macroeconomic or interindustry model (particularly for the interindustry model) as the economic module in an energy system such as IFFS or the NEMS system.

[5] A distinction is made between the industrial energy sector and the overall industrial sector economy. At EIA, when we refer to the industrial sector, we are referring to the energy activity. The overall industrial sector economy is a much more extensive and complex entity, consisting of not only energy and energy processes, but all capital, labor and materials decision making that go with it.

The Data Resources, Inc. (DRI) model is a good example of a macroeconomic model and it is currently being used in EIA for economic modeling. This model is based upon the equilibrium between the production-side and consumption-side expenditures in the economy along with (hundreds of) equations that provide significant relationships among the sectors. Another example is the macroeconomic model of Wharton Econometrics. The industrial sector in each of these models lacks detail, especially for energy.

The Hudson/Jorgensen model and the Jorgensen/Wilcoxen Dynamic General Equilibrium Model (DGEM) both have much more detailed industrial sectors which are based quite explicitly upon a production function/cost function approach. There are several industries represented, with production functions based upon flows of capital, labor, materials and energy. One primary characteristic of these models is the interdependence among the sectors (or industries) in the economy. Although these models have more detail, they are not strictly energy models and typically energy is a small part of the model. In addition, these models do not use any explicit representations of how energy is used, but rather rely upon the simplifying concept of aggregate production functions along with other simplifying assumptions relating to full employment and the substitutability of factors of production.

Input-Output Models

An input-output model is distinguished by the accounting for the flows of outputs from one industry to be used as inputs in other industries. Because of this interindustry dependence, any set of "correct" output flows from industry must be the same as all the input requirements in the economy (including to other sectors and outside the economy). Technically, the input-output analysis is not a general equilibrium analysis because although the interdependence of the various industries and the correct flow of product is the critical factor, this satisfies the technical relationships rather than the market based relationships. Additional cost factors can be brought into the analysis to solve for a general equilibrium. Typically, there are also simplifying assumptions that must be made for the input-output analysis, including that each industry produces homogeneous products, industries use fixed input ratios and production in each industry is subject to constant returns to scale.

The Long-term Interindustry Forecasting Tool (LIFT) from INFORUM at the University of Maryland [57] is a hybrid of a large macroeconomic model and a 78-sector input-output model. This provides for a theoretically satisfying general economic equilibrium along with the technical relationships for the flows among industries. This model is mentioned here because there has been some interest in using features from it for the macroeconomic modeling at EIA. The difficulty would be in separating out the macroeconomic part of the model from the energy parts for all the sectors (residential, commercial, transportation and industrial) including the energy production and conversion sectors. As has been discussed earlier, the separation which is made at EIA is somewhat artificial, but useful so that a great deal of detail can be built into the energy aspects of demand and supply. In reality, these are simultaneous and therefore it is difficult to separate them in a model like LIFT which has been built with them together.

Industrial Process Models

Industrial process models generally take a bottom-up approach to modeling energy use in the industrial sector. Individual processes, technologies or equipment are represented in the model. In the forecast, as new processes, technologies or equipment are to be added to the capital base, the model makes choices from among various options by competing the processes, technologies or equipment on an economic basis. There are a number of difficulties associated with building a process model for models for the entire industrial sector, the first of which is that they require vast amounts of knowledge and resources. The resources have simply not been available nor are they expected to become available. In some cases, the approach has been to consider a process model for only a specific industry or for a specific energy source. In addition, the extensiveness of these models make them very complex so that they are not typically accessible or transparent. The common developmental approach is to have experts with engineering backgrounds do a variety of studies to determine the various current and potential processes, technologies or equipment and to characterize each with a variety of economic factors such as capital cost, operating costs, maintenance costs, energy costs, lifetime, and others. These characteristics are used in various algorithms to make choices among the processes based upon economic decision making rules.

However, the industrial sector is very complex and capital stock decisions are made with a wide variety of motivations; these are the subject of much of the entire field of industrial organization in economics (see [85] for a discussion of this and several of the following points). A simple minimization of life-cycle cost may not be an appropriate rule. Moreover, there can be any number of other attributes associated with the process, technology or equipment that are externalities in the decision process or which are more important than the strictly economic variables. It may be more straightforward to characterize the decision making rules in an energy industry such as electric utilities, where the product is much more homogeneous, knowledge is and has been more available, the processes, technologies or equipment are better understood and in many cases a public utility commission mandates the rules to be used in decision making.

An additional difficulty in the industrial sector is that there is no clear way to know whether the characterization of the future processes, technologies and equipment has captured all possibilities. The characterization may be imperfect with respect to the processes available for competition or with respect to the attributes associated with that process. This can be a very significant problem and can imply that any error associated with this means that there really is no need to fine-tune anything else. It has been suggested that this is a common error and that it will typically cause the model to underestimate the potential for conservation of energy [85].

Another problem with using a process model to model energy is that energy is usually a small part of the capital choice decision. Even in some energy-intensive industries, energy can still be only a small part of the capital choice decision. For example, it has been suggested that the penetration of continuous casting in the blast furnace and basic steel products industry, which saves very large amounts of energy, was motivated not by the desire to save industrial energy, but by the opportunity it provides for quality control. Another example is that future movements away from chemical pulping to mechanical pulping in the paper industry are not driven by energy economics but by environmental considerations. This choice also largely drives the extent of renewables consumption in the paper industry, because the single largest category of renewables is pulping liquor from the chemical pulping process. Recycling in the paper industry also has a significant influence upon the pulping process choices and on the amount of bleaching. Even if all the economic attributes of the processes could be determined, strict life-cycle costing does not capture all these non-economic considerations in an economic algorithm.

It is also difficult to assess the quality of the details of a process model, because there is typically no information about the details beyond the data that was put together for the model. The model can be assessed on an overall basis, but this does not provide any insight on whether the extra details have helped to provide better forecasts. Other models that are constructed on an overall basis can also provide forecasts. In general, an assessment of the 1977 ISTUM-1 model at a fairly aggregate level over the period 1977 to 1990 did not seem to indicate that the model performed particularly well, even on an overall basis.[6]

The ISTUM model is an industrial process-level model which was developed in the mid to late 1970's [38]. The model is very large and extensive and requires a vast data base of technologies. The original development effort was over an extended period of time and at least one stage utilized the equivalent of about two dozen full-time personnel. ISTUM is the seminal industrial process model and is perhaps the best known. Parts of ISTUM have been updated in various ways (the details are not clear) by Energy and Environmental Analysis, Inc. (EEA) into ISTUM-2 [37] and they occasionally run the model for various analyses, primarily for an annual forecast by the Gas Research Institute. Some industries in ISTUM have been redone for use on

[6] The 1977 ISTUM model that begins forecasting in 1977 (its base year is 1976) was acquired by this office and was run over the historical period to 1990 using historical prices and historical level of output. The results were mixed.

the IBM PC, most notably the paper industry in British Columbia, Canada [58]. It is not anticipated that ISTUM would be used directly for the new EIA industrial model, but some of the detail that is available in ISTUM might be used to help provide information for the new EIA model.

The INDEPTH Level 2 model is also an industrial process-level model and was developed for the EPRI [28, 36]. It consists of an extremely detailed examination of 25 principal industrial production processes and the activities that make up each process. The model was developed with the intention that it would be used by electric utilities interested in how the introduction of new technologies and production processes would affect the electricity demand of their manufacturing clients. Along these lines, the model does not attempt to provide coverage for all of the manufacturing sector industries at a national level, nor does it pay significant attention to modeling other than for electricity. While the INDEPTH Level 2 model could be used to represent an industry, it is so process-specific that the most likely use would be to model actual or idealized plants operated by an electric utility's customers. The INDEPTH system has never received a high degree of acceptance among utility planning staffs as the EPRI residential and commercial models have. In part this may have been because most utilities had developed other in-house modeling approaches to forecasting industrial demand, and in part it may have been due to the cumbersome data requirements that are needed to do justice to the INDEPTH system's full capabilities.[7]

Apparently, the INDEPTH models are being phased out by EPRI and a set of industrial end-use models named INFORM, developed by Regional Economic Research, Inc. (RER) for EPRI, are being used instead. The model's end uses include motors, process heating, process drying and curing, melting, welding and cutting, electrolytic processes, lighting, HVAC and miscellaneous. For each end use, INFORM examines three sets of market decisions. These are fuel and

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[7] This information is based on the DAC report referred to above. Apparently, both INDEPTH Level 1 and INDEPTH Level 2 models have been used by only 3 utilities with only 1 significant user of Level 2.

technology decisions, which determine market shares; efficiency choices, which account for competition among efficiency options; and usage levels, which reflect production levels.

The Oak Ridge Industrial Model (ORIM) [83, 84], the Industrial Combustion Emissions (ICE) and the IFCAM models are older, process-type models that actually use a lot of hybrid features. They are apparently not being currently used. ORIM uses a mix of features of both top-down and bottom-up models, dealing with very generic energy services, manufacturing services and technologies. Although the technologies are generic, the data requirements are still extensive. The model also uses a vintage accounting structure. The Industrial Regional Activity and Energy Demand Model (INRAD) was used by Argonne National Laboratory to model industrial activity and energy demand for the National Acid Precipitation Assessment Program (NAPAP) studies [15].

Hybrid Econometric and Hybrid Accounting Models

This class of models is expected to have the most relevance to the new EIA industrial model. They consist of various equations and relationships that are implemented on an accounting structure.

The Long-Term Industrial Energy Forecasting (LIEF) model has been in development over the last few years [85]. There are several characteristics of this new model which strongly influenced the development of the new EIA industrial model (LIEF covers only the manufacturing sector). The first task of this model is to properly disaggregate the manufacturing sector according to output growth rates and energy intensities so that the way that energy is used can be properly accounted for. The point is made that disaggregation into the 2-digit SICs is not satisfactory for long-term forecasting. The problem is not that there are too few 2-digit sectors, but that they are improperly aggregated for energy analysis. The idea is to reorganize the manufacturing sector into 4 to 10 sectors based upon energy intensity and output growth rates (the current version is organized into 4 sectors).

The long-term, real energy intensity forecasting technique used by LIEF rests on a sequence of three major decision areas: 1) the choice of the fundamental production process, which is autonomous in the sense that it is not sensitive to energy prices, 2) the choice of energy-related technologies which are sensitive to energy price, and 3) the operational decisions which are more of a short-term nature and not of interest in long-term forecasting. The choice of energy-related technologies in the model uses the conservation supply curve (CSC) as the basic analytical tool. However, the procedures used to estimate or characterize the CSC relationship are not based upon detailed lists of technologies, but rather are based on statistical estimation. In this forecasting sequence, the model uses variables other than price, which provide useful policy-analysis handles. Sectoral energy intensities are principally related to autonomous (price-independent) time trends, and to energy prices, implicit capital recovery factors, slope and intercept parameters for the CSCs and the rate of penetration of conservation technologies.

The NEMS Industrial Demand Model shares the concern with the proper disaggregation and accounting for energy use in the industrial sector. In addition, the model shares and borrows from major concepts, including the idea that choice of fundamental process change is autonomous (not price related) and the use of a conservation supply curve or something similar for energy intensity changes that is not necessarily built up from a detailed list of technologies. The basic model equation also recognizes the distinction between energy consumed in new equipment versus that of existing equipment and this basic idea is expected to be extended in the EIA model with a full vintage structure. Finally, it is desired that the overall feeling of accessibility, transparency and familiarity that the authors associate with LIEF, will also be associated with the EIA industrial model.

The industrial energy demand model described in [78] is a relatively straightforward structural representation for industrial energy use. The primary features of the model are that it is based on production-function-like concepts (explicitly considering the prices of all input factors), considers the long-term substitution potential between fossil fuels and electricity (using relative prices) and incorporates vintaging of the existing capital stock in making energy consumption decisions. The model has been exercised and estimated for the primary metals industry based upon input data over the period 1958 through 1982. The major features of this model are also concerns in the new EIA industrial model and have influenced its development. The idea that the vintage of the capital stock impacts significantly upon the way that energy can be consumed in industry is carried through into the new model which is designed as a "putty-clay" representation.

The FOSSIL2 industrial sector model was constructed in 1985 by Applied Energy Services for the DOE Office of Policy, Planning and Analysis [9]. The industrial sector model is based on an end-use engineering process approach, but works at a very high level of aggregation (no industry disaggregation). This makes it necessary to exogenously input overall changes in industry composition and product/process shifts. However, the model does maintain some sense of vintage and models 4 types of energy service demands (such as boilers, process heat, machine drive/electrolytic and feedstocks). The distinction between energy consumption in new versus existing equipment and between components such as BSC and PA uses is carried through into the NEMS Industrial Demand Model.

4. Model Structure

Flow Diagrams

Figure 9 presents the calculational flow for the NEMS Industrial Demand Model. The figure shows each of the model subroutines and the corresponding data inputs and outputs, as appropriate. The following section provides the solution algorithms for the model.

Figure 9. Module Calculational Flow

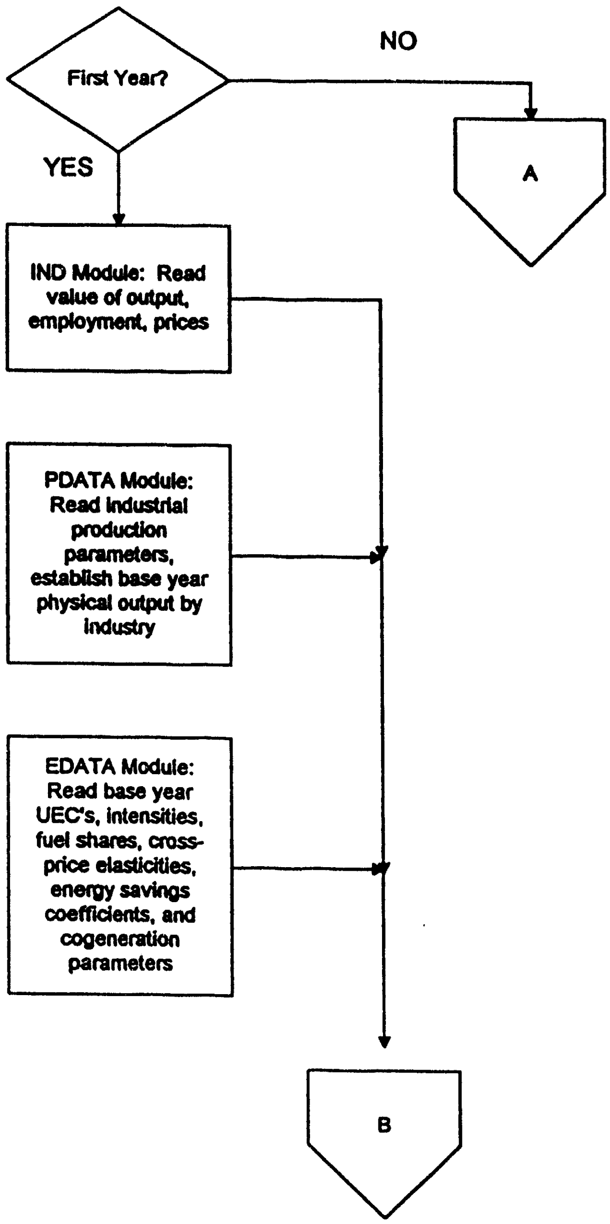


Figure 9. Module Calculational Flow, cont.

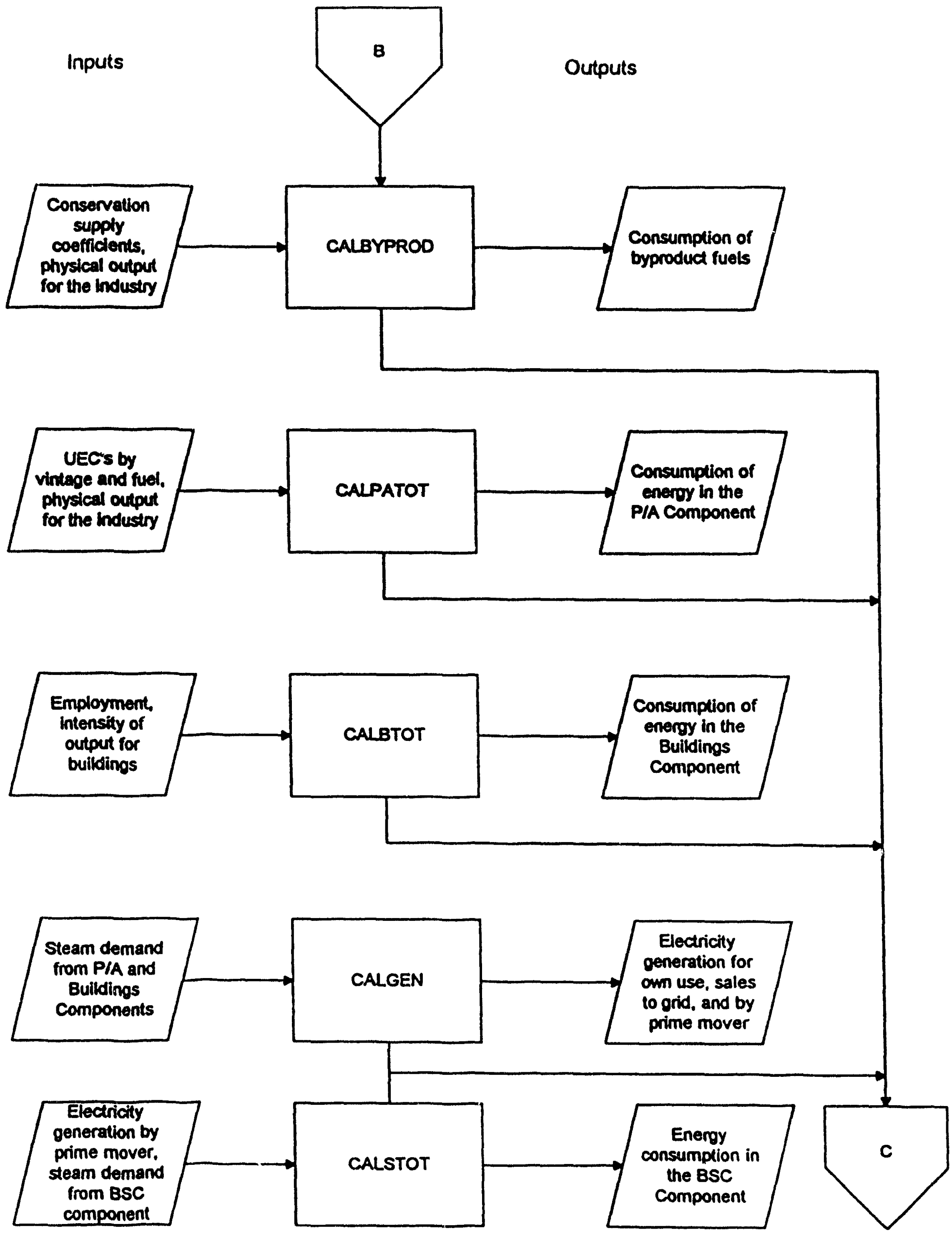


Figure 9. Module Calculational Flow, cont.

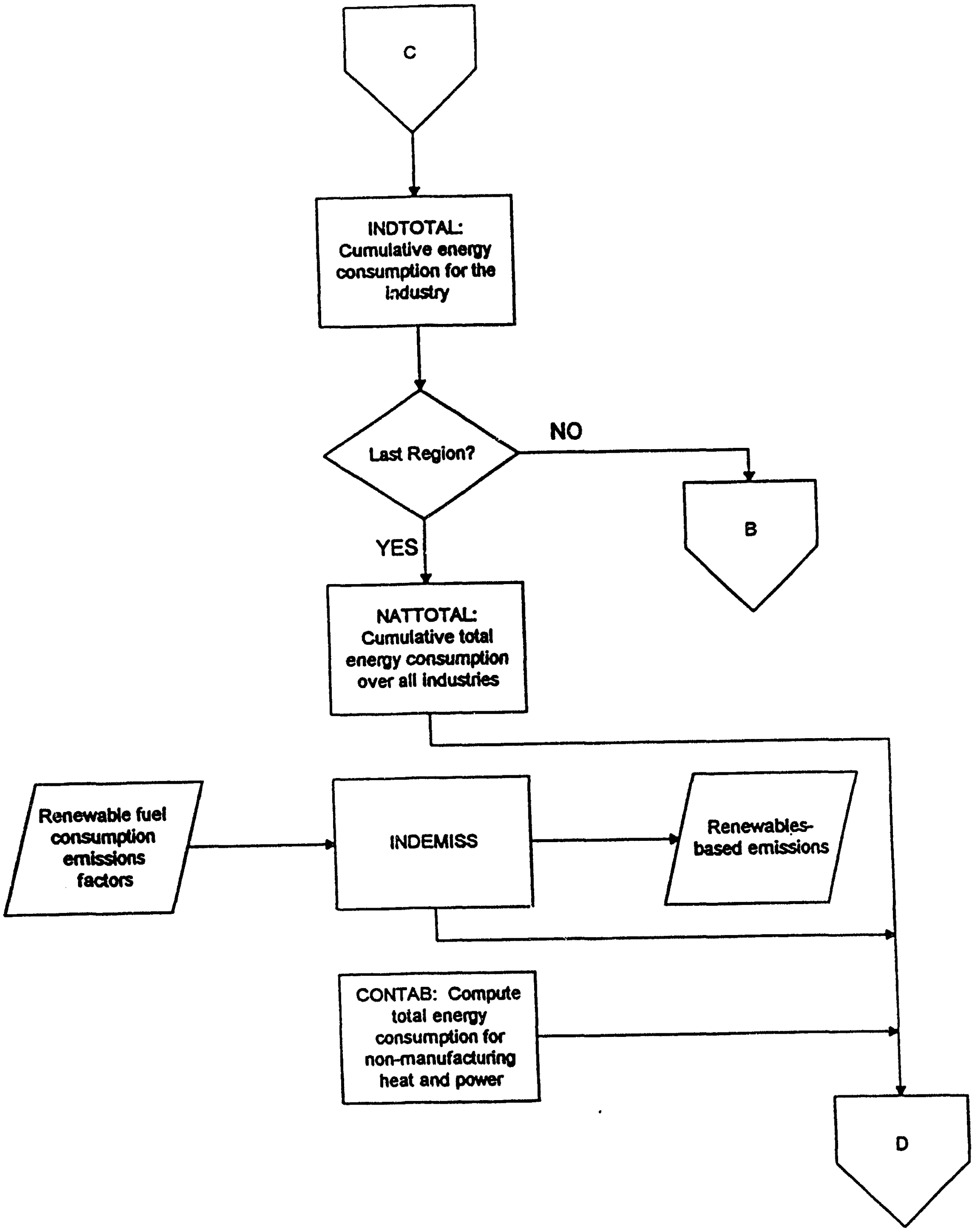


Figure 9. Module Calculational Flow, cont.

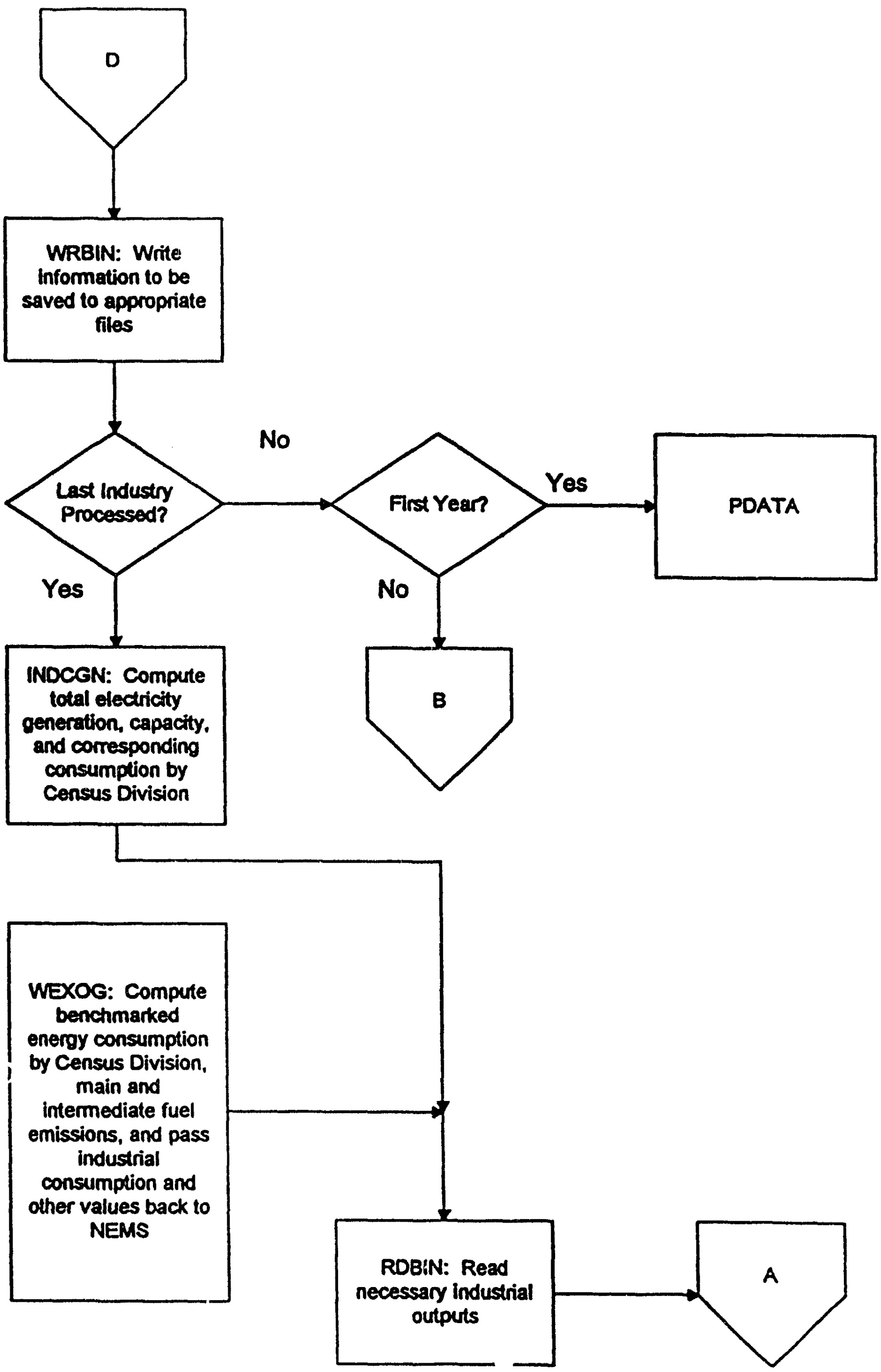
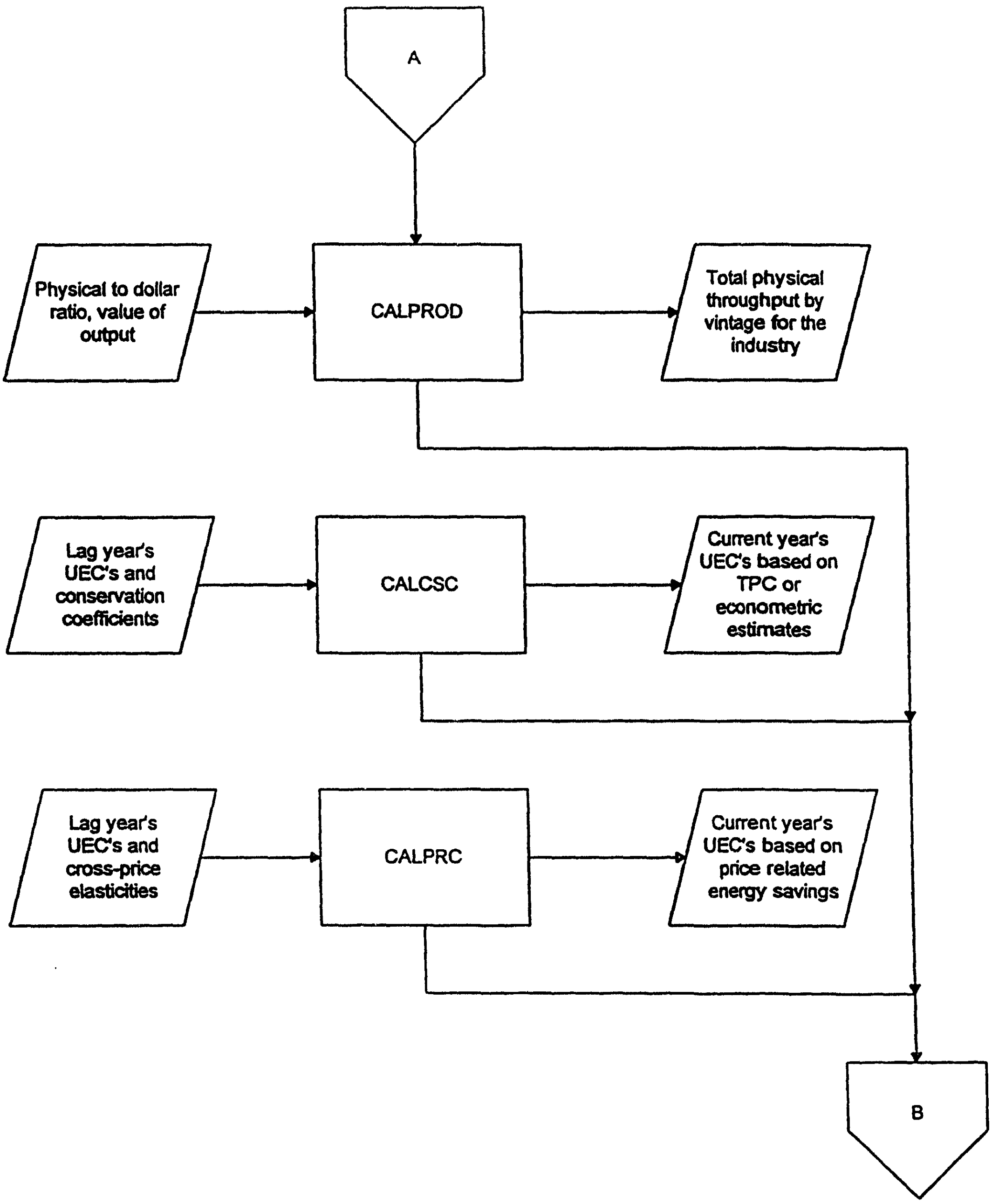


Figure 9. Module Calculational Flow, cont.



Subroutines and Equations

This section provides the solution algorithms for the Industrial Model. The order in which the equations are presented follows the logic of the FORTRAN source code very closely to facilitate an understanding of the code and its structure. In several instances, a variable name will appear on both sides of an equation. This is a FORTRAN programming device that allows a previous calculation to be updated (for example, multiplied by a factor) and re-stored under the same variable name.

IND

IND is the main industrial subroutine called by NEMS. This subroutine retrieves data for gross output for both the manufacturing and non-manufacturing industries from the NEMS Macroeconomic (MACRO) model. Employment is also obtained from the MACRO model for each non-agricultural industry. Prices for the various fuels as well as the previous year's consumption are obtained from NEMS COMMON blocks. For the first model year, consumption is obtained from the *State Energy Data System 1990* (SEDS). Because data for the industrial model are available only for the four Census regions, the energy prices obtained from NEMS, available for each of the nine Census divisions, are combined using a weighted average of the fuel prices in each of the four Census regions as shown in the following equation for the first model year. A similar weighted average is used for all other model years, however, the previous year's consumption is used rather than 1990 SEDS consumption.

$$PRCX_{elec,r} = \frac{\sum_{d=1}^{NUM_r} DPRCX_{elec,r} \ x \ QSELIN_{d,1990}}{\sum_{d=1}^{NUM_r} QSELIN_{d,1990}} \qquad (5)$$

where:

$PRCX_{elec,r}$	=	Price for electricity in Census region r,
NUM_r	=	Number of Census divisions in Census region r,

$DPRCX_{elec,d}$	=	Price of electricity in Census division *d*, and
$QSELIN_{d,1990}$	=	SEDS consumption of electricity in Census division *d* in 1990.

Prices for biomass and steam are not available from NEMS. The price for biomass is assumed to be 2.0 dollars per MMBtu for all Census regions. The price of steam is an average of the prices of natural gas, coal, and residual oil. IND calls two subroutines: ISEAM, the subroutine that guides the industrial model calculations, and WEXOG, the subroutine that reports the results back to NEMS.

ISEAM

ISEAM controls all of the industrial model calculations. It opens external files for debugging, binary files for restarting on successive iterations and forecast years, and the input data files. In the first model year and only on the first iteration, ISEAM calls two subroutines: RCNTRL and INDEMISI to read the control file and emissions input file. ISEAM then calls REXOG to read in exogenous inputs on each model run. For the first model year, ISEAM calls the following subroutines for each Census region within each industry: PDATA, EDATA, CALBYPROD, CALPATOT, CALBTOT, CALGEN, CALSTOT, and INDTOTAL. After the forecast for the last Census region for a particular industry has been calculated, the following three subroutines are called: NATTOTAL, INDEMISS, and CONTAB. After the first model year, ISEAM calls two subroutines, RDBIN to read the restart files, and MODCAL to carry out model calculations. After all model calculations have been completed, ISEAM calculates industry totals and saves information to the restart files in the subroutine WRBIN. Finally, after each industry has been processed, ISEAM calls the subroutine INDCGN to report industrial cogeneration estimates to NEMS.

Subroutine RCNTRL

RCNTRL reads data from the input file INDRUN. This file contains internal control variables for the industrial model. Data in this file come from a series of questions the user is asked at the beginning of a run. The data consists of indicator variables for subroutine tracing, debugging, writing summary tables, calculating unit energy consumption using technology possibility curve (TPC) parameters, calculating unit energy consumption using price elasticities, including imports and exports in the model, and benchmarking. This file also contains the beginning model year, the ending model year, the number of industries to be modeled, and input file names.

Subroutine INDEMISI

INDEMISI reads emission factors from an input file. Uncontrolled emissions factors for each fuel, expressed in metric tons per million Btu, are read in for each of the following pollutants: carbon, carbon monoxide, carbon dioxide, methane, sulfur dioxide, nitrogen oxide, volatile organic compounds (VOC), and particulates. Controlled emissions factors for each fuel, expressed in fractional terms, are also read in from the input file for each of the pollutants. Fractional sulfur contents are obtained for each fuel for use in calculating emissions of SO_x. Currently, only the carbon emissions are reported.

Subroutine REXOG

REXOG prepares exogenous data obtained from the NEMS MACRO model for use in the industrial model. Dollar value of output and employment are aggregated over the appropriate Census divisions to obtain data at the Census region level. Employment data is obtained from NEMS at the two digit SIC level. Therefore, for several industries modeled in the industrial model, employment data must be shared out between industries at the same two digit SIC level. In particular, the chemical industry (SIC 28) is grouped into bulk chemicals (SICs 281, 282, 286, and 287) and other chemical. Employment for the petroleum industry must be shared out between refining and all other petroleum. The stone, clay, and glass industry and the primary metals industry also require sharing out of employment data.

Subroutine PDATA

PDATA is the subroutine that reads in data for the process and assembly component of the model. For each region in each industry, the following data is read from the ENPROD input file: industry name, industry code[8], Census region, number of process steps, an indicator variable indicating the units of unit energy consumption (physical or dollar units), value of production, and cumulative output. For each process step, the following data is read from the input file: process step number, number of links, the process steps linked to the current step, physical throughput to each process step, the retirement rate, and process step name.

Note that only the energy-intensive industries have steps. However, two industries, food and kindred products and bulk chemicals, do not have linkages among steps because the steps represent end-uses (e.g., refrigeration and freezing in the food and kindred products industry). As a result, the downstep throughput for food and kindred products and bulk chemicals is equal to one. A linkage is defined as a link between more than one process step. For example, in the paper and allied products industry, the wood preparation process step is linked to the virgin fibers pulping process step. The down-step throughput is the fraction of total throughput for an industry at a process step if it is linked to the final consumption. If the process step is linked to another process step, then the down-step throughput is the fraction of the linked process step plus the fraction of final consumption. The following example illustrates this procedure.

Figure 10 shows the process flow for the paper and allied products industry. The algebraic representation is as follows:

Let:

$Y_1 \equiv$ Number of tons of paper to be produced.

$Y_2 \equiv$ Number of tons of material to go through the bleaching process.

$Y_3 \equiv$ Number of tons of material to go through the waste fiber pulping process.

$Y_4 \equiv$ Number of tons of material to go through the mechanical pulping process.

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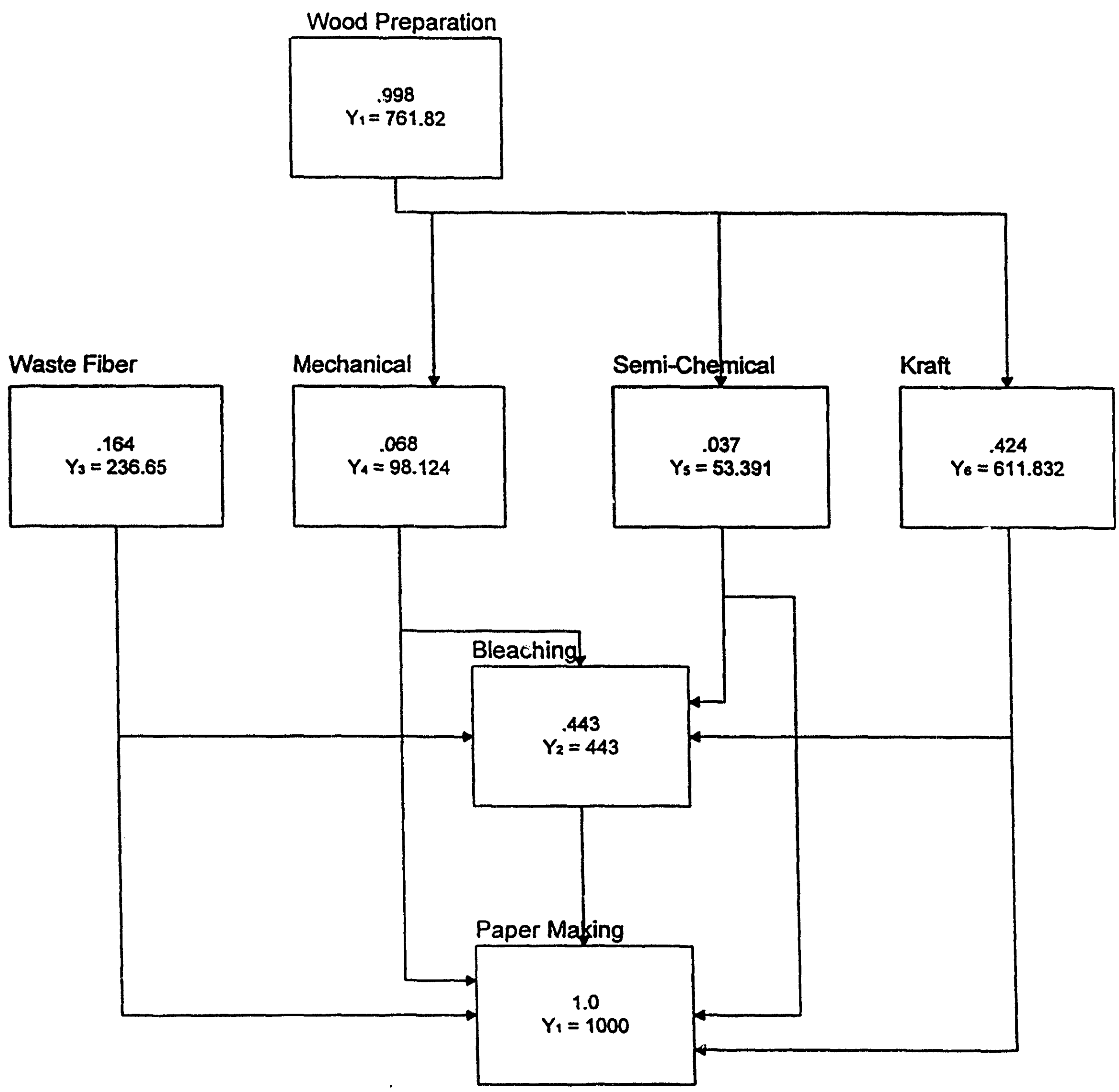
[8]This industry code is the industrial model code, not the SIC code.

Figure 10. Paper and Allied Products Industry Process Flow



$Y_5 \equiv$ Number of tons of material to go through the semi-mechanical pulping process.

$Y_6 \equiv$ Number of tons of material to go through the Kraft pulping process.

$Y_7 \equiv$ Number of tons of material to go through the wood preparation process.

Then, we have the following:

$Y_1 =$ Some value of output, in tons (from the MACRO Module).

$Y_2 = 0.443\ Y_1$

$Y_3 = 0.164\ Y_1 + 0.164\ Y_2$

$Y_4 = 0.068\ Y_1 + 0.068\ Y_2$

$Y_5 = 0.037\ Y_1 + 0.037\ Y_2$

$Y_6 = 0.424\ Y_1 + 0.424\ Y_2$

$Y_7 = 0.998\ Y_4 + 0.998\ Y_5 + 0.998\ Y_6$

If $Y_1 = 1{,}000$ tons of paper to be produced, then $Y_2 = 443$, $Y_3 = 236.65$, $Y_4 = 98.124$, $Y_5 = 53.391$, $Y_6 = 611.836$, and $Y_7 = 761.82$.

The papermaking process is as follows. We need 761.82 tons of output from the wood preparation process and 236.65 tons of output from the waste fiber pulping process. Of the 761.82 tons of material, 98.124 tons flow through mechanical pulping, 53.391 tons into semi-mechanical pulping, and 611.832 tons into the Kraft pulping process. 443 tons from the sum of output of the waste fiber, mechanical, semi-mechanical, and Kraft pulping processes goes through the bleaching process. This 443 tons along with the remainder of the output from each process goes to the final stage in papermaking.

Physical throughput is obtained for two vintages, old and new. Old vintage is considered to be any capital installed in 1990 or earlier. Middle vintage includes installations from 1991 to the lag of the current forecast year. New vintage includes any capital installed in the current forecast year.

PDATA forms the ratio of physical output to 1990 value of output for the energy-intensive industries with the exception of the food and kindred products and bulk chemical industries. This constant ratio is applied to physical output in subsequent years. The physical output value PHDRAT is converted to a ratio with the same name.

$$PHDRAT = \frac{PHDRAT}{PRODVX_{i,r}} \quad (6)$$

where:

$PHDRAT$	=	Ratio of physical units to value of output, and
$PRODVX_{i,r}$	=	Value of output for industry i in Census region r.

If the Unit Energy Consumption (UEC) is in physical units, then the following equation is used.

$$PRODX_{i,r} = PHDRAT \times PRODVX_{i,r} \quad (7)$$

where:

$PRODX_{i,r}$	=	Output in physical units for industry i in Census region r,
$PHDRAT$	=	Ratio of physical units to value of output, and
$PRODVX_{i,r}$	=	Value of output for industry i in Census region r.

If the UEC is in dollar units, then the following equation is used.

$$PRODX_{i,r} = PRODVX_{i,r} \quad (8)$$

where:

$PRODX_{i,r}$	=	Value of output for industry i in Census region r, and
$PRODVX_{i,r}$	=	Value of output for industry i in Census region r.

If the current process step is linked to final consumption (i.e., if there are no intermediate steps between the current step and final output), then the following equation is used:

$$PRODSUM_{s,l} = PRODFLOW_{old,s,l} \times PRODX_{i,r} \tag{9}$$

where:

$PRODSUM_{s,l}$	=	Amount of throughput used at process step s through link l,
$PRODFLOW_{old,s,l}$	=	Down-step throughput to process step s linked by link l for old vintage, and
$PRODX_{i,r}$	=	Output for industry i in Census region r.

Note that PRODFLOW is a parameter that represents the relative production throughput to a subsequent production step in the energy-intensive industries. The linkage parameter indicates which production step is involved.

If the current process step is linked to one or more intermediate process steps, then the following equation is used:

$$PRODSUM_{s,l} = PRODFLOW_{old,s,l} \times PRODCUR_{total,IP} \tag{10}$$

where:

$PRODSUM_{s,l}$	=	Amount of throughput used at process step s through link l,
$PRODFLOW_{old,s,l}$	=	Down-step throughput to process step s linked by link l for old vintage, and
$PRODCUR_{total,IP}$	=	Current production at process step IP linked to process step s through link l for all vintages.

In either case, the total production at each process step is determined through the following equation:

$$PRODCUR_{total,s} = \sum_{l=1}^{NTMAX_s} PRODSUM_{s,l} \qquad (11)$$

where:

$PRODCUR_{total,s}$	=	Current production at process step s for all vintages,
$NTMAX_s$	=	Number of links at process step s, and
$PRODSUM_{s,l}$	=	Amount of throughput used at process step s through link l.

Subroutine EDATA

EDATA reads energy related data from the input file ENPROD. For each process step, the number of fuels used at the process step and the number of byproducts are obtained from ENPROD. For each fuel type within each process step, initial unit energy consumption (UEC), an intercept term for use in econometric equations, technology possibility curve (TPC) coefficient, and cross price elasticities are read in for both old and new vintage. EDATA reads in similar data for each byproduct fuel for each process step. The values for UEC, TPC coefficient, and cross price elasticities for new vintage are assigned to the variables for middle vintage.

This subroutine is also responsible for reading energy data for the buildings component. The number of fuels used for lighting, either none or one for electricity, is obtained as well as the initial UEC. The same information is obtained for heating, ventilation, and cooling (HVAC). There are three fuels considered for HVAC, electricity, natural gas, and steam.

Data for the boiler/steam/cogeneration (BSC) component is obtained through the EDATA subroutine. The number of non-byproduct fuels consumed in the BSC component is read in as well as boiler fuel shares, cross price elasticities, and the boiler efficiencies for each fuel. Boiler shares are normalized to sum to one. The number of byproduct fuels consumed in the BSC component is read in. Several variables are read concerning cogeneration of electricity, including initial steam demand, 1990 total electricity generation and generation for own use, and capacity utilization. Regression parameter estimates are read for steam demand and generation. Four prime movers, internal combustion engines, combustion turbines, steam turbines, and renewables are considered in the industrial model. For each prime mover, a share of total generation, a heat rate, and an efficiency are read from the input file.

Subroutine CALBYPROD

The industrial model consumes all byproduct fuels prior to purchasing any fuels. This subroutine calculates the energy savings or the current location on the technology possibility curve (TPC) based on the current year's industry production and the previous year's industry production for each process step, fuel, and old and new vintage as shown in the following equation. Currently, only the paper and allied products industry has a TPC for byproducts. For all other industries the UEC remains unchanged.

$$BYPCSCCUR_{v,f,s} = \left[\frac{PRODCUR_{total,s}}{PRODLAG_{total,s}}\right]^{BYPCSC_{v,f,s}} \qquad (12)$$

$BYPCSCCUR_{v,f,s}$	=	Current energy savings for byproduct fuel f at process step s for vintage v,
$PRODCUR_{total,s}$	=	Current production at process step s for all vintages,
$PRODLAG_{total,s}$	=	Lagged production at process step s for all vintages, and
$BYPCSC_{v,f,s}$	=	Byproduct technology possibility curve coefficient for byproduct fuel f at process step s for vintage v.

The energy savings for middle vintage is a weighted average (by production) of the current year's energy savings for new vintage and the previous year's energy savings for middle vintage.

$$BYPCSCCUR_{mid,f,s} = \frac{(PRODCUR_{new,s} \times BYPCSCCUR_{new,f,s}) + (PRODCUR_{mid,s} \times BYPCSCLAG_{mid,f,s})}{PRODCUR_{new,s} + PRODCUR_{mid,s}} \quad \textbf{(13)}$$

where:

$BYPCSCCUR_{mid,f,s}$	=	Current energy savings for byproduct fuel f at process step s for mid vintage,
$PRODCUR_{new,s}$	=	New production at process step s,
$BYPCSCCUR_{new,f,s}$	=	Current energy savings for byproduct fuel f at process step s for new vintage,
$PRODCUR_{mid,s}$	=	Existing production at process step s for mid vintage, and,
$BYPCSCLAG_{mid,f,s}$	=	Lagged location on the byproduct technology possibility curve for byproduct fuel f at process step s for middle vintage.

CALBYPROD calculates the rate of byproduct energy produced for each process step, fuel, and vintage shown in the following equation. This value is based on the previous year's rate of production and the current energy savings for each vintage.

$$BYPINT_{v,f,s} = BYPINTLAG_{v,f,s} \times BYPCSCCUR_{v,f,s} \quad \textbf{(14)}$$

where:

$BYPINT_{v,f,s}$	=	Rate of byproduct energy production for byproduct fuel f at process step s for vintage v,
$BYPINTLAG_{v,f,s}$	=	Lagged rate of byproduct energy production for byproduct fuel f at process step s for vintage v, and

$BYPCSCCUR_{v,f,s}$ = Current energy savings for byproduct fuel f at process step s for vintage v.

The byproduct rate of production is used to calculate the quantity of byproduct energy produced by multiplying total production at the process step by the production rate.

$$BYPQTY_{v,f,s} = PRODCUR_{v,s} \times BYPINT_{v,f,s} \tag{15}$$

where:

$BYPQTY_{v,f,s}$ = Byproduct energy production for byproduct fuel f at process step s for vintage v,

$PRODCUR_{v,s}$ = Production at process step s for vintage v, and

$BYPINT_{v,f,s}$ = Rate of byproduct energy production for byproduct fuel f at process step s for vintage v.

The byproduct rate of production is ther verted from million Btu to trillion Btu. Byproduct production is subdivided into three categc n fuels, intermediate fuels, and renewable fuels.

Byproduct production for each group of fuels is determined by summing byproduct production over the individual process steps for each fuel and vintage as shown below for main byproduct fuels. The equations for intermediate and renewable fuels are similar.

$$ENBYPM_{f,v} = \sum_{s=1}^{MPASTP} BYPQTY_{v,f,s} \tag{16}$$

where:

$ENBYPM_{f,v}$ = Byproduct energy production for main byproduct fuel f for vintage v,

$MPASTP$ = Number of process steps, and

$BYPQTY_{v,f,s}$ = Byproduct energy production for byproduct fuel f at process step s for vintage v.

Subroutine CALPATOT

CALPATOT calculates the total energy consumption from the process and assembly component. In the first model year, this subroutine calls CALINTER to calculate an intercept term for further use in econometric equations. Note that CALINTER does not apply to the energy-intensive industries. Energy consumption at each process step is determined by multiplying the current production at that particular process step by the unit energy consumption (UEC) for that process step. Energy consumption is calculated for each fuel and vintage using the following equation.

$$ENPQTY_{v,f,s} = PRODCUR_{v,s} \times ENPINT_{v,f,s} \tag{17}$$

where:

$ENPQTY_{v,f,s}$	=	Consumption of fuel f at process step s for vintage v,
$PRODCUR_{v,s}$	=	Production at process step s for vintage v, and
$ENPINT_{v,f,s}$	=	Unit energy consumption of fuel f at process step s for vintage v.

Four energy products that are used for non-fuel purposes are modeled differently. These products are asphalt and road oil, liquid petroleum gas feedstocks, petrochemical feedstocks, and natural gas feedstocks. For the construction industry, the consumption of asphalt and road oil for all model years after 1990 is determined through the following equation.

$$ENPQTY_{v,asp,s} = ENPINT_{v,asp,s} \times PRODZERO_{v,s} + 0.4 \times [PRODCUR_{v,s} - PRODZERO_{v,s}] \tag{18}$$

where:

$ENPQTY_{v,asp,s}$	=	Consumption of asphalt and road oil at process step s for vintage v,

$ENPINT_{v,asp,s}$	=	Unit energy consumption of asphalt and road oil at process step s for vintage v,
$PRODZERO_{v,s}$	=	1990 production at process step s for vintage v for the construction industry, and
$PRODCUR_{v,s}$	=	Production at process step s for vintage v.

For all years after 1990, feedstock consumption in the bulk chemical industry is computed as shown below for natural gas feedstocks. Equations for liquid petroleum gas feedstocks and petrochemical feedstocks are similar.

$$ENPQTY_{v,ngf,s} = ENPINT_{r,g,f} \times PRODZERO_{v,s} + 0.25 \times (PRODCUR_{v,s} - PRODZERO_{v,s}) \quad (19)$$

where:

$ENPQTY_{v,ngf,s}$	=	Consumption of natural gas feedstock at process step s for vintage v,
$ENPINT_{v,ngf,s}$	=	Unit energy consumption of natural gas feedstock at process step s for vintage v,
$PRODZERO_{v,s}$	=	1990 production at process step s for vintage v for the construction industry, and
$PRODCUR_{v,s}$	=	Production at process step s for vintage v.

Consumption of each fuel is converted to trillion Btu. Energy consumption is subdivided into main fuels, intermediate fuels, and renewable fuels. Main fuels include the following:

- electricity consumed in the PA or BLD components,
- core and non-core natural gas,
- natural gas feedstocks,
- steam coal,
- coking coal (including net coke imports),
- residual oil,

- distillate oil,
- liquid petroleum gas for heat and power,
- liquid petroleum gas for feedstocks,
- motor gasoline,
- still gas,
- petroleum coke,
- asphalt and road oil,
- petrochemical feedstocks,
- other petroleum feedstocks, and
- other petroleum.

Intermediate fuels include the following:

- steam,
- coke oven gas,
- blast furnace gas,
- other byproduct gas,
- waste heat, and
- coke.

Renewable fuels include the following:

- hydropower,
- biomass--wood,
- biomass--pulping liquor,
- geothermal,
- solar,
- photovoltaic,
- wind, and
- municipal solid waste.

Energy consumption for the three fuel groups is determined for each fuel by summing over the process steps as shown below for main fuels. The equations for intermediate and renewable fuels are similar.

$$ENPMQTY_f = \sum_{s=1}^{MPASTP} ENPQTY_{total,f,s} \qquad (20)$$

where:

$ENPMQTY_f$	=	Consumption of main fuel f in the process/assembly component,
$MPASTP$	=	Number of process steps, and
$ENPQTY_{total,f,s}$	=	Consumption of fuel f at process step s for all vintages.

Energy consumption for coke imports is calculated as the difference between coke consumption and coke production. In the current industrial model, coke is consumed only in the blast furnace/basic oxygen furnace process step in the blast furnace and basic steel products industry. Coke is produced only in the coke oven process step in the blast furnace and basic steel products industry. The equation for net coke imports is shown below.

$$ENPMQTY_{coke} = ENPIQTY_{coke} - \left[PRODCUR_{total,co} \ x \ \frac{24.8}{10^6} \right] \qquad (21)$$

where:

$ENPMQTY_{coke}$	=	Consumption of coke imports in the process/assembly component,

$ENPIQTY_{coke}$ = Consumption of coke in the process/assembly component,

$PRODCUR_{total,co}$ = Current production at the coke oven process step for all vintages, and

$24.8/10^6$ = Conversion factor, where there are 24.8 million btu per short ton of coke converted to trillion Btu.

Subroutine CALINTER

CALINTER calculates an intercept term used to calculate unit energy consumption (UEC) by an econometric approach. The intercept calibrates projected consumption for the base year to actual consumption. The non-energy-intensive industries, with a few exceptions, utilize an econometric equation to estimate UECs. (The energy-intensive industries, with the exception of the feedstock process step in the bulk chemical industry, use an approach developed by Arthur D. Little (ADL) to estimate unit energy consumption.) For each fuel, an intercept term is calculated in CALINTER based on the UEC, cumulative output, own-price elasticities, and cross price elasticities. The purpose of the intercept term is to calibrate the results for the first model year. The intercept term is calculated for old vintage in the following equation. The intercept for new vintage is assumed to equal the intercept for old vintage. An intercept term is not required for middle vintage calculations.

$$EINTER_{old,f,s} = \frac{ENPINT_{old,f,s}}{[CUMOUT88]^{BCSC_{old,f,s}} \ x \ \prod_{t=1}^{11} [WPRC_t]^{BELAS_{old,f,s,t}}} \qquad (22)$$

where:

$EINTER_{old,f,s}$ = Intercept at process step s for fuel f for old vintage,

$ENPINT_{old,f,s}$ = Unit energy consumption of fuel f at process step s for old vintage,

$CUMOUT88$	=	Cumulative output through the year 1988,
$BCSC_{old,f,s}$	=	Energy savings coefficient at process step s for fuel f and old vintage,
$WPRC_t$	=	Price for fuel t in 1987 dollars, and
$BELAS_{old,f,s,t}$	=	Own price elasticity at process step s for fuel f for old vintage, and cross price elasticity at process step s for fuel f and fuel t for old vintage.

Subroutine CALBTOT

CALBTOT calculates the total energy consumption for buildings. The energy consumption for buildings is calculated for two building uses, lighting and HVAC. Total energy consumption is determined for electricity, natural gas, and steam by multiplying industry employment by the building unit energy consumption as shown in the following equation.

$$ENBQTY_{e,f} = EMPLX_{i,r} \ x \ ENBINT_{e,f} \tag{23}$$

where:

$ENBQTY_{e,f}$	=	Consumption of fuel f for building end use e,
$EMPLX_{i,r}$	=	Employment for industry i in Census region r, and
$ENBINT_{e,f}$	=	Unit energy consumption of fuel f for building end use e.

Subroutine CALGEN

CALGEN calculates electricity generation and the quantity of steam used to generate electricity. The following two equations calculate the total demand for electricity and steam. The total demand for electricity is determined by summing the electricity consumed in the PA component and in the BLD component (no electricity is consumed in boilers). Total steam demand is calculated in the same manner as electricity demand.

$$ELDEM = ENPMQTY_{elec} + ENBQTY_{total,elec} \quad (24)$$

where:

$ELDEM$	=	Total electricity demand from process/assembly and buildings,
$ENPMQTY_{elec}$	=	Consumption of electricity in the process/assembly component, and
$ENBQTY_{total,elec}$	=	Consumption of electricity for all building end uses.

$$STEMCUR = ENBQTY_{hvac,steam} + ENPIQTY_{steam} \quad (25)$$

where:

$STEMCUR$	=	Total steam demand,
$ENBQTY_{hvac,steam}$	=	Consumption of steam for HVAC, and
$ENPIQTY_{steam}$	=	Consumption of steam in the process/assembly component.

Total electricity generation is based on an econometric equation (see Appendix E). To utilize the regression parameters, an intercept term must be calculated on the first call to CALGEN. The intercept is the natural log of the ratio of 1990 generation to the predicted value for the current year based on the regression parameters.

$$GINTER = \ln\left[\frac{GEN90}{STEMCUR_{90}^{GSTEAM}}\right] \qquad (26)$$

where:

$GINTER$	=	Intercept term for electricity generation,
$GEN90$	=	1990 generation of electricity,
$STEMCUR_{90}$	=	Total steam demand for 1990, and
$GSTEAM$	=	Steam demand coefficient.

Electricity generation is then determined through the equation shown below based on the intercept term and an estimated parameter for steam demand.

$$ELGEN_{total} = e^{GINTER} \; x \; STEMCUR^{GSTEAM} \qquad (27)$$

where:

$ELGEN_{total}$	=	Electricity generation for all prime movers,
$GINTER$	=	Intercept for electricity generation,
$STEMCUR$	=	Total steam demand, and
$GSTEAM$	=	Steam demand coefficient.

Generation of electricity is converted from Btu to megawatt hours. Capacity for electric generation is determined from total generation of electricity and input data on capacity utilization. The following equation calculates capacity for electric generation.

$$ELCAP = \frac{ELGEN_{total} \times 10^9}{GENUTIL \times 3412.0 \times 365.25 \times 24.0} \quad (28)$$

where:

$ELCAP$	=	Capacity for electricity generation,
$ELGEN_{total}$	=	Electricity generation from all prime movers,
$GENUTIL$	=	Capacity utilization for cogeneration,
3412.0	=	Conversion factor, 3412.0 Btu per kilowatthour,
365.25	=	Number of days per year,
24.0	=	Number of hours per day, and
10^9	=	Conversion factor to convert to megawatts.

Electricity generation for own use is based on an econometric equation (see Appendix E). An intercept term is calculated on the first call to CALGEN. This intercept is based on 1990 own use generation, total electricity generation, and a parameter estimate for own use generation.

$$OINTER = \ln\left[\frac{OWN90}{(ELGEN_{total})^{OGEN}}\right] \quad (29)$$

where:

$OINTER$	=	Intercept for own use generation,
$OWN90$	=	1990 electricity generation for own use,
$ELGEN_{total}$	=	Electricity generation from all prime movers, and
$OGEN$	=	Own use generation coefficient.

Electricity generation for own use is then calculated from the following equation.

$$ELOWN = e^{OINTER} \times ELGEN_{total}^{OGEN} \qquad (30)$$

where:

$ELOWN$	=	Electricity generation for own use,
$OINTER$	=	Intercept for own use generation,
$ELGEN_{total}$	=	Electricity generation from all prime movers, and
$OGEN$	=	Own use generation coefficient.

Electricity generation for sales to the grid is calculated as the difference between total generation and generation for own use. Electricity generation is calculated for each of the four prime movers based on the share of total generation for each prime mover as shown below.

$$ELGEN_m = ELGEN_{total} \times GENEQPSHR_m \qquad (31)$$

where:

$ELGEN_m$	=	Electricity generation from prime mover m,
$ELGEN_{total}$	=	Electricity generation from all prime movers, and
$GENEQPSHR_m$	=	Share of generation for prime mover m.

Total industrial cogeneration for sales to the grid and own use and total capacity for generation are incremented as the processing of each industry is completed.

Subroutine CALSTOT

CALSTOT calculates total fuel consumption in the BSC component. Fuel consumption for non-steam turbines is calculated by multiplying electricity generation by internal combustion engines and combustion turbines by the appropriate heat rates. The equation for internal combustion engines is presented below and a similar equation is used for combustion turbines. (Note that $ELGEN_{ICE}$ is calculated in CALGEN where it is one of the prime movers.) CALSTOT also calls the subroutine FUELBOIL. FUELBOIL calculates total fuel consumption in boilers and steam turbines.

$$ICEFUEL = ELGEN_{ice} \times \frac{GENEQPHTRT_{ice}}{3412.0} \tag{32}$$

where:

$ICEFUEL$	=	Fuel consumption for electricity generation from internal combustion engines,
$ELGEN_{ice}$	=	Electricity generation from internal combustion engines,
$GENEQPHTRT_{ice}$	=	Heat rate for internal combustion engines, and
3412.0	=	Conversion factor to convert from Kwh to Btu.

Steam generated from cogeneration of electricity, shown below for internal combustion turbines, is determined through the efficiency for each prime mover obtained from the input file. A similar equation exists for combustion turbines.

$$ICESTEAM = (ICEFUEL - ELGEN_{ice}) \times GENEQPSTEFF_{ice} \tag{33}$$

where:

$ICESTEAM$	=	Cogeneration of steam from internal combustion engines,
$ICEFUEL$	=	Fuel consumption for electricity generation from internal combustion engines,
$ELGEN_{ice}$	=	Electricity generation from internal combustion engines, and
$GENEQPSTEFF_{ice}$	=	Efficiency for internal combustion engines.

Steam generated from boilers is calculated as the difference between total steam demand and the quantity of steam generated from internal combustion engines and combustion turbines.

$$BOILSTEAM = STEMCUR - (ICESTEAM + GCTSTEAM) \tag{34}$$

where:

BOILSTEAM	=	Steam generated from boilers,
STEMCUR	=	Total steam demand,
ICESTEAM	=	Cogeneration of steam from internal combustion engines, and
GCTSTEAM	=	Cogeneration of steam from combustion turbines.

Fuel consumption in steam turbines and boilers is processed in the subroutine FUELBOIL called by CALSTOT. The four fuels considered for cogeneration are coal, oil, natural gas, and renewables/other. The fuels consumed for cogeneration are calculated by summing fuel consumption over fuels for each of the four prime movers. It is assumed that all coal and renewables consumed for cogeneration are consumed in steam turbines. Internal combustion engines are assumed to consume only distillate oil, and all combustion turbines use natural gas. The following equation is the computation of consumption of distillate oil for cogeneration. The equations for the other fuels are similar.

$$CGFUEL_{oil,total,r} = STFUEL_{oil} + ICEFUEL \tag{35}$$

where:

$CGFUEL_{oil,total,r}$	=	Consumption of distillate oil for cogeneration of electricity for all uses in Census region *r*,
$STFUEL_{oil}$	=	Consumption of distillate oil in steam turbines, and
ICEFUEL	=	Fuel consumption for electricity generation from internal combustion engines.

The total fuel consumption for cogeneration is shared between generation for own use and sales to the grid based on the proportion of total generation allotted to each use. The following equation calculates fuel consumption for own use generation. Fuel consumption for sales to the grid is calculated as the difference between total fuel consumption for all uses and fuel consumption for own use generation.

$$CGFUEL_{f,own,r} = CGFUEL_{f,total,r} \times \left[\frac{ELOWN}{ELGEN_{total}} \right] \tag{36}$$

where:

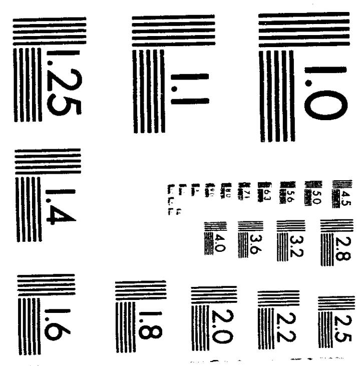
$CGFUEL_{f,own,r}$	=	Consumption of fuel *f* for cogeneration of electricity for own use in Census region *r*,
$CGFUEL_{f,total,r}$	=	Consumption of fuel *f* for cogeneration of electricity for all uses in Census region *r*,
$ELOWN$	=	Electricity generation for own use, and
$ELGEN_{total}$	=	Electricity generation from all prime movers.

Total industrial fuel use for cogeneration is incremented after each industry is processed.

Subroutine FUELBOIL

FUELBOIL calculates total fuel consumption in boilers and steam turbines. An average intensity, shown below, is determined from boiler fuel shares and the unit energy consumption to generate steam.

$$AVGINT = \sum_{f=1}^{IFSMAX} BSSHR_f \times ENSINT_f \tag{37}$$


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

where:

$AVGINT$	=	Average intensity,
$IFSMAX$	=	Number of fuels consumed in the BSC component,
$BSSHR_f$	=	Share of total fuel consumption in the BSC component for fuel f, and
$ENSINT_f$	=	Intensity of fuel f in the BSC component.

The quantity of steam generated by byproduct fuels is determined by dividing the byproduct energy produced by the unit energy consumption for each main, intermediate, and renewable fuel.

$$BYPSTM = \sum_{f=1}^{IFSBYPM} \frac{BYPBSCM_f}{BYSINT_f} + \sum_{f=1}^{IFSBYPI} \frac{BYPBSCI_f}{BYSINT_f} + \sum_{f=1}^{IFSBYPR} \frac{BYPBSCR_f}{BYSINT_f} \tag{38}$$

where:

$BYPSTM$	=	Amount of steam generated from all byproduct fuels,
$IFSBYPM$	=	Number of byproduct main fuels,
$BYPBSCM_f$	=	Byproduct consumption of main fuel f in the BSC component,
$BYSINT_f$	=	Intensity for byproduct fuel f consumed in the BSC component,
$IFSBYPI$	=	Number of byproduct intermediate fuels,
$BYPBSCI_f$	=	Byproduct consumption of intermediate fuel f in the BSC component,
$IFSBYPR$	=	Number of byproduct renewable fuels, and
$BYPBSCR_f$	=	Byproduct consumption of renewable fuel f in the BSC component.

The following equation calculates the quantity of steam to be generated from purchased fuels. The quantity of steam to be generated from purchased fuels is the difference between the amount of steam consumed in boilers and the amount of steam generated from all byproduct fuels.

$$STEMCURF = STEMCUR - BYPSTM \tag{39}$$

where:

STEMCURF	=	Amount of steam to be generated from purchased fuels,
STEMCUR	=	Total steam demand, and
BYPSTM	=	Amount of steam generated from all byproduct fuels.

The total quantity of fuel consumed to generate steam is calculated below from the total steam demand from purchased fuels, the average intensity, and boiler fuel shares.

$$ENSQTY_f = STEMCURF \ x \ AVGINT \ x \ BSSHR_f \tag{40}$$

where:

$ENSQTY_f$	=	Consumption of fuel *f* to generate steam,
STEMCURF	=	Amount of steam to be generated from purchased fuels,
AVGINT	=	Average intensity, and
$BSSHR_f$	=	Share of total fuel consumption in the BSC component for fuel *f*.

The amount of fuel consumed in the BSC component must be adjusted to exclude the amount of diesel used in internal combustion engines as shown in the following equation. A similar equation exists to exclude natural gas consumed in combustion turbines.

$$ENSQTY_f = ENSQTY_f - ICEFUEL \qquad (41)$$

where:

$ENSQTY_f$	=	Consumption of fuel *f* to generate steam, and
$ICEFUEL$	=	Fuel consumption for electricity generation from internal combustion engines.

The amount of each fuel and byproduct consumed in steam turbines is determined by fuel shares, total generation from steam turbines, and the heat rate for steam turbines. The following equation calculates the fuel consumption in steam turbines. A similar equation exists for byproduct fuel consumption in steam turbines.

$$STFUEL_f = \left[\frac{ENSQTY_f}{\sum_{f=1}^{IFSMAX} ENSQTY_f + \sum_{f=1}^{IFSBYP} BYSQTY_f} \right] x\ ELGEN_{st}\ x\ \frac{GENEQPHTRT_{st}}{3412.0} \qquad (42)$$

where:

$STFUEL_f$	=	Consumption of fuel *f* in steam turbines,
$ENSQTY_f$	=	Consumption of fuel *f* to generate steam,
$IFSMAX$	=	Number of fuels consumed in the BSC component,
$IFSBYP$	=	Number of byproducts consumed in the BSC component,
$BYSQTY_f$	=	Consumption of byproduct fuel *f* in the BSC component,
$ELGEN_{st}$	=	Electricity generation from steam turbines,

$GENEQPHTRT_{st}$	=	Heat rate for steam turbines, and
3412.0	=	Conversion factor to convert from kilowatt hours to Btu.

Subroutine INDTOTAL

The consumption estimates derived in the PA, BSC, and BLD components are combined in INDTOTAL to produce an overall energy consumption figure for each industry. The consumption estimates include byproduct consumption for each of the main, intermediate, and renewable fuels. Only electricity, natural gas, and steam include consumption from buildings. For all fuels except electricity and natural gas, the following equation is used.

$$QTYMAIN_{f,r} = ENPMQTY_f + ENBQTY_{total,f} + ENSQTY_f + BYPBSCM_f \tag{43}$$

where:

$QTYMAIN_{f,r}$	=	Consumption of main fuel f in Census region r,
$ENPMQTY_f$	=	Consumption of main fuel f in the PA component,
$ENBQTY_{total,f}$	=	Consumption of fuel f for all building end uses,
$ENSQTY_f$	=	Consumption of fuel f to generate steam, and
$BYPBSCM_f$	=	Byproduct consumption of main fuel f to generate electricity from the BSC component.

Consumption of electricity is defined as purchased electricity only, therefore, electricity generation for own use is removed from the consumption estimate.

$$QTYMAIN_{elec,r} = ENPMQTY_{elec} + ENBQTY_{total,elec} - ELOWN \tag{44}$$

where:

$QTYMAIN_{elec,r}$	=	Consumption of purchased electricity in Census region r,
$ENPMQTY_{elec}$	=	Consumption of electricity in the PA component,
$ENBQTY_{total,elec}$	=	Consumption of electricity for all building end uses, and
$ELOWN$	=	Electricity generated for own use.

Subroutine NATTOTAL

After processing all four Census regions for an industry, NATTOTAL computes a national industry estimate of energy consumption. This subroutine also computes totals over all fuels for main, intermediate, and renewable fuels. Total consumption for the entire industrial sector for each main, intermediate, and renewable fuel is determined by aggregating as each industry is processed as shown in the following equation.

$$TQMAIN_{f,r} = \sum_{i=1}^{INDMAX} QTYMAIN_{f,r} \tag{45}$$

where:

$TQMAIN_{f,r}$	=	Total consumption for main fuel f in Census region r,
$INDMAX$	=	Number of industries, and
$QTYMAIN_{f,r}$	=	Consumption of main fuel f in Census region r.

Subroutine INDEMISS

INDEMISS is the subroutine that calculates emissions for each industry. Emissions are calculated for each of the following pollutants: carbon, carbon monoxide, carbon dioxide, methane, sulfur dioxide, nitrogen oxide, volatile organic compounds, and particulates. Emissions for each fuel and pollutant are based on uncontrolled and controlled emissions factors. Emissions are calculated for the main fuels and renewable fuels. No emission calculations are necessary for intermediate fuels. The equation below calculates emissions for each renewable fuel. Emissions from renewable fuels are calculated similarly. Currently, only carbon emissions have been implemented.

$$EMIRENW_{f,p,r} = QTYRENW_{f,r} \times UNCONTEMISSFACT_{f,p} \times EMISSCONTROLFAC_{f,p} \quad (46)$$

where:

$EMIRENW_{f,p,r}$	=	Emissions of pollutant p from renewable fuel f in Census region r,
$QTYRENW_{f,r}$	=	Consumption of renewable fuel f in Census region r,
$UNCONTEMISSFACT_{f,p}$	=	Uncontrolled emission factor for pollutant p using fuel f, and
$EMISSCONTROLFAC_{f,p}$	=	Emissions control factor for pollutant p using fuel f.

For emissions of SO_x, the following equation is used..

$$EMIRENW_{f,sox,r} = EMIRENW_{f,sox,r} \times SULFURCONT_{f} \quad (47)$$

where:

$EMIRENW_{f,sox,r}$	=	Emissions of SO_x from renewable fuel f in Census region r, and
$SULFURCONT_{f}$	=	Sulfur content of fuel f.

Total emissions from all renewable fuels and emissions from the industrial sector are calculated in the two equations below.

$$TOTEMIS_{renw,p,r} = \sum_{f=1}^{8} EMIRENW_{f,p,r} \tag{48}$$

where:

$TOTEMIS_{renw,p,r}$	=	Total emissions of pollutant p from renewables in Census region r, and
$EMIRENW_{f,p,r}$	=	Emissions of pollutant p from renewable fuel f in Census region r.

$$TEMISR_{f,p,r} = \sum_{i=1}^{INDMAX} EMIRENW_{f,p,r} \tag{49}$$

where:

$TEMISR_{f,p,r}$	=	Total emissions of pollutant p for renewable fuel f in Census region r,
$INDMAX$	=	Number of industries, and
$EMIRENW_{f,p,r}$	=	Emissions of pollutant p from renewable fuel f in Census region r.

Subroutine CONTAB

CONTAB is responsible for reporting consumption values for the energy-intensive industries and energy consumption for heat and power for non-energy-intensive industries. Energy consumption for manufacturing heat and power is computed by summing total consumption of each fuel over all the manufacturing industries. The consumption for heat and power will include consumption from the energy-intensive industries. The following fuels are considered for manufacturing heat and power: electricity, natural gas except for feedstock and lease and plant gas, steam coal, coking coal, net coke imports, residual oil, distillate oil, liquid petroleum gas, still gas, petroleum coke, other petroleum and total renewables. The following equation calculates consumption of main fuels for manufacturing heat and power. A similar equation exists for renewable fuels.

$$TMANHP_f = \sum_{i=7}^{INDMAX} \sum_{f=1}^{NUM_{fg}} QTYMAIN_{f,total} \tag{50}$$

where:

$TMANHP_f$	=	Total manufacturing consumption of fuel f for heat and power,
$INDMAX$	=	Number of industries,
NUM_{fg}	=	Number of fuels in fuel group fg, and
$QTYMAIN_{f,total}$	=	Consumption of main fuel f in all Census regions.

Energy consumption for non-manufacturing heat and power is considered separately from the manufacturing industries. Fuels considered for non-manufacturing heat and power include: electricity, natural gas, steam coal, residual oil, distillate oil, liquid petroleum gas, motor gasoline, renewables and other petroleum. A consumption table is also produced for miscellaneous feedstocks. All industries are included here and the following fuels are considered: natural gas feedstocks, liquid petroleum gas feedstocks, asphalt and road oils, petrochemical feedstocks, lubes and waxes, and other petroleum feedstocks.

A consumption table for each of the energy-intensive industries is produced in CONTAB. Consumption figures are reported for each of the fuels used in each particular industry. There is a total renewables fuel group for each energy-intensive industry. Consumption for the chemical industry includes bulk chemicals and the non-energy-intensive industry other chemicals. The equation below calculates consumption of main fuels in the food and kindred products industry. All other energy-intensive industries have similar equations.

$$TFOODCON_f = \sum_{f=1}^{NUM_{fg}} QTYMAIN_{f,total} \tag{51}$$

where:

$TFOODCON_f$	=	Total consumption of fuel f in the food and kindred products industry,
NUM_{fg}	=	Number of fuels in fuel group fg, and
$QTYMAIN_{f,total}$	=	Consumption of main fuel f for all Census regions.

Subroutine WRBIN

WRBIN writes data for each industry to a binary file. Two different binary files are created. The first contains variables and coefficients that do not change over years, but change over industries. This binary file also contains data that do not change over years, but change over processes. The second binary file contains data that change from year to year.

Subroutine INDCGN

After all industries and regions have been processed, INDCGN calculates industrial cogeneration variables to report to NEMS. Two files are opened to read existing capacity for 1990 and 1991 and planned capacity for the years 1992 to 1996. The first file reads year, existing capacity, Census region, and fuel type for the following four fuels: coal, oil, natural gas, and other. The second file reads planned capacity for the years 1992 to 1996, Census division, SIC, prime mover, year, and fuel type. Existing capacity for 1990 and 1991 and planned capacity for 1992 through 1996 are shared out between own use and sales to the grid based on the ratio of own use generation to total generation of electricity.

Existing capacity was shared from Census regions to Census divisions based on the electricity share for each Census division from 1990 SEDS. For 1990 and 1991, the following equation is used for own use generation. A similar equation exists for generation for sales to the grid.

$$CAPD_{d,y,f,own,pl} = \left[\frac{ELOTOT_r}{ELOTOT_r + ELSTOT_r} \right] x \ CAPREG_{r,y,f,total} \ x \ DIVSHARE_d \tag{52}$$

where:

$CAPD_{d,y,f,own,pl}$	=	Existing or planned capacity for cogeneration of electricity for own use for Census division d using fuel f in year y,
$ELOTOT_r$	=	Total industrial electricity generation for own use in Census region r,
$ELSTOT_r$	=	Total industrial electricity generation for sales to the grid in Census region r,
$CAPREG_{r,y,f,total}$	=	Existing capacity for cogeneration of electricity for all uses for Census region r using fuel f in year y, and
$DIVSHARE_d$	=	Electricity share for Census division d.

For the years 1992 through 1996, the capacity for each Census division is augmented with the planned capacity for each Census division, fuel, use, and year. The following equation is the equation for own use and the equation for sales to the grid is similar.

$$CAPD_{d,y,f,own,pl} = CAPD_{d,y-1,f,own,pl} + \left[\frac{ELOTOT_r}{ELOTOT_r + ELSTOT_r}\right] x\ CAPDIV_{d,y,f,total,pl} \qquad (53)$$

where:

$CAPD_{d,y,f,own,pl}$	=	Existing or planned capacity for cogeneration of electricity for own use in Census division d using fuel f in year y,
$CAPD_{d,y-1,f,own,pl}$	=	Existing or planned capacity for cogeneration of electricity for own use in Census division d using fuel f in year $y-1$,
$ELOTOT_r$	=	Total industrial electricity generation for own use in Census region r,
$ELSTOT_r$	=	Total industrial electricity generation for sales to the grid in Census region r, and
$CAPDIV_{d,y,f,total,pl}$	=	Planned capacity for electricity generation for all uses for Census division d using fuel f in year y.

The following equation calculates fuel consumption for each Census division.

$$DIVFUEL_{d,f,u} = GENTOT_{f,u,r}\ x\ DIVSHARE_d \qquad (54)$$

where:

$DIVFUEL_{d,f,u}$	=	Consumption of fuel f for cogeneration of electricity for use u in Census division d,
$GENTOT_{f,u,r}$	=	Total consumption of fuel f for cogeneration of electricity for use u in Census region r, and
$DIVSHARE_d$	=	Electricity share for Census division d.

Total generation, generation for own use, and generation for sales to the grid are shared from Census regions to the Census divisions. The shares are 1990 electricity shares for each Census division from the *State Energy Data System 1990* (SEDS). Capacity for own use generation and generation for sales to the grid are also shared from Census regions to Census divisions. Own use generation and generation for sales to the grid are converted from trillion Btu to gigawatt hours. Capacity for own use and sales to the grid are converted to megawatts. The following equation computes capacity for own use. A similar equation is used to calculate capacity for sales to the grid.

$$CAPGW_{d,f,own,pl} = ELCTOT_r \ x \left[\frac{ELOTOT_r}{ELOTOT_r + ELSTOT_r}\right] x \ DIVSHARE_d \ x \left[\frac{DIVFUEL_{d,f,own}}{DIVFUEL_{d,total,own}}\right] \tag{55}$$

where:

$CAPGW_{d,f,own,pl}$	=	Existing or planned capacity for cogeneration of electricity for own use using fuel *f* in Census division *d*,
$ELCTOT_r$	=	Capacity for industrial electricity generation in Census region *r*,
$ELOTOT_r$	=	Total industrial electricity generation for own use in Census region *r*,
$ELSTOT_r$	=	Total industrial electricity generation for sales to the grid in Census region *r*,
$DIVSHARE_d$	=	Electricity share for Census division *d*,
$DIVFUEL_{d,f,own}$	=	Consumption of fuel *f* for cogeneration of electricity for own use in Census division *d*, and
$DIVFUEL_{d,total,own}$	=	Consumption of all fuels for cogeneration of electricity for own use in Census division *d*.

The following equation calculates electric generation for own use.

$$GENGWH_{d,f,own} = ELOTOT_r \ x \ DIVSHARE_d \ x \left[\frac{DIVFUEL_{d,f,own}}{DIVFUEL_{d,total,own}}\right] x \ \frac{10^6}{3412.0} \tag{56}$$

where:

$GENGWH_{d,f,own}$	=	Cogeneration of electricity for own use using fuel f in Census division d,
$ELOTOT_r$	=	Total industrial electricity generation for own use in Census region r,
$DIVSHARE_d$	=	Electricity share for Census division d,
$DIVFUEL_{d,f,own}$	=	Consumption of fuel f for cogeneration of electricity for own use in Census division d,
$DIVFUEL_{d,total,own}$	=	Consumption of all fuels for cogeneration of electricity for own use in Census division d, and
$10^6/3412.0$	=	Conversion factor to convert trillion Btu to megawatts.

For the years 1990 to 1996, planned capacity is obtained from the following equation and unplanned capacity is set equal to zero.

$$CAPGW_{d,f,u,pl} = CAPD_{d,y,f,u,pl} \tag{57}$$

where:

$CAPGW_{d,f,u,pl}$	=	Existing or planned capacity for cogeneration of electricity for use u using fuel f in Census division d, and
$CAPD_{d,y,f,u,pl}$	=	Existing or planned capacity for cogeneration for use u in Census division d using fuel f in year y.

For all years after 1996, if the previous year's capacity for electricity generation is less than or equal to the current year's capacity, then the following equation calculates planned capacity.

$$CAPGW_{d,f,u,pl} = CAPD_{d,y-1,f,u,pl} + \left[CAPGW_{d,f,u,pl} - CAPGWLAG_{d,y,f,u,pl}\right] \qquad \textbf{(58)}$$

where:

$CAPGW_{d,f,u,pl}$	=	Planned capacity for cogeneration of electricity for use *u* using fuel *f* in Census division *d*,
$CAPD_{d,y-1,f,u,pl}$	=	Existing or planned capacity for cogeneration for use *u* using fuel *f* in Census division *d* in year *y-1*,
$CAPGW_{d,f,u,pl}$	=	Planned capacity for cogeneration of electricity for use *u* using fuel *f* in Census division *d*, and
$CAPGWLAG_{d,f,u,pl}$	=	Lagged planned capacity for cogeneration of electricity for use *u* using fuel *f* in Census division *d*.

If the previous year's capacity is greater than the current year's capacity, then the following equation is used.

$$CAPGW_{d,f,u,pl} = CAPD_{d,y-1,f,u,pl} \qquad \textbf{(59)}$$

where:

$CAPGW_{d,f,u,pl}$	=	Planned capacity for cogeneration of electricity for use *u* using fuel *f* in Census division *d*, and
$CAPD_{d,y-1,f,u,pl}$	=	Existing or planned capacity for cogeneration of electricity for use *u* using fuel *f* in Census division *d* in year *y-1*.

Subroutine WEXOG

WEXOG is the subroutine that reports variables to NEMS. All consumption values calculated at the regional level must be shared to the Census division level. The shares, computed in the following equation, are based on 1990 SEDS fuel consumption data. In the first and second model year, this subroutine calls IBSEDS to calculate benchmark factors for consumption.

$$FUELSHARE_{elec,d} = \frac{QSELIN_{d,1990}}{\sum_{d=1}^{NUM_r} QSELIN_{d,1990}} \tag{60}$$

where:

$FUELSHARE_{elec,d}$	=	Share of consumption of electricity in Census division d,
$QSELIN_{d,1990}$	=	SEDS consumption of electricity in Census division d in 1990, and
NUM_r	=	Number of Census divisions in Census region r.

The shares for renewable fuels, calculated through the following equation, are based on the value of output from the paper and lumber industries since most renewable fuel consumption occurs in these industries.

$$DSRENW_{f,d} = \frac{OUTIND_{13,d} + OUTIND_{11,d}}{\sum_{d=1}^{NUM_r} (OUTIND_{13,d} + OUTIND_{11,d})} \tag{61}$$

where:

$DSRENW_{f,d}$	=	Share of output for renewable fuel f in Census division d,
$OUTIND_{13,d}$	=	Gross value of output for the paper and allied products industry in Census division d,
$OUTIND_{11,d}$	=	Gross value of output for the lumber and wood products industry in Census division d, and
NUM_r	=	Number of Census divisions in Census region r.

Energy consumption for each main and renewable fuel is computed by multiplying the consumption computed by the model at the Census region level by the appropriate Census division share.

$$DQMAIN_{f,d} = TQMAIN_{f,r} \times FUELSHARE_{f,d} \tag{62}$$

where:

$DQMAIN_{f,d}$	=	Consumption of main fuel f in Census division d,
$TQMAIN_{f,r}$	=	Total consumption of main fuel f in Census region r, and
$FUELSHARE_{f,d}$	=	Share of consumption of fuel f in Census division d.

Petroleum refineries lease and plant natural gas use, and fuels consumed for cogeneration in the oil and gas industry are not modeled explicitly in the industrial model. However, energy consumption from these industries is accounted for in total consumption from the industrial sector. Therefore, computed energy consumption values must be augmented by fuels consumed by refineries. In particular, the following fuels are consumed by refineries: electricity, natural gas, steam coal, residual oil, distillate oil, liquid petroleum gas, still gas, petroleum coke, and other petroleum. The following equation computes industrial consumption of natural gas for each Census division. All other fuels have similar equations with refinery consumption and oil and gas consumption included only where appropriate.

$$BMAIN_{ng,d} = \left[\sum_{f=3}^{5} DQMAIN_{f,d}\right] + QNGRF_{d,y} + \sum_{u=1}^{2} CGOGQ_{d,y,ng,u} \tag{63}$$

where:

$BMAIN_{ng,d}$	=	Consumption of natural gas in Census division d,
$DQMAIN_{f,d}$	=	Consumption of natural gas fuel f in Census division d,
$QNGRF_{d,y}$	=	Natural gas consumed by petroleum refining industry in Census division d in year y, and
$CGOGQ_{d,y,ng,u}$	=	Consumption of natural gas from cogeneration of electricity for use u in enhanced oil recovery in Census division d in year y.

Also accounted for in WEXOG are the supply of coal liquids and coal gases as shown in the following equation for industrial coal consumption.

$$BMAIN_{coal,d} = DQMAIN_{coal,d} + QCLRF_{d,y} + COPRCLQ_{d,y} + COPRCLG_{d,y} + \sum_{u=1}^{2} CGOGQ_{d,y,coal,u} \tag{64}$$

where:

$BMAIN_{coal,d}$	=	Consumption of coal in Census division d,
$DQMAIN_{coal,d}$	=	Consumption of coal in Census division d,
$QCLRF_{d,y}$	=	Coal consumed by petroleum refining industry in Census division d in year y,
$COPRCLQ_{d,y}$	=	Supply of coal liquids in Census division d in year y,
$COPRCLG_{d,y}$	=	Supply of coal gases in Census division d in year y, and
$CGOGQ_{d,y,coal,u}$	=	Consumption of coal from cogeneration of electricity for use u in enhanced oil recovery in Census division d in year y.

After all industrial consumption has been accounted for, the resulting values are benchmarked to SEDS consumption values that are calculated in the subroutine IBSEDS. Consumption of renewable fuels are benchmarked to the values in the Annual Energy Review June 1993.

$$OTHIND_{f,d} = \left[BMAIN_{f,d} \; x \; \frac{\sum_{y=1}^{MSEDYR} BENCHFAC_{f,d}}{2.0} \right] - BMAIN_{f,d} \tag{65}$$

where:

$OTHIND_{f,d}$	=	Consumption of fuel f for "other industry" in Census division d,
$BMAIN_{f,d}$	=	Consumption of fuel f in Census division d,
$MSEDYR$	=	Index of SEDS years, and
$BENCHFAC_{f,d}$	=	Benchmark factor for fuel f in Census division d.

Benchmarked consumption values are then passed into the appropriate variables for reporting to NEMS. The following equation calculates consumption of electricity. Equations for other fuels are similar.

$$QELIN_{d,y} = BMAIN_{elec,d} + OTHIND_{elec,d} \tag{66}$$

where:

$QELIN_{d,y}$	=	Industrial consumption of electricity in Census division d in year y,
$BMAIN_{elec,d}$	=	Consumption of electricity in Census division d, and
$OTHIND_{elec,d}$	=	Consumption of electricity for "other industry" in Census division d.

The following two equations represent the consumption of core and non-core natural gas.

$$QGFIN_{d,y} = \left[BMAIN_{ng,d} + OTHIND_{ng,d}\right] x \left[\frac{DQMAIN_{cng,d} + DQMAIN_{fds,d}}{BMAIN_{ng,d}}\right] \quad (67)$$

where:

$QGFIN_{d,y}$	=	Industrial consumption of core natural gas in Census division d in year y,
$BMAIN_{ng,d}$	=	Consumption of natural gas in Census division d,
$OTHIND_{ng,d}$	=	Consumption of natural gas for "other industry" in Census division d,
$DQMAIN_{cng,d}$	=	Consumption of core natural gas in Census division d, and
$DQMAIN_{fds,d}$	=	Consumption of feedstock natural gas in Census division d.

$$QGIIN_{d,y} = (BMAIN_{ng,d} + OTHIND_{ng,d}) - QGFIN_{d,y} \quad (68)$$

where:

$QGIIN_{d,y}$	=	Industrial consumption of non-core natural gas in Census division d in year y,
$BMAIN_{ng,d}$	=	Consumption of natural gas in Census division d,
$OTHIND_{ng,d}$	=	Consumption of natural gas for "other industry" in Census division d, and
$QGFIN_{d,y}$	=	Industrial consumption of core natural gas in Census division d in year y.

Consumption of total petroleum is calculated as follows.

$$QTPIN_{d,y} = \sum_{f=6}^{15} BMAIN_{f,d} + OTHIND_{f,d} \tag{69}$$

where:

$QTPIN_{d,y}$	=	Industrial consumption of total petroleum in Census division d in year y,
$BMAIN_{f,d}$	=	Consumption of fuel f in Census division d, and
$OTHIND_{f,d}$	=	Consumption of fuel f for "other industry" in Census division d.

Industrial consumption of biomass is calculated in the following equation.

$$QBMIN_{d,y} = \left[\sum_{f=2}^{3} DQRENW_{f,d}\right] + \left[\sum_{u=1}^{2} CGOGQ_{d,y,bm,u}\right] + QBMRF_{d,y} \tag{70}$$

where:

$QBMIN_{d,y}$	=	Industrial consumption of biomass in Census division d in year y,
$DQRENW_{f,d}$	=	Consumption of renewable fuel f in Census division d,
$CGOGQ_{d,y,bm,u}$	=	Consumption of biomass from cogeneration of electricity for use u in enhanced oil recovery in Census division d in year y, and
$QBMRF_{d,y}$	=	Biomass consumed by petroleum refining industry in Census division d in year y.

Consumption of total renewables is calculated through the following equation.

$$QTRIN_{d,y} = QHOIN_{d,y} + QBMIN_{d,y} + QGEIN_{d,y} + QSTIN_{d,y} + QPVIN_{d,y} + QWIIN_{d,y} + QMSIN_{d,y} \quad (71)$$

where:

$QTRIN_{d,y}$	=	Industrial consumption of total renewables in Census division d in year y,
$QHOIN_{d,y}$	=	Industrial consumption of hydropower in Census division d in year y,
$QBMIN_{d,y}$	=	Industrial consumption of biomass in Census division d in year y,
$QGEIN_{d,y}$	=	Industrial consumption of geothermal in Census division d in year y,
$QSTIN_{d,y}$	=	Industrial consumption of solar thermal in Census division d in year y,
$QPVIN_{d,y}$	=	Industrial consumption of photovoltaic in Census division d in year y,
$QWIIN_{d,y}$	=	Industrial consumption of wind in Census division d in year y, and
$QMSIN_{d,y}$	=	Industrial consumption of municipal solid waste in Census division d in year y.

Currently, only biomass (including pulping liquor) and hydropower are implemented in the model.

Variables pertaining to industrial cogeneration of electricity including generation for own use and sales to the grid, capacity, and fuel consumption are also passed to the appropriate NEMS variables. Cogeneration data from the refining and oil and gas industries are included in the industrial cogeneration data passed to NEMS as shown in the following equation for capacity. Similar equations are used to incorporate refining and oil and gas cogeneration for own use and sales to the grid as well as fuel consumption.

$$CGINDCAP_{d,y,f,u,pl} = CAPGW_{d,f,u,pl} + CGRECAP_{d,y,f,u,pl} + CGOGCAP_{d,y,f,u} \tag{72}$$

where:

$CGINDCAP_{d,y,f,u,pl}$	=	Industrial planned capacity for cogeneration for use u using fuel f in Census division d in year y,
$CAPGW_{d,f,u,pl}$	=	Existing or planned capacity for cogeneration of electricity for use u using fuel f in Census division d,
$CGRECAP_{d,y,f,u,pl}$	=	Refinery planned capacity for cogeneration for use u using fuel f in Census division d in year y, and
$CGOGCAP_{d,y,f,u,pl}$	=	Oil and gas planned capacity for cogeneration for use u using fuel f in Census division d in year y.

Total consumption is calculated below.

$$CGINDQ_{d,y,f,u} = DIVFUEL_{d,f,u} + CGREQ_{d,y,f,u} + CGOGQ_{d,y,f,u} \tag{73}$$

where:

$CGINDQ_{d,y,f,u}$	=	Industrial consumption of fuel f for cogeneration of electricity for use u in Census division d in year y,
$DIVFUEL_{d,f,u}$	=	Consumption of fuel f for cogeneration of electricity for use u in Census division d,
$CGREQ_{d,y,f,u}$	=	Consumption of fuel f from cogeneration of electricity for use u in refineries in Census division d in year y, and
$CGOGQ_{d,y,f,u}$	=	Consumption of fuel f from cogeneration of electricity for use u in enhanced oil recovery in Census division d in year y.

Consumption values for manufacturing heat and power must be augmented by fuels purchased for refineries before passing to NEMS as shown in the following equation.

$$MANHP_{elec,y} = TMANHP_{elec} + QELRF_{d,y} \tag{74}$$

where:

$MANHP_{elec,y}$	=	Consumption of electricity for manufacturing heat and power in year y,
$TMANHP_{elec}$	=	Total manufacturing consumption of electricity for heat and power, and
$QELRF_{d,y}$	=	Electricity consumed by petroleum refining industry in Census division d in year y.

Consumption of natural gas, coal, residual, distillate, liquid petroleum gas, still gas, petroleum coke, and others are calculated in a similar fashion.

Consumption for non-manufacturing heat and power is adjusted to include consumption from oil and gas mining.

$$NONHP_{f,y} = TNONHP_f + \sum_{u=1}^{2} CGOGQ_{total,y,f,u} \tag{75}$$

where:

$NONHP_{f,y}$	=	Consumption of fuel f for non-manufacturing heat and power in year y,
$TNONHP_f$	=	Total non-manufacturing consumption of fuel f for heat and power, and
$CGOGQ_{total,y,f,u}$	=	Consumption of fuel f from cogeneration of electricity for use u in enhanced oil recovery in all Census divisions in year y.

Consumption for miscellaneous feedstocks in each of the energy-intensive industries are passed to the appropriate variables for usage by NEMS. Emissions are computed based on the benchmarked values shown below.

$$DEMIMAIN_{f,p,d} = \left[BMAIN_{f,d} + OTHIND_{f,d}\right] \times UNCONTEMISSFACT_{f,p} \times EMISSCONTROLFAC_{f,p} \quad (76)$$

where:

$DEMIMAIN_{f,p,d}$	=	Emissions of pollutant p from main fuel f in Census division d,
$BMAIN_{f,d}$	=	Consumption of main fuel f in Census division d,
$OTHIND_{f,d}$	=	Consumption of fuel f from other industry in Census division d,
$UNCONTEMISSFACT_{f,p}$	=	Uncontrolled emission factor for pollutant p using fuel f, and
$EMISSCONTROLFAC_{f,p}$	=	Emissions control factor for pollutant p using fuel f.

Emissions for natural gas and liquid petroleum gas must be adjusted to remove feedstocks as shown in the following two equations.

$$\begin{aligned} DEMIMAIN_{ng,p,d} = {} & (BMAIN_{ng,d} + OTHIND_{ng,d}) - (BENCHFAC_{ng,d} \times DQMAIN_{ng,d}) + \\ & (BENCHFAC_{ng,d} \times QLPIN_{d,y} \times UNCONTEMISSFACT_{cng,p} \times EMISSCONTROLFAC_{cng,p}) + \\ & (BENCHFAC_{ng,d} \times DQMAIN_{ng,d} \times UNCONTEMISSFACT_{fng,p} \times EMISSCONTROLFAC_{fng,p}) \end{aligned} \quad (77)$$

where:

$DEMIMAIN_{ng,p,d}$	=	Emissions of pollutant p from natural gas in Census division d,

$BMAIN_{ng,d}$	=	Consumption of natural gas in Census division d,
$OTHIND_{ng,d}$	=	Consumption of natural gas from other industry in Census division d,
$BENCHFAC_{ng,d}$	=	Benchmark factor for natural gas in Census division d,
$DQMAIN_{ng,d}$	=	Consumption of natural gas in Census division d,
$QLPIN_{d,y}$	=	Industrial consumption of lease and plant natural gas in Census division d in year y,
$UNCONTEMISSFACT_{cng,p}$	=	Uncontrolled emission factor for pollutant p using core natural gas,
$EMISSCONTROLFAC_{cng,p}$	=	Emissions control factor for pollutant p using core natural gas,
$UNCONTEMISSFACT_{fng,p}$	=	Uncontrolled emission factor for pollutant p using feedstock natural gas, and
$EMISSCONTROLFAC_{fng,p}$	=	Emissions control factor for pollutant p using feedstock natural gas.

$$DEMIMAIN_{lpg,p,d} = \left((BMAIN_{lpg,d} + OTHIND_{lpg,d}) - (BENCHFAC_{lpg,d} \text{ x } DQMAIN_{lpg,d}\right) \text{ x } \left(UNCONTEMISSFACT_{lpghp,p} \text{ x } EMISSCONTROLFAC_{lpghp,p}\right) + (BENCHFAC_{lpg,d} \text{ x } DQMAIN_{lpg,d} \text{ x } UNCONTEMISSFACT_{lpgf,p} \text{ x } EMISSCONTROLFAC_{lpgf,p}) \quad (78)$$

where:

$DEMIMAIN_{lpg,p,d}$	=	Emissions of pollutant p from liquid petroleum gas in Census division d,
$BMAIN_{lpg,d}$	=	Consumption of liquid petroleum gas in Census division d,
$OTHIND_{lpg,d}$	=	Consumption of liquid petroleum gas from "other industry" in Census division d,

$BENCHFAC_{lpg,d}$ = Benchmark factor for liquid petroleum gas in Census division d,

$DQMAIN_{lpg,d}$ = Consumption of liquid petroleum gas in Census division d,

$UNCONTEMISSFACT_{lpghp,p}$ = Uncontrolled emission factor for pollutant p using liquid petroleum gas for heat and power,

$EMISSCONTROLFAC_{lpghp,p}$ = Emissions control factor for pollutant p using liquid petroleum gas for heat and power,

$UNCONTEMISSFACT_{lpgf,p}$ = Uncontrolled emission factor for pollutant p using liquid petroleum gas for feedstocks, and

$EMISSCONTROLFAC_{lpgf,p}$ = Emissions control factor for pollutant p using liquid petroleum gas for feedstocks.

For emissions of SO_x the following equation is used. Currently, only carbon emissions have been implemented.

$$DEMIMAIN_{f,p,d} = DEMIMAIN_{f,p,d} \times SULFURCONT_f \qquad (79)$$

where:

$DEMIMAIN_{f,p,d}$ = Emissions of pollutant p from main fuel f in Census division d, and

$SULFURCONT_f$ = Sulfur content of fuel f.

Emissions for renewables are calculated by the equation below.

$$DEMIRENW_{f,p,d} = TEMISR_{f,p,r} \times DSRENW_{f,d} \qquad (80)$$

where:

$DEMIRENW_{f,p,d}$ = Emissions of pollutant p from renewable fuel f in Census division d,

$TEMISR_{f,p,r}$ = Total emissions of pollutant p from renewable fuel f in Census region r, and

$DSRENW_{f,d}$ = Consumption of renewable fuel f in Census division d.

Emissions are calculated through the following equations. Emissions of methane and particulates are assigned a value of zero.

$$EMINCX_{f,p,d,y} = \sum_{f=1}^{NUM_{fg}} DEMIMAIN_{f,p,d} \tag{81}$$

where:

$EMINCX_{f,p,d,y}$ = Emissions of pollutant p from fuel f in Census division d in year y,

NUM_{fg} = Number of fuels in fuel group fg, and

$DEMIMAIN_{f,p,d}$ = Emissions of pollutant p from main fuel f in Census division d.

$$EMINC_{f,p,y} = \frac{EMINCX_{f,p,total,y}}{10^6} \tag{82}$$

where:

$EMINC_{f,p,y}$ = Industrial emissions of pollutant p from fuel f in year y,

$EMINCX_{f,p,total,y}$	=	Emissions of pollutant p from fuel f in all Census divisions in year y, and
10^6	=	Conversion factor to convert to million metric tons.

Subroutine IBSEDS

IBSEDS calculates benchmark factors for consumption. The benchmark factors are based on the ratio of SEDS consumption of the fuel to the consumption calculated by the industrial model.

$$BENCHFAC_{f,d} = \frac{SEDSIND_{f,d}}{BMAIN_{f,d}} \tag{83}$$

where:

$BENCHFAC_{f,d}$	=	Benchmark factor for fuel f in Census division d,
$SEDSIND_{f,d}$	=	SEDS consumption of fuel f in Census division d, and
$BMAIN_{f,d}$	=	Consumption of main fuel f in Census division d.

The benchmark factor for biomass is computed as follows.

$$BENCHFAC_{bm,d} = \frac{BIOFUELS_d}{\sum_{f=2}^{3} DQRENW_{f,d}} \tag{84}$$

where:

$BENCHFAC_{bm,d}$	=	Benchmark factor for biomass in Census division d,

$BIOFUELS_d$	=	Consumption of biofuels in Census division *d*, and
$DQRENW_{f,d}$	=	Consumption of renewable fuel *f* in Census division *d*.

A category labeled "Other Industry" is computed as the difference between the benchmarked consumption and the modeled consumption.

$$OTHIND_{f,d} = (BENCHFAC_{f,d} \times BMAIN_{f,d}) - BMAIN_{f,d} \qquad (85)$$

where:

$OTHIND_{f,d}$	=	Consumption of fuel *f* for "other industry" in Census division *d*,
$BENCHFAC_{f,d}$	=	Benchmark factor for fuel *f* in Census division *d*, and
$BMAIN_{f,d}$	=	Consumption of main fuel *f* in Census division *d*.

Subroutine RDBIN

RDBIN is called by the main industrial subroutine ISEAM on model runs after the first model year. This subroutine reads the previous year's data from the binary files. The previous year's values are assigned to lagged variables for price, value of output, and employment. The previous year's UECs, TPC coefficients, price elasticities, and intercepts are read into the variables for initial UEC, TPC, price elasticity, and intercept. Process specific data is read into either a lagged variable or an initial estimate variable. Three cumulative variables are calculated in this subroutine for future use. A cumulative output variable, a cumulative UEC, and a cumulative production variable are computed for each fuel and process step.

MODCAL

MODCAL performs like the main industrial subroutine ISEAM in all years after the first model year. In subsequent years, no data must be read from the input files, however, UECs and TPC coefficients must be adjusted to reflect the new model year, whereas the first model year uses only initial estimates of these values. MODCAL calls the following subroutines: CALPROD, CALCSC, CALPRC, CALPATOT, CALBYPROD, CALBTOT, CALGEN, CALBSC, CALSTOT, INDTOTAL, NATTOTAL, INDEMISS, and CONTAB. Similar to the functioning of ISEAM, the subroutines NATTOTAL, INDEMISS, and CONTAB are called only after the last region for an industry has been processed.

Subroutine CALPROD

CALPROD determines the throughput for production flows for the process and assembly component. Existing old and middle vintage production is adjusted by the retirement rate of capital through the following equations for the manufacturing industries.

$$PRODCUR_{old,s} = \left[PRODCUR_{old,s} + IDLCAP_{old,s}\right] x \; (1 - PRODRETR_s) \tag{86}$$

where:

$PRODCUR_{old,s}$	=	Existing production for process step s for old vintage,
$IDLCAP_{old,s}$	=	Idle production at process step s for old vintage, and
$PRODRETR_s$	=	Retirement rate at process step s.

$$PRODCUR_{mid,s} = (PRODCUR_{mid,s} + PRODCUR_{new,s}) \; x \; (1 - PRODRETR_s) \tag{87}$$

where:

$PRODCUR_{mid,s}$ = Existing production at process step s for mid vintage,

$PRODCUR_{new,s}$ = Production at process step s for new vintage,

$PRODRETR_s$ = Retirement rate at process step s.

For the non-manufacturing industries, the following two equations are used for old vintage and middle vintage production.

$$PRODCUR_{old,s} = PRODCUR_{old,s} + IDLCAP_{old,s} \quad \textbf{(88)}$$

where:

$PRODCUR_{old,s}$ = Existing production at process step s for old vintage, and

$IDLCAP_{old,s}$ = Idle production for process step s for old vintage.

$$PRODCUR_{mid,s} = PRODCUR_{mid,s} + PRODCUR_{new,s} \quad \textbf{(89)}$$

where:

$PRODCUR_{mid,s}$ = Existing production at process step s for mid vintage, and

$PRODCUR_{new,s}$ = Production at process step s for new vintage.

Total production throughput for the industry is calculated. If the initial UEC is in physical units, the value of output for the current year is multiplied by the fixed ratio of physical units to value of output calculated on the first model run in the subroutine PDATA.

$$PRODX_{i,r} = PHDRAT \times PRODVX_{i,r} \quad \textbf{(90)}$$

where:

$PRODX_{i,r}$	=	Value of output in physical units for industry i in Census region r,
$PHDRAT$	=	Ratio of physical units to value of output, and
$PRODVX_{i,r}$	=	Value of output for industry i in Census region r.

If the initial UEC is in dollar units, then the current year's value of output is used to determine total production throughput.

For each process step that is linked to final consumption, then the total production throughput is calculated by the following procedure:

1. The total production throughput for all vintages is calculated in the following equation by multiplying the down-step throughput to the process step by the value of output.

$$PRODCUR_{total,s} = PRODFLOW_{old,s,l} \times PRODX_{i,r} \tag{91}$$

where:

$PRODCUR_{total,s}$	=	Production at process step s for all vintages,
$PRODFLOW_{old,s,l}$	=	Down-step throughput to process step s by link l for old vintage, and
$PRODX_{i,r}$	=	Value of output for industry i in Census region r.

2. If the total production throughput for all vintages is greater than the existing old and middle vintage production, then new production must be added. The new production becomes the difference between the total production throughput for all vintages and existing production.

$$PRODCUR_{new,s} = PRODCUR_{total,s} - PRODCUR_{old,s} - PRODCUR_{mid,s} \tag{92}$$

where:

$PRODCUR_{new,s}$	=	New production at process step s for new vintage,
$PRODCUR_{total,s}$	=	Total production at process step s for all vintages,
$PRODCUR_{old,s}$	=	Existing production at process step s for old vintage, and
$PRODCUR_{mid,s}$	=	Existing production at process step s for mid vintage.

Middle vintage production is unaltered.

3. If the total production throughput for all vintages equals existing production, then no new production is installed and middle vintage production is unaltered.

4. If the total production throughput for all vintages is less than existing production, then no new production capacity is installed. Idle production becomes the difference between total production throughput for all vintages and existing production. Idle production is determined through the following equation.

$$IDLCAP_{old,s} = PRODCUR_{old,s} + PRODCUR_{mid,s} - PRODCUR_{total,s} \tag{93}$$

where:

$IDLCAP_{old,s}$	=	Idle production for process step s for old vintage,
$PRODCUR_{old,s}$	=	Existing production at process step s for old vintage,
$PRODCUR_{mid,s}$	=	Existing production at process step s for mid vintage, and
$PRODCUR_{total,s}$	=	Production at process step s for all vintages.

Old vintage production is then reduced by the following equation:

$$PRODCUR_{old,s} = PRODCUR_{old,s} - IDLCAP_{old,s} \quad (94)$$

where:

$PRODCUR_{old,s}$	=	Existing production at process step s for old vintage, and
$IDLCAP_{old,s}$	=	Idle production for process step s for old vintage.

If the process step is not linked to final consumption, then the following procedure determines production for the process step:

1. If no new production has been added, then the total production for the current process step is augmented by multiplying the down-step throughout by the total production throughput of the final consumption. This is shown in the following two equations.

$$PRODSUM_{new,s,l} = PRODCUR_{total,IP} \times PRODFLOW_{old,s,l} \quad (95)$$

where:

$PRODSUM_{new,s,l}$	=	Amount of throughput used at process step s through link l for new vintage,
$PRODCUR_{total,IP}$	=	Production at process step IP linked to process step s through link l for all vintages, and
$PRODFLOW_{old,s,l}$	=	Down-step throughput to process step s linked by link l for old vintage.

$$PRODCUR_{total,s} = PRODCUR_{total,s} + PRODSUM_{new,s,l} \quad (96)$$

where:

$PRODCUR_{total,s}$	=	Production at process step s for all vintages, and

$PRODSUM_{new,s,l}$	=	Amount of throughput used at process step s through link l for new vintage.

If the current link is the last link for the process step, then there is no new capital installed. Production for old vintage becomes the difference between the total for all vintages and the production for middle vintage.

$$PRODCUR_{old,s} = PRODCUR_{total,s} - PRODCUR_{mid,s} \tag{97}$$

where:

$PRODCUR_{old,s}$	=	Existing production at process step s for old vintage,
$PRODCUR_{total,s}$	=	Production at process step s for all vintages, and
$PRODCUR_{mid,s}$	=	Existing production at process step s for mid vintage.

If the production for old vintage is less than zero, then all of the old and part of the middle vintage production is retired. If the production for middle vintage is less than zero, then the remaining middle vintage production is retired.

2. If new production is added, then production is augmented by multiplying the down-step throughput to the current process step through the current link as shown in the equations below.

$$PRODSUM_{new,s,l} = PRODCUR_{new,JP} \times PRODFLOW_{new,s,l} \tag{98}$$

where:

$PRODSUM_{new,s,l}$	=	Amount of throughput used at process step s through link l for new vintage,

$PRODCUR_{new,IP}$	=	Production at process step *IP* linked to process step *s* through link *l* for new vintages, and
$PRODFLOW_{new,s,l}$	=	Down-step throughput to process step *s* linked by link *l* for new vintage.

$$PRODCUR_{new,s} = PRODCUR_{new,s} + PRODSUM_{new,s,l} \qquad (99)$$

where:

$PRODCUR_{new,s}$	=	Production at process step *s* for new vintage, and
$PRODSUM_{new,s,l}$	=	Amount of throughput used at process step *s* through link *l* for new vintage.

If the current link is the last link for the process step, then middle vintage production is unaltered.

If the new production at the first process step is not zero, then the total production at a particular process step is determined by summing the production for old, middle, and new vintage.

Subroutine CALCSC

CALCSC is called to update unit energy consumption. CALCSC calls one of three subroutines, CALCSC1, CALCSC2, or CALCSC3 depending on the type of approach for a particular fuel, process step, and industry. CALCSC1 maintains constant UECs. CALCSC2 applies the econometric approach for non-energy-intensive industries. CALCSC3 applies the engineering approach for energy-intensive industries.

Subroutine CALCSC1

CALCSC1 updates UECs based on the previous year's UEC. Unit energy consumption for each fuel, process step, and vintage is updated in the equation below. This approach yields constant UECs over time.

$$ENPINT_{v,f,s} = ENPINTLAG_{v,f,s} \tag{100}$$

where:

$ENPINT_{v,f,s}$	=	Unit energy consumption of fuel f at process step s for vintage v, and
$ENPINTLAG_{v,f,s}$	=	Lagged unit energy consumption of fuel f at process step s for vintage v.

Subroutine CALCSC2

CALCSC2 updates UECs through an econometrically estimated equation. Energy savings, or the location on the technology possibility curve, is calculated in the following equation for old and new vintage and is based on the total cumulative output raised to the coefficient.

$$CSCCUR_{v,f,s} = \left[CUMOUT_{total,s}\right]^{BCSC_{v,f,s}} \tag{101}$$

where:

$CSCCUR_{v,f,s}$	=	Current energy savings at process step s for fuel f for vintage v,

$CUMOUT_{total,s}$	=	Cumulative output, from 1958 through the lag of the current year, at process step s for all vintages, and
$BCSC_{v,f,s}$	=	Energy savings coefficient at process step s for fuel f and vintage v.

As noted on page 121, CUMOUT is calculated in RDBIN.

The unit energy consumption for old and new vintage is calculated by multiplying the intercept term calculated in CALINTER by the current energy savings.

$$ENPINT_{v,f,s} = EINTER_{v,f,s} \times CSCCUR_{v,f,s} \tag{102}$$

where:

$ENPINT_{v,f,s}$	=	Unit energy consumption of fuel f at process step s for vintage v,
$EINTER_{v,f,s}$	=	Intercept at process step s for fuel f for vintage v, and
$CSCCUR_{v,f,s}$	=	Current energy savings at process step s for fuel f for vintage v.

The UEC for middle vintage is computed in the following equation as the ratio of the cumulative unit energy consumption to cumulative production for new vintage, i.e., it is simply the weighted average UEC.

$$ENPINT_{mid,f,s} = \frac{SUMPINT_{f,s}}{CUMPROD_{new,s}} \tag{103}$$

where:

$ENPINT_{mid,f,s}$	=	Unit energy consumption of fuel f at process step s for mid vintage,
$SUMPINT_{f,s}$	=	Cumulative unit energy consumption of fuel f at process step s, and
$CUMPROD_{new,s}$	=	Cumulative production at process step s for new vintage.

As noted on page 121, the cumulative variables are calculated in RDBIN.

Subroutine CALCSC3

CALCSC3 computes UECs according to an approach suggested by Arthur D. Little (ADL). The energy savings for old and new vintage is calculated below as the exponential of the TPC coefficient multiplied by a yearly index.

$$CSCCUR_{v,f,s} = e^{BCSC_{v,f,s} \times (CURIYR - 1)} \tag{104}$$

where:

$CSCCUR_{v,f,s}$	=	Current energy savings (0 < fraction < 1) at process step s for fuel f for vintage v,
$BCSC_{v,f,s}$	=	Energy savings coefficient at process step s for fuel f and vintage v, and
$CURIYR$	=	Current year index.

The unit energy consumption for old and new vintage is computed as in CALCSC2 by multiplying the current energy savings by the intercept. In a few process steps, fuel shares are expected to change over time due to technology changes. These process steps are cold rolling, blast furnaces, and electric arc furnaces in the blast furnace and basic steel products industry and dry process clinker in the hydraulic cement industry. The following equation calculates the unit energy consumption of electricity in the cold rolling process step. Similar equations exist for other fuels used in cold rolling and for the blast furnace/basic oxygen furnace process step (see Table E-8, Appendix E).

$$ENPINT_{new,elec,s} = EINTER_{new,elec,s} \times CSCCUR_{new,elec,s} \times \frac{1}{0.20}\left[0.20 + \frac{(0.21 - 0.20) \times (CURIYR - 1)}{25}\right] \quad (105)$$

where:

$ENPINT_{new,elec,s}$	=	Unit energy consumption of electricity at process step s for new vintage,
$EINTER_{new,elec,s}$	=	Intercept at process step s for electricity for new vintage,
$CSCCUR_{new,elec,s}$	=	Current energy savings at process step s for electricity and new vintage, and
$CURIYR$	=	Current year index.

The UECs for middle vintage are calculated as in CALCSC2 and shown below, by the ratio of cumulative UEC to cumulative production for all process steps and industries, i.e., the weighted average UEC.

$$ENPINT_{mid,f,s} = \frac{SUMPINT_{f,s}}{CUMPROD_{new,s}} \quad (106)$$

where:

$ENPINT_{mid,f,s}$	=	Unit energy consumption of fuel f at process step s for middle vintage,
$SUMPINT_{f,s}$	=	Cumulative unit energy consumption of fuel f at process step s, and
$CUMPROD_{new,s}$	=	Cumulative production at process step s for new vintage.

Subroutine CALPRC

CALPRC is called to update unit energy consumption based on price parameters. CALPRC calls one of the three subroutines CALPRC1, CALPRC2, or CALPRC3, depending on the approach to be taken. CALPRC1 assumes unit energy consumption is constant. CALPRC2 uses an econometric equation to update UECs. CALPRC3 is currently not implemented.

Subroutine CALPRC1

The unit energy consumption is unaltered by CALPRC1.

Subroutine CALPRC2

CALPRC2 calculates unit energy consumption based on price related conservation using an econometric equation. Average prices for each fuel are calculated to accommodate the equation. Price based energy savings is calculated below as the product of the average price of a particular fuel raised to each cross price elasticity for both old and new vintage.

$$PRCCUR_{v,f,s} = \prod_{t=1}^{11} \left[WPRC_t\right]^{BELAS_{v,f,s,t}} \tag{107}$$

where:

$PRCCUR_{v,f,s}$	=	Current energy savings based on price for fuel f at process step s for vintage v,
$WPRC_t$	=	Price for fuel t in 1987 dollars, and
$BELAS_{v,f,s,t}$	=	Own price elasticity at process step s for fuel f for old vintage and cross price elasticity at process step s for fuel f and fuel t for old vintage.

Unit energy consumption is then computed by multiplying the unit energy consumption by the price based energy savings.

$$ENPINT_{v,f,s} = ENPINT_{v,f,s} \times PRCCUR_{v,f,s} \tag{108}$$

where:

$ENPINT_{v,f,s}$	=	Unit energy consumption of fuel f at process step s for vintage v, and
$PRCCUR_{v,f,s}$	=	Current energy savings based on price for fuel f at process step s for vintage v.

Subroutine CALBSC

CALBSC calculates boiler fuel shares for the current year. Boiler fuel shares are based on the previous year's boiler fuel share, the ratio of the current year's price to the previous year's price, and cross price elasticities as shown in the following two equations.

$$BSSHR_f = \begin{array}{l} BSSHRLAG_f \times \left[\dfrac{PRCX_{f,r}}{PRCXLAG_f}\right]^{BSSHRE_f} \times \left[\dfrac{PRCX_{ng,r}}{PRCXLAG_{ng}}\right]^{BSSHRNG_f} \\ \times \left[\dfrac{PRCX_{oil,r}}{PRCXLAG_{oil}}\right]^{BSSHROIL_f} \times \left[\dfrac{PRCX_{coal,r}}{PRCXLAG_{coal}}\right]^{BSSHRCL_f} \end{array} \tag{109}$$

where:

$BSSHR_f$	=	Share of total fuel consumption in the BSC component for fuel f,
$BSSHRLAG_f$	=	Lagged boiler share for fuel f,
$PRCX_{f,r}$	=	Price for fuel f in Census region r,

$PRCXLAG_f$	=	Lagged price for fuel f,
$BSSHRE_f$	=	Own price elasticity for fuel f,
$BSSHRNG_f$	=	Cross price elasticity of natural gas with fuel f,
$BSSHROIL_f$	=	Cross price elasticity of oil with fuel f, and
$BSSHRCL_f$	=	Cross price elasticity of steam coal with fuel f.

The boiler shares are normalized to make sure that when less of a particular fuel is consumed in the boiler, that the same amount is picked up by some other fuel.

$$BSSHR_f = \frac{BSSHR_f}{\sum_{f=1}^{IFSMAX} BSSHR_f} \qquad (110)$$

where:

$BSSHR_f$	=	Share of total fuel consumption in the BSC component for fuel f, and
$IFSMAX$	=	Number of fuels consumed in the BSC component.

Appendix A. Data Sources, Input Parameters, Model Variables

Introduction

This appendix describes the module inputs, module parameters, and output variables for the Industrial model. A list of the subscripts used in variable definitions and equations is provided in Table A-1. The variable list in Table A-2 references the module inputs, module parameters, and module outputs. Each item is accompanied by its definition as well as its dimensions.

Table A-3 categorizes each item listed in Table A-2 as "Module Inputs", "Module Parameters", "Calculated Variable", or "Module Outputs". This table also lists the equation reference to link variables in Table A-2 to the equations represented in Appendix B. Table A-3 provides the units of measurement where applicable for each variable.

The remainder of this appendix contains supporting discussion on the input data, including the sources of the data and any transformations occurring offline.

Table A-1. Subscript Definitions

Subscript	Definition	Possible values
d	Census division	d = 1,...,9
e	Building end use	e = 1 lighting 2 HVAC
f	Fuel	Main fuels f = 1 electricity 2 cogenerated electricity 3 core natural gas 4 non-core natural gas 5 feedstock natural gas 6 lease and plant natural gas 7 steam coal 8 coking coal 9 net coke imports 10 residual oil 11 distillate oil 12 liquid petroleum gas for heat and power 13 liquid petroleum gas for feedstocks 14 motor gasoline 15 still gas 16 petroleum coke 17 asphalt and road oil 18 lubes and waxes 19 petrochemical feedstocks 20 kerosene 21 other petroleum feedstocks 22 other petroleum Intermediate fuels f = 1 steam 2 coke oven gas 3 blast furnace gas 4 other byproduct gas 5 waste heat 6 coke Renewable fuels f = 1 hydropower 2 biomass-wood 3 biomass-pulping liquor 4 geothermal 5 solar 6 photovoltaic 7 wind 8 municipal solid waste

Subscript	Definition		Possible values
i	Industry	i =	1 agriculture - crops 2 agriculture - other 3 coal mining 4 oil and gas mining 5 metal and other non-metallic mining 6 construction 7 food and kindred products 8 tobacco products 9 textile mill products 10 apparel and other textile products 11 lumber and wood products 12 furniture and fixtures 13 paper and allied products 14 printing and publishing 15 bulk chemicals 19 other chemicals and allied products 20 petroleum refining 21 asphalt and miscellaneous coal products 22 rubber and miscellaneous plastics products 23 leather and leather products 24 glass and glass products 25 cement, hydraulic 26 other stone, clay, and glass products 27 blast furnace and basic steel products 28 primary aluminum 29 other primary metals 30 fabricated metals 31 industrial machinery 32 electronic and other electric equipment 33 transportation equipment 34 instruments and related products 35 miscellaneous manufacturing industries
l	Link	l =	1,...,NTMAX,
m	Prime mover	m =	1 internal combustion engine 2 combustion turbine 3 steam turbine 4 renewables
p	Pollutant	p =	1 carbon 2 carbon monoxide 3 carbon dioxide 4 methane 5 sulfur dioxide 6 nitrogen oxide 7 volatile organic compounds 8 particulates
r	Census region	r =	1,...,4
s	Process step	s =	1,...,MPASTP
t	Fuel type for cross price elasticities	t =	1 own price 2 electricity 3 natural gas 4 steam coal 5 petroleum oil 6 motor gasoline 7 asphalt 8 other petroleum 9 liquid petroleum gas 10 distillate oil 11 residual oil

Subscript	Definition		Possible values
u	Use of cogenerated electricity	u =	1 sales to the grid 2 own use
v	Vintage	v =	1 old 2 middle 3 new
y	Year	y =	1990,...,2010

Table A-2. NEMS Industrial Sector Model Variables

Model Variable	Definition and Dimensions	Page Reference
ALUMCON	Consumption of fuel *f* from the primary aluminum industry in year *y*	A-22, B-95
AVGINT	Average intensity	92, 94, A-19, B-42, B-44
BCSC	Energy savings coefficient at process step *s* for fuel *f* and vintage *v*	84, 130, 131, A-19, A-25, A-42, B-18, B-19, B-31
BELAS	Own price elasticity at process step *s* for fuel *f* for vintage *v* and cross price elasticity at process step *s* for fuel *f* and fuel *t* for vintage *v*	84, 134, A-19, A-27, B-30, B-31
BENCHFAC	Benchmark factor for fuel *f* in Census division *d*	110, 116, 117, 121, A-19, B-87, B-96, B-97, B-100, B-101
BIOFUELS	Consumption of biofuels in Census division *d*	121, A-19, B-101
BMAIN	Consumption of main fuel *f* in Census division *d*	108 to 111, 116, 117, 120, 121, A-19, B-82 to B-88, B-95 to B-97, B-100, B-101
BOILSTEAM	Steam generated from boilers	90, A-19, B-39
BSSHR	Share of total fuel consumption in the BSC component for fuel *f*	92, 94, 134, A-16, A-28, B-43, B-44, B-47, B-48
BSSHRCL	Cross price elasticity for steam coal with fuel *f*	135, A-19, A-29, B-47
BSSHRE	Own price elasticity for fuel *f*	135, A-19, A-31, B-47
BSSHRLAG	Lagged boiler share for fuel *f*	135, A-19, B-47
BSSHRNG	Cross price elasticity for natural gas with fuel *f*	135, A-19, A-33, B-47
BSSHROIL	Cross price elasticity for oil with fuel *f*	135, A-19, A-35, B-47
BYPBSCI	Byproduct consumption of intermediate fuel *f* in the BSC component	93, A-19, B-43
BYPBSCM	Byproduct consumption of main fuel *f* in the BSC component	93, 96, A-19, B-43, B-67
BYPBSCR	Byproduct consumption of renewable fuel *f* in the BSC component	93, A-19, B-43, B-67
BYPCSC	Byproduct technology possibility curve coefficient for byproduct fuel *f* at process step *s* for vintage *v*	76, A-19, A-37, B-61
BYPCSCCUR	Current energy savings for byproduct fuel *f* at process step *s* for vintage *v*	76 to 78, A-19, B-61, B-62
BYPCSCLAG	Lagged energy savings for byproduct fuel *f* at process step *s* for vintage *v*	77, A-19, B-62

Model Variable	Definition and Dimensions	Page Reference
BYPINT	Rate of byproduct energy production for byproduct fuel *f* at process step *s* for vintage *v*	77, 78, A-16, A-38, B-62, B-63
BYPINTLAG	Lagged rate of byproduct energy production for byproduct fuel *f* at process step *s* for vintage *v*	78, A-19, B-62
BYPQTY	Byproduct energy production for byproduct fuel *f* at process step *s* for vintage *v*	78, 79, A-19, B-63 to B-65
BYPSTM	Amount of steam generated from all byproduct fuels	92, 93, A-19, B-43, B-44
BYSINT	Intensity for byproduct fuel *f* consumed in the BSC component	93, A-16, A-39, B-43
BYSQTY	Consumption of byproduct fuel *f* in the BSC component	95, A-19, B-45, B-46
CAPD	Existing or planned capacity for cogeneration of electricity for use *u* in Census division *d* using fuel *f* in year *y*	101, 102, 105, 106, A-19, B-50, B-51, B-53, B-56, B-57
CAPDIV	Planned capacity for electricity generation for use *u* in Census division *d* using fuel *f* in year *y*	102, A-20, B-51
CAPGW	Planned or unplanned capacity for cogeneration of electricity for use *u* using fuel *f* in Census division *d*	103, 105, 106, 113, A-20, B-54 to B-57, B-90
CAPGWLAG	Lagged planned or unplanned capacity for cogeneration of electricity for use *u* using fuel *f* in Census division *d*	105, A-20, B-56
CAPREG	Existing or planned capacity for cogeneration of electricity for use *u* in Census region *r* using fuel *f* in year *y*	102, A-16, A-40, B-49, B-50
CEMENTCON	Consumption of fuel *f* by the hydraulic cement industry in year *y*	A-22, B-94
CGFUEL	Consumption of fuel *f* for cogeneration of electricity for use *u* in Census region *r*	91, A-20, B-39 to B-42
CGINDCAP	Industrial capacity for cogeneration for use *u* using fuel *f* in Census division *d* in year *y*	113, A-22, B-90
CGINDGEN	Industrial cogeneration of electricity for use *u* using fuel *f* in Census division *d* in year *y*	A-22, B-91
CGINDQ	Industrial consumption of fuel *f* for cogeneration of electricity for use *u* in Census division *d* in year *y*	114, A-22, B-91
CGOGCAP	Oil and gas capacity for cogeneration for use *u* using fuel *f* in Census division *d* in year *y*	113, A-16, B-90
CGOGGEN	Oil and gas cogeneration of electricity for use *u* using fuel *f* in Census division *d* in year *y*	A-16, B-91
CGOGQ	Consumption of fuel *f* from cogeneration of electricity for use *u* in enhanced oil recovery in Census division *d* in year *y*	108, 109, 112, 114, 115, A-16, B-83, B-84, B-89, B-91, B-92

Model Variable	Definition and Dimensions	Page Reference
CGRECAP	Refinery capacity for cogeneration for use *u* using fuel *f* in Census division *d* in the year *y*	113, A-16, B-90
CGREGEN	Refinery cogeneration of electricity for use *u* using fuel *f* in Census division *d* in year *y*	A-16, B-91
CGREQ	Consumption of fuel *f* from cogeneration of electricity for use *u* in refineries in Census division *d* in year *y*	114, A-16, B-91
CHEMCON	Consumption of fuel *f* by the chemical industry in year *y*	A-23, B-93
COPRCLG	Supply of coal gases in Census division *d* in year *y*	109, A-16, B-83
COPRCLQ	Supply of coal liquids in Census division *d* in year *y*	109, A-16, B-83
CSCCUR	Current energy savings at process step *s* for fuel *f* for vintage *v*	129 to 132, A-20, A-48, B-17 to B-29
CUMOUT	Cumulative output, from 1958 through the lag of the current year, at process step *s* for all vintages	130, A-20, B-17
CUMOUT88	Cumulative output through the year 1988	84, A-16, A-41, B-31
CUMPROD	Cumulative production at process step *s* for vintage *v*	131, 132, A-20, B-18, B-29
DEMIMAIN	Emissions of pollutant *p* from main fuel *f* in Census division *d*	115 to 119, A-20, B-95 to B-98
DEMIRENW	Emissions of pollutant *p* from renewable fuel *f* in Census division *d*	118, A-20, B-98, B-99
DIVFUEL	Consumption of fuel *f* for cogeneration of electricity for use *u* in Census division *d*	103, 104, 114, A-20, B-52 to B-55, B-91
DIVSHARE	Electricity share for Census division *d*	102 to 104, A-16, B-50, B-52 to B-55
DQMAIN	Consumption of main fuel *f* in Census division *d*	107 to 111, 116, 117, A-20, B-81 to B-86, B-88, B-96, B-97
DQRENW	Consumption of renewable fuel *f* in Census division *d*	112, 121, A-20, B-82, B-89, B-101
DSRENW	Share of output for renewable fuel *f* in Census division *d*	107, 118, A-20, A-42, B-81, B-82, B-98
EINTER	Intercept at process step *s* for fuel *f* for vintage *v*	84, 130, 132, A-16, A-42, A-48, B-18 to B-30
ELCAP	Capacity for electricity generation	87, A-20, B-34, B-37
ELCTOT	Capacity for industrial electricity generation in Census region *r*	103, A-20, B-37, B-48, B-54, B-55
ELDEM	Total electricity demand from process/assembly and buildings	85, A-20, B-32
ELGEN	Electricity generation from prime mover *m*	86 to 91, 95, A-20, B-33 to B-35, B-37, B-38, B-41, B-45
ELOTOT	Total industrial electricity generation for own use in Census region *r*	102 to 104, A-20, B-36, B-48, B-50, B-51, B-53 to B-55

Model Variable	Definition and Dimensions	Page Reference
ELOWN	Electricity generation for own use	88, 91, 96, A-20, B-35, B-36, B-40, B-65
ELSALE	Electricity generation for sales to the grid	A-20, B-35, B-36
ELSTOT	Total industrial electricity generation for sales to the grid in Census region *r*	102, 104, A-20, B-36, B-49 to B-51, B-54, B-55
EMINC	Industrial emissions of pollutant *p* from fuel *f* in year *y*	119, A-23, B-99
EMINCC	Industrial emissions of pollutant *p* in Census division *d* in year *y*	A-20, B-100
EMINCX	Emissions of pollutant *p* from fuel *f* in Census division *d* in year *y*	119, A-20, B-98 to B-100
EMIRENW	Emissions of pollutant *p* from renewable fuel *f* in Census region *r*	97 to 99, A-20, B-71 to B-73
EMISSCONTROLFAC	Emission control factor for pollutant *p* using fuel *f*	98, 116 to 118, A-16, A-44, B-71, B-95 to B-97
EMPIND	Employment for industry *i* in Census division *d*	A-16, B-60
EMPLX	Employment for industry *i* in Census region *r*	84, A-20, B-4, B-60, B-61
ENBINT	Unit energy consumption of fuel *f* for building end use *e*	85, A-16, A-45, B-4
ENBQTY	Consumption of fuel *f* for building end use *e*	84, 85, 96, A-20, B-4, B-32, B-65 to B-67
ENBYPI	Byproduct energy production for intermediate byproduct fuel *f* for vintage *v*	A-20, B-64
ENBYPM	Byproduct energy production for main fuel *f* for vintage *v*	79, A-20, B-64
ENBYPR	Byproduct energy production for renewable byproduct fuel *f* for vintage *v*	A-20, B-65
ENPINT	Unit energy consumption of fuel *f* at process step *s* for vintage *v*	79, 80, 84, 129 to 134, A-16, A-47, B-5, B-6, B-17 to B-31
ENPINTLAG	Lagged unit energy consumption of fuel *f* at process step *s* for vintage *v*	129, A-20, A-47, B-17
ENPIQTY	Consumption of intermediate fuel *f* in the PA component	83, 85, A-20, B-9, B-32, B-67
ENPMQTY	Consumption of main fuel *f* in the PA component	82, 83, 85, 95, 96, A-21, B-8, B-9, B-32, B-66
ENPQTY	Consumption of fuel *f* at process step *s* for vintage *v*	79, 80, 82, A-21, B-5 to B-9
ENPRQTY	Consumption of renewable fuel *f* in the PA component	A-21, B-9, B-67
ENSINT	Intensity of fuel *f* in the BSC component	92, A-16, A-49, B-43
ENSQTY	Consumption of fuel *f* to generate steam	94 to 96, A-21, B-44 to B-46, B-66, B-67
FOODCON	Consumption of fuel *f* by the food and kindred products industry in year *y*	A-23, B-93

Model Variable	Definition and Dimensions	Page Reference
FUELSHARE	Share of consumption for fuel *f* in Census division *d*	106, 108, A-21, B-82
GCTFUEL	Fuel consumption for electricity generation from combustion turbines	A-21, B-37, B-38, B-40, B-45, B-46
GCTSTEAM	Cogeneration of steam from combustion turbines	90, A-21, B-38, B-39
GEN90	1990 generation of electricity	86, A-16, A-50, B-33
GENEQPHTRT	Heat rate for prime mover *m*	89, 95, A-16, A-51, B-37, B-45
GENEQPSHR	Share of generation for prime mover *m*	88, A-16, A-52, B-36
GENEQPSTEFF	Efficiency for prime mover *m*	90, A-16, A-53, B-38
GENGWH	Cogeneration of electricity for use *u* using fuel *f* in Census division *d*	104, A-21, B-53, B-54, B-57, B-91
GENTOT	Total consumption of fuel *f* for cogeneration of electricity for use *u* in Census region *r*	103, A-21, B-42, B-49, B-52
GENUTIL	Capacity utilization for cogeneration	87, A-16, A-54, B-34
GINTER	Intercept for electricity generation	86, A-21, B-33
GLASSCON	Consumption of fuel *f* by the glass and glass products industry in year *y*	A-23, B-94
GSTEAM	Steam demand coefficient	86, A-19, A-55, B-33
ICEFUEL	Fuel consumption for electricity generation from internal combustion engines	89 to 91, 94, A-21, B-37 to B-39, B-45, B-46
ICESTEAM	Cogeneration of steam from internal combustion engines	89, 90, A-21, B-38, B-39
IDLCAP	Idle production for process step *s* for vintage *v*	122, 123, 125, 126, A-21, B-10, B-11, B-13
IDVAL	Units of value of production	A-16, A-56
IFBYP	Number of byproducts consumed at process step *s*	A-17, B-64
IFMAX	Number of fuels consumed at process step *s*	A-17, B-8
IFSBYP	Number of byproducts consumed in the BSC component	95, A-17, B-45, B-46
IFSBYPI	Number of byproduct intermediate fuels	93, A-21, B-43
IFSBYPM	Number of byproduct main fuels	93, A-21, B-43
IFSBYPR	Number of byproduct renewable fuels	93, A-21, B-43
IFSMAX	Number of fuels consumed in the BSC component	92, 95, 135, A-17, B-42, B-45, B-46, B-48
INDDIR	Industry code	A-17, A-57
INDMAX	Number of industries	97, 99, 100, A-17, B-36, B-37, B-42, B-73 to B-75
INDNAME	Industry name	A-17
INDNUM	Industry index number	A-17
INDREG	Census region for the industry	A-17

Model Variable	Definition and Dimensions	Page Reference
INDSTEPNAME	Step name for process step *s*	A-17, A-59
IPASTP	Process step linked to process step *s* by link *l*	A-17
ISTP	Process step number	A-17
ITYPE	Equation type for fuel *f* at process step *s*	A-17, A-62
MANHP	Consumption of fuel *f* for manufacturing heat and power in year *y*	114, A-23, B-92
MC_MFGO	Gross value of output for manufacturing industry *i* in Census division *d* in year *y*	A-17, B-58
MC_NMFGO	Gross value of output for non-manufacturing industry *i* in Census division *d* in year *y*	A-17, B-58
MISCFD	Consumption of miscellaneous fuels and feedstocks *f* in year *y*	A-23, B-92
MPASTP	Number of process steps	79, 82, A-3, A-17, B-8, B-9, B-64, B-65
MSEDYR	Index of SEDS years	109, A-17, B-86
NONHP	Consumption of fuel *f* for non-manufacturing heat and power in year *y*	115, A-23, B-92
NSTEP	Process step number	A-17
NTMAX	Number of links for process step *s*	75, A-3, A-17, B-104
OGEN	Own use generation coefficient	88, A-19, A-63, B-34, B-35
OINTER	Intercept for own use generation	88, A-21, B-34, B-35
OTHIND	Consumption of fuel *f* for "other industry" in Census division *d*	109 to 111, 116, 117, 121, A-21, B-86, B-87, B-88, B-95 to B-97, B-101, B-102
OUTIND	Gross value of output for industry *i* in Census division *d*	107, A-21, B-58, B-60, B-80
OWN90	1990 electricity generation for own use	88, A-17, A-64, B-34
PAPERCON	Consumption for fuel *f* by the paper and allied products industry in year *y*	A-23, B-93
PCLIN	Industrial price of steam coal for Census division *d* in year *y*	A-17
PDSIN	Industrial price of distillate for Census division *d* in year *y*	A-17
PELIN	Industrial price of electricity for Census division *d* in year *y*	A-17
PGFIN	Industrial price of core natural gas in Census division *d* in year *y*	A-17
PGIIN	Industrial price of non-core natural gas in Census division *d* in year *y*	A-17
PHDRAT	Ratio of physical units to value of output	73, 124, A-17, A-65, B-11, B-102
PKSIN	Industrial price of kerosene in Census division *d* in year *y*	A-17

Model Variable	Definition and Dimensions	Page Reference
PLGIN	Industrial price of liquid petroleum gas in Census division *d* in year *y*	A-17
PLPIN	Industrial price of lease and plant fuel in Census division *d* in year *y*	A-17
PMCIN	Industrial price of metallurgical coal in Census division *d* in year *y*	A-17
PMGIN	Industrial price of motor gasoline in Census division *d* in year *y*	A-17
PNGIN	Industrial price of natural gas in Census division *d* in year *y*	A-17
POTIN	Industrial price of other petroleum in Census division *d* in year *y*	A-17
PRCCUR	Current energy savings based on price for fuel *f* at process step *s* for vintage *v*	133, 134, A-21, B-30
PRCX	Price for fuel *f* in Census region *r*	69, 135, A-21, B-47, B-59
PRCXLAG	Lagged price of fuel *f*	135, A-21, B-47
PRLIN	Industrial price of low sulfur residual fuel in Census division *d* in year *y*	A-18
PRODCUR	Production at process step *s* for vintage *v*	74 to 80, 83, 122 to 128, A-21, B-5, B-6, B-9 to B-16, B-61 to B-63, B-103, B-104
PRODFLOW	Down-step throughput to process step *s* linked by link *l* for vintage *v*	74, 124, 126, 128, A-18, A-66, B-12, B-14, B-16, B-103, B-104
PRODLAG	Lagged production at process step *s* and vintage *v*	76, A-21, B-61
PRODRETR	Retirement rate at process step *s*	122, 123, A-18, A-67, B-10
PRODSUM	Amount of throughput used at process step *s* through link *l* for vintage *v*	74, 75, 126 to 128, A-21, B-14, B-16, B-103, B-104
PRODVX	Value of output for industry *i* in Census region *r*	73, 124, A-18, B-11, B-12, B-60, B-102, B-103
PRODX	Output in either physical units or dollar units for industry *i* in Census region *r*	73, 74, 124, A-21, B-11, B-12, B-102, B-103
PRODZERO	1990 production at process step *s* for vintage *v*	A-21, B-5, B-6
PRSIN	Industrial price of residual fuel in Census division *d* in year *y*	A-18
PTPIN	Industrial price of all petroleum in Census division *d* in year *y*	A-18
QASIN	Industrial consumption of asphalt and road oil for Census division *d* in year *y*	A-23
QBMIN	Industrial consumption of biomass for Census division *d* in year *y*	112, A-23, B-89, B-90
QBMRF	Biomass consumed by the petroleum refining industry in Census division *d* in year *y*	112, A-18, B-89
QCIIN	Industrial net coke imports for Census division *d* in year *y*	A-23

Model Variable	Definition and Dimensions	Page Reference
QCLIN	Industrial consumption of steam coal for Census division *d* in year *y*	A-23
QCLRF	Coal consumed by the petroleum refining industry in Census division *d* in year *y*	109, A-18, B-83
QDSIN	Industrial consumption of distillate for Census division *d* in year *y*	A-23
QDSRF	Distillate consumed by the petroleum refining industry in Census division *d* in year *y*	A-18, B-84
QELIN	Industrial consumption of electricity in Census division *d* in year *y*	110, A-23, B-60, B-87
QELRF	Electricity consumed by the petroleum refining industry in Census division *d* in year *y*	114, A-18, B-74, B-82, B-92
QGEIN	Industrial consumption of geothermal for Census division *d* in year *y*	112, A-23, B-90
QGFIN	Industrial consumption of core natural gas in Census division *d* in year *y*	110, 111, A-23, B-87, B-88
QGFRF	Refinery consumption of core natural gas for Census division *d* in year *y*	A-18
QGIIN	Industrial consumption of non-core natural gas for Census division *d* in year *y*	111, A-23, B-88
QGIRF	Refinery consumption of non-core natural gas for Census division *d* in year *y*	A-18
QHOIN	Industrial consumption of hydropower for Census division *d* in year *y*	112, A-23, B-89
QKSIN	Industrial consumption of kerosene for Census division *d* in year *y*	A-23
QLGIN	Industrial consumption of liquid petroleum gas for Census division *d* in year *y*	A-23
QLGRF	Liquid petroleum gas consumed by the petroleum refining industry for Census division *d* in year *y*	A-18, B-85
QLPIN	Industrial consumption of lease and plant fuel for Census division *d* in year *y*	116, A-23, B-96
QMCIN	Industrial consumption of metallurgical coal for Census division *d* in year *y*	A-23
QMGIN	Industrial consumption of motor gasoline for Census division *d* in year *y*	A-23
QMSIN	Industrial consumption of municipal solid waste for Census division *d* in year *y*	113, A-23, B-90
QNGIN	Industrial consumption of natural gas for Census division *d* in year *y*	A-23
QNGRF	Natural gas consumed by the petroleum refining industry for Census division *d* in year *y*	108, A-18, B-83

Model Variable	Definition and Dimensions	Page Reference
QOTIN	Industrial consumption of other petroleum for Census division *d* in year *y*	A-23
QOTRF	Other petroleum consumed by the petroleum refining industry for Census division *d* in year *y*	A-18, B-86
QPCIN	Industrial consumption of petroleum coke for Census division *d* in year *y*	A-23
QPCRF	Petroleum coke consumed by the petroleum refining industry for Census division *d* in year *y*	A-18, B-85
QPFIN	Industrial consumption of petrochemical feedstocks for Census division *d* in year *y*	A-23
QPVIN	Industrial consumption of photovoltaic for Census division *d* in year *y*	113, A-23, B-90
QRLIN	Industrial consumption of low sulfur residual fuel for Census division *d* in year *y*	A-23
QRLRF	Residual fuel consumed by the petroleum refining industry in Census division *d* in year *y*	A-18, B-84
QRSIN	Industrial consumption of residual fuel for Census division *d* in year *y*	A-23
QSASIN	SEDS consumption of asphalt and road oil in Census division *d* in SEDS year *y*	A-18
QSCIIN	SEDS net coke imports in Census division *d* in SEDS year *y*	A-18
QSCLIN	SEDS consumption of steam coal in Census division *d* in SEDS year *y*	A-18
QSDSIN	SEDS consumption of distillate in Census division *d* in SEDS year *y*	A-18
QSELIN	SEDS consumption of electricity in Census division *d* in year *y*	70, 106, A-18, B-59, B-81
QSGIN	Industrial consumption of still gas for Census division *d* in year *y*	A-23
QSGRF	Still gas consumed by the petroleum refining industry for Census division *d* in year *y*	A-18, B-85
QSKSIN	SEDS consumption of kerosene in Census division *d* in year *y*	A-18
QSLGIN	SEDS consumption of liquid petroleum gas in Census division *d* in year *y*	A-18
QSLPIN	SEDS consumption of lease and plant fuel in Census division *d* in year *y*	A-18
QSMCIN	SEDS consumption of metallurgical coal in Census division *d* in year *y*	A-18
QSMGIN	SEDS consumption of motor gasoline in Census division *d* in year *y*	A-18
QSNGIN	SEDS consumption of natural gas in Census division *d* in year *y*	A-18

Model Variable	Definition and Dimensions	Page Reference
QSOTIN	SEDS consumption of other petroleum in Census division *d* in year *y*	A-18
QSPCIN	SEDS consumption of petroleum coke in Census division *d* in year *y*	A-18
QSPFIN	SEDS consumption of petrochemical feedstocks in Census division *d* in year *y*	A-18
QSRLIN	SEDS consumption of residual fuel in Census division *d* in year *y*	A-18
QSSGIN	SEDS consumption of still gas in Census division *d* in year *y*	A-18
QSTIN	Industrial consumption of solar thermal in Census division *d* in year *y*	112, A-23, B-90
QTPIN	Industrial consumption of total petroleum in Census division *d* in year *y*	111, A-23, B-88
QTRIN	Industrial consumption of total renewables in Census division *d* in year *y*	112, A-24, B-89
QTSIN	Total industrial energy consumption in Census division *d* in year *y*	A-24
QTYINTR	Consumption of intermediate fuel *f* in Census region *r*	A-21, B-67 to B-70
QTYMAIN	Consumption of main fuel *f* in Census region *r*	95 to 97, 100, A-22, B-65 to B-70, B-73 to B-80
QTYRENW	Consumption of renewable fuel *f* in Census region *r*	97, A-22, B-67 to B-71, B-74, B-76 to B-80
QWIIN	Industrial consumption of wind in Census division *d* in year *y*	113, A-24, B-90
REFCON	Consumption of fuel *f* by the petroleum refining industry in year *y*	A-24, B-94
SEDSIND	SEDS consumption of fuel *f* in Census division *d*	120, A-22, B-100
STBYP	Consumption of byproduct fuel *f* in steam turbines	A-22, B-40, B-46
STEELCON	Consumption of fuel *f* by the blast furnace and basic steel products industry in year *y*	A-24, B-95
$STEMCUR_{90}$	Total steam demand in 1990	86, A-19, A-68, B-32, B-33
STEMCUR	Total steam demand	85, 86, 90, 93, A-22, B-37, B-39, B-44
STEMCURF	Amount of steam to be generated from purchased fuels	93, 94, A-22, B-43, B-44
STFUEL	Consumption of fuel *f* in steam turbines	91, 95, A-22, B-39, B-40, B-45
SULFURCONT	Sulfur content of fuel *f*	98, 118, A-19, A-69, B-71, B-98
SUMPINT	Cumulative unit energy consumption of fuel *f* at process step *s*	131, 132, A-22, B-18, B-29
TALUMCON	Total consumption of fuel *f* from the primary aluminum industry	A-22, B-80, B-95

Model Variable	Definition and Dimensions	Page Reference
TCEMENTCON	Total consumption of fuel *f* from the hydraulic cement industry	A-22, B-78, B-79, B-94
TCHEMCON	Total consumption of fuel *f* from the bulk chemicals industry	A-22, B-77, B-93
TEMISM	Total emissions of pollutant *p* from main fuel *f* in Census region *r*	A-22
TEMISR	Total emissions of pollutant *p* for renewable fuel *f* in Census region *r*	99, 118, A-22, B-73, B-98
TFOODCON	Total consumption of fuel *f* from the food and kindred products industry	100, A-22, B-75, B-76, B-93
TGLASSCON	Total consumption of fuel *f* from the glass and glass products industry	A-22, B-77, B-78, B-94
TMANHP	Total manufacturing consumption of fuel *f* for heat and power	99, 114, A-22, B-73, B-74, B-92
TMISCFD	Total consumption of miscellaneous fuels and feedstocks fuel *f*	A-22, B-75, B-92
TNONHP	Total non-manufacturing consumption of fuel *f* for heat and power	115, A-22, B-74, B-92
TOTEMIS	Total emissions of pollutant *p* from fuel *f* in Census region *r*	98, A-22, B-72
TPAPERCON	Total consumption of fuel *f* from the paper and allied products industry	A-22, B-76, B-93
TQINTR	Total consumption of intermediate fuel *f* in Census region *r*	A-22, B-70
TQMAIN	Total consumption of main fuel *f* in Census region *r*	97, 108, A-22, B-70, B-81
TQRENW	Total consumption of renewable fuel *f* in Census region *r*	A-22, B-70, B-82
TREFCON	Total consumption of fuel *f* from the petroleum refining industry	A-22, B-74, B-94
TSTEELCON	Total consumption of fuel *f* from the blast furnace and basic steel products industry	A-22, B-79, B-95
UNCONTEMISSFACT	Uncontrolled emission factor for pollutant *p* using fuel *f*	98, 116, 117, A-19, A-70, B-71, B-95 to B-97
WPRC	Price for fuel *t* in 1987 dollars	84, 133, A-22, B-30, B-31

Table A-3. NEMS Industrial Module Inputs and Outputs

Model Variable	Equation	Units
MODULE INPUTS	(including inputs received from other NEMS modules)	
BSSHR	B-88, B-91, B-98, B-99	NA
BYPINT	B-131, B-132	IDVAL = 1: MMBtu/ton except for elec. Kwh/ton; IDVAL = 2: Trillion Btu/ Billion 1987 $
BYSINT	B-89	NA
CAPREG	B-104 to B-106	Megawatts
CGOGCAP	B-201	Megawatts
CGOGGEN	B-202	Gigawatt hours
CGOGQ	B-184, B-185, B-187, B-199, B-203, B-205	Trillion Btu
CGRECAP	B-201	Megawatts
CGREGEN	B-202	Gigawatt hours
CGREQ	B-203	Trillion Btu
COPRCLG	B-185	Trillion Btu
COPRCLQ	B-185	Trillion Btu
CUMOUT88	B-61	IDVAL = 1: Tons; IDVAL = 2: Billion 1987 $
DIVSHARE	B-105, B-106, B-109, B-113 to B-116	NA
EINTER	B-35, B-38 to B-57, B-61	IDVAL = 1: MMBtu/ton except for elec. Kwh/ton; IDVAL = 2: Trillion Btu/ Billion 1987 $
EMISSCONTROLFAC	B-154, B-215 to B-217	Metric tons/Trillion Btu
EMPIND	B-127	Millions
ENBINT	B-1	Trillion Btu/Thousand
ENPINT	B-3 to B-6, B-33, B-35, B-36, B-38 to B-58, B-60, B-61	IDVAL = 1: MMBtu/ton except for elec. Kwh/ton; IDVAL = 2: Trillion Btu/ Billion 1987 $
ENSINT	B-88	NA
GEN90	B-64	Trillion Btu
GENEQPHTRT	B-74, B-75, B-94, B-95	Trillion Btu/kWh
GENEQPSHR	B-70	NA
GENEQPSTEFF	B-76, B-77	NA
GENUTIL	B-66	NA
IDVAL	Used in If statements	NA

Model Variable	Equation	Units
IFBYP	B-135	NA
IFMAX	B-10	NA
IFSBYP	B-94, B-95	NA
IFSMAX	B-88, B-94, B-95, B-99	NA
INDDIR	Used in If statements	NA
INDMAX	B-71 to B-73, B-87, B-151 to B-153, B-159 to B-161, B-164	NA
INDNAME		NA
INDNUM	Used in If statements	NA
INDREG	Used in If statements	NA
INDSTEPNAME		NA
IPASTP	Used in If statements	NA
ISTP	Used in If statements	NA
ITYPE	Used in If statements	NA
MC_MFGO	B-123	Millions
MC_NMFGO	B-122	Millions
MPASTP	B-11 to B-13, B-136 to B-138	NA
MSEDYR	B-193	NA
NSTEP	Used in If statements	NA
NTMAX	B-234	NA
OWN90	B-67	Trillion Btu
PCLIN	B-124, B-125	1987 $/Million Btu
PDSIN	B-124, B-125	1987 $/Million Btu
PELIN	B-124, B-125	1987 $/Million Btu
PGFIN	B-124, B-125	1987 $/Million Btu
PGIIN	B-124, B-125	1987 $/Million Btu
PHDRAT	B-19, B-229, B-230	NA
PKSIN	B-124, B-125	1987 $/Million Btu
PLGIN	B-124, B-125	1987 $/Million Btu
PLPIN	B-124, B-125	1987 $/Million Btu
PMCIN	B-124, B-125	1987 $/Million Btu
PMGIN	B-124, B-125	1987 $/Million Btu
PNGIN	B-124, B-125	1987 $/Million Btu
POTIN	B-124, B-125	1987 $/Million Btu
PRLIN	B-124, B-125	1987 $/Million Btu

Model Variable	Equation	Units
PRODFLOW	B-21, B-26, B-30, B-232, B-233	NA
PRODRETR	B-15, B-16	NA
PRODVX	B-19, B-20, B-126, B-229 to B-231	Billion 1987 $
PRSIN	B-124, B-125	1987 $/Trillion Btu
PTPIN	B-124, B-125	1987 $/Trillion Btu
QBMRF	B-199	Trillion Btu
QCLRF	B-185	Trillion Btu
QDSRF	B-188	Trillion Btu
QELRF	B-162, B-183, B-204	Trillion Btu
QGFRF	B-162	Trillion Btu
QGIRF	B-162	Trillion Btu
QLGRF	B-189	Trillion Btu
QNGRF	B-184	Trillion Btu
QOTRF	B-192	Trillion Btu
QPCRF	B-191	Trillion Btu
QRLRF	B-187	Trillion Btu
QSASIN	B-124	Trillion Btu
QSCIIN	B-124	Trillion Btu
QSCLIN	B-124	Trillion Btu
QSDSIN	B-124	Trillion Btu
QSELIN	B-124, B-179	Trillion Btu
QSGRF	B-162, B-190	Trillion Btu
QSKSIN	B-124	Trillion Btu
QSLGIN	B-124	Trillion Btu
QSLPIN	B-124	Trillion Btu
QSMCIN	B-124	Trillion Btu
QSMGIN	B-124	Trillion Btu
QSNGIN	B-124	Trillion Btu
QSOTIN	B-124	Trillion Btu
QSPCIN	B-124	Trillion Btu
QSPFIN	B-124	Trillion Btu
QSRLIN	B-124	Trillion Btu
QSSGIN	B-124	Trillion Btu
$STEMCUR_{90}$	B-64	Trillion Btu

Model Variable	Equation	Units
SULFURCONT	B-155, B-218	NA
UNCONTEMISSFACT	B-154, B-215 to B-217	Metric tons/Trillion Btu
MODULE PARAMETERS		
BCSC	B-34, B-37, B-61	NA
BELAS	B-59, B-61	NA
BSSHRCL	B-98	NA
BSSHRE	B-98	NA
BSSHRNG	B-98	NA
BSSHROIL	B-98	NA
BYPCSC	B-129	NA
GSTEAM	B-64, B-65	NA
OGEN	B-67, B-68	NA
CALCULATED VARIABLES		
AVGINT	B-88, B-91	NA
BENCHFAC	B-193, B-216, B-217, B-225 to B-227	NA
BIOFUELS	B-226	Trillion Btu
BMAIN	B-183 to B-197, B-215 to B-217, B-225, B-227	Trillion Btu
BOILSTEAM	B-78	Trillion Btu
BSSHRLAG	B-98	NA
BYPBSCI	B-89	Trillion Btu
BYPBSCM	B-89, B-141	Trillion Btu
BYPBSCR	B-89, B-144	Trillion Btu
BYPCSCCUR	B-129 to B-131	NA
BYPCSCLAG	B-130	NA
BYPINTLAG	B-131	IDVAL = 1: MMBtu/ton except for elec. kWh/ton; IDVAL = 2: Trillion Btu/ Billion 1987 $
BYPQTY	B-132 to B-138	Trillion Btu
BYPSTM	B-89, B-90	Trillion Btu
BYSQTY	B-94, B-95	Trillion Btu
CAPD	B-105 to B-108, B-112, B-117 to B-119	Megawatts
CAPDIV	B-107, B-108	Megawatts
CAPGW	B-115 to B-119, B-121, B-201	Megawatts

Model Variable	Equation	Units
CAPGWLAG	B-118	Megawatts
CGFUEL	B-79 to B-87	Trillion Btu
CSCCUR	B-34, B-35, B-37 to B-57	NA
CUMOUT	B-34	IDVAL = 1: Tons; IDVAL = 2: Billion 1987 $
CUMPROD	B-36, B-58	IDVAL = 1: Tons; IDVAL = 2: Billion 1987 $
DEMIMAIN	B-215 to B-218, B-220	Metric tons
DEMIRENW	B-219, B-221	Metric tons
DIVFUEL	B-109 to B-111, B-113 to B-116, B-203	Trillion Btu
DQMAIN	B-181, B-183 to B-192, B-195, B-216, B-217	Trillion Btu
DQRENW	B-182, B-198, B-199, B-226	Trillion Btu
DSRENW	B-180, B-182, B-219	Trillion Btu
ELCAP	B-66, B-73	Megawatts
ELCTOT	B-73, B-100, B-115, B-116	Megawatts
ELDEM	B-62	Trillion Btu
ELGEN	B-65 to B-70, B-74 to B-77, B-83, B-94, B-95	Trillion Btu
ELOTOT	B-71, B-101, B-105, B-107, B-113, B-115, B-116	Trillion Btu
ELOWN	B-68, B-69, B-71, B-83, B-139	Trillion Btu
ELSALE	B-69, B-72	Trillion Btu
ELSTOT	B-72, B-102, B-105, B-107, B-114 to B-116	Trillion Btu
EMINCC	B-224	Metric tons
EMINCX	B-220 to B-224	Million metric tons
EMIRENW	B-154 to B-159	Metric tons
EMPLX	B-1, B-127, B-128	Thousands
ENBQTY	B-1, B-2, B-62, B-63, B-139, B-140, B-142	Trillion Btu
ENBYPI	B-137	Trillion Btu
ENBYPM	B-136	Trillion Btu
ENBYPR	B-138	Trillion Btu
ENPINTLAG	B-33	IDVAL = 1: MMBtu/ton except for elec. kWh/ton IDVAL = 2: Trillion Btu/ Billion 1987 $
ENPIQTY	B-12, B-14, B-63, B-142, B-143	Trillion Btu
ENPMQTY	B-11, B-14, B-62, B-139 to B-141	Trillion Btu
ENPQTY	B-3 to B-13	Trillion Btu

Model Variable	Equation	Units
ENPRQTY	B-13, B-144	Trillion Btu
ENSQTY	B-91 to B-97, B-140 to B-144	Trillion Btu
FUELSHARE	B-179, B-182	NA
GCTFUEL	B-75, B-77, B-81, B-93, B-97	Trillion Btu
GCTSTEAM	B-77, B-78	Trillion Btu
GENGWH	B-113, B-114, B-120, B-202	Gigawatthours
GENTOT	B-87, B-103, B-109	Trillion Btu
GINTER	B-64, B-65	NA
ICEFUEL	B-74, B-76, B-80, B-92, B-96	Trillion Btu
ICESTEAM	B-76, B-78	Trillion Btu
IDLCAP	B-15, B-17, B-23, B-24	IDVAL = 1: MMBtu/ton except for elec. kWh/ton IDVAL = 2: Trillion Btu/ Billion 1987 $
IFSBYPI	B-89	NA
IFSBYPM.	B-89	NA
IFSBYPR	B-89	NA
OINTER	B-67, B-68	Trillion Btu
OTHIND	B-193 to B-197, B-215 to B-217, B-227, B-228	Trillion Btu
OUTIND	B-122, B-123, B-126, B-180	Billion 1987 $
PRCCUR	B-59, B-60	1987 $/Million Btu
PRCX	B-98, B-124, B-125	1987 $/Million Btu
PRCXLAG	B-98	1987 $/Million Btu
PRODCUR	B-3 to B-6, B-14 to B-18, B-21 to B-32, B-129, B-130, B-132, B-232 to B-234	IDVAL = 1: Tons IDVAL = 2: Billion 1987 $
PRODLAG	B-129	IDVAL = 1: Tons IDVAL = 2: Billion 1987 $
PRODSUM	B-26, B-27, B-30, B-31, B-233, B-234	IDVAL = 1: MMBtu/ton except for elec. kWh/ton IDVAL = 2: Trillion Btu/ Billion 1987 $
PRODX	B-19 to B-21, B-230 to B-232	IDVAL = 1: Tons IDVAL = 2: Billion 1987 $
PRODZERO	B-3 to B-5	IDVAL = 1: Tons IDVAL = 2: Billion 1987 $
QTYINTR	B-142, B-143, B-146, B-149, B-152	Trillion Btu
QTYMAIN	B-139 to B-141, B-145, B-148, B-151, B-160, B-163 to B-165, B-167, B-169, B-171, B-173, B-175, B-177	Trillion Btu

Model Variable	Equation	Units
QTYRENW	B-144, B-147, B-150, B-153, B-154, B-161, B-166, B-168, B-170, B-172, B-174, B-176, B-178	Trillion Btu
SEDSIND	B-225	Trillion Btu
STBYP	B-82, B-95	Trillion Btu
STEMCUR	B-63, B-65, B-78, B-90	Trillion Btu
STEMCURF	B-90, B-91	Trillion Btu
STFUEL	B-79 to B-82, B-94	Trillion Btu
SUMPINT	B-36, B-58	Trillion Btu/ton
TALUMCON	B-177, B-178, B-214	Trillion Btu
TCEMENTCON	B-173, B-174, B-211	Trillion Btu
TCHEMCON	B-169, B-170, B-209	Trillion Btu
TEMISR	B-159, B-219	Metric tons
TFOODCON	B-165, B-166, B-207	Trillion Btu
TGLASSCON	B-171, B-172, B-210	Trillion Btu
TMANHP	B-160, B-161, B-204	Trillion Btu
TMISCFD	B-164, B-206	Trillion Btu
TNONHP	B-163, B-205	Trillion Btu
TOTEMIS	B-158	Metric tons
TPAPERCON	B-167, B-168, B-208	Trillion Btu
TQINTR	B-152	Trillion Btu
TQMAIN	B-151, B-181	Trillion Btu
TQRENW	B-153, B-182	Trillion Btu
TREFCON	B-162, B-212	Trillion Btu
TSTEELCON	B-175, B-176, B-213	Trillion Btu
WPRC	B-59, B-61	1987 dollars
MODULE OUTPUTS		
ALUMCON	B-214	Trillion Btu
CEMENTCON	B-211	Trillion Btu
CGINDCAP	B-201	Megawatts
CGINDGEN	B-202	Gigawatt hours
CGINDQ	B-203	Trillion Btu
CHEMCON	B-209	Trillion Btu
EMINC	B-223	Metric tons
FOODCON	B-207	Trillion Btu

Model Variable	Equation	Units
GLASSCON	B-210	Trillion Btu
MANHP	B-204	Trillion Btu
MISCFD	B-206	Trillion Btu
NONHP	B-205	Trillion Btu
PAPERCON	B-208	Trillion Btu
QASIN	B-125, B-194	Trillion Btu
QBMIN	B-199, B-200	Trillion Btu
QCIIN	B-125, B-194	Trillion Btu
QCLIN	B-125, B-194	Trillion Btu
QDSIN	B-125, B-194	Trillion Btu
QELIN	B-125, B-194	Trillion Btu
QGEIN	B-200	Trillion Btu
QGFIN	B-195, B-196	Trillion Btu
QGIIN	B-196	Trillion Btu
QHOIN	B-198, B-200	Trillion Btu
QKSIN	B-125, B-194	Trillion Btu
QLGIN	B-125, B-194	Trillion Btu
QLPIN	B-194, B-216	Trillion Btu
QMCIN	B-125, B-194	Trillion Btu
QMGIN	B-125, B-194	Trillion Btu
QMSIN	B-200	Trillion Btu
QNGIN	B-125, B-194	Trillion Btu
QOTIN	B-125, B-194	Trillion Btu
QPCIN	B-125, B-194	Trillion Btu
QPFIN	B-125, B-194	Trillion Btu
QPVIN	B-200	Trillion Btu
QRLIN	B-125, B-194	Trillion Btu
QRSIN	B-125, B-194	Trillion Btu
QSGIN	B-125, B-194	Trillion Btu
QSTIN	B-200	Trillion Btu
QTPIN	B-197	Trillion Btu
QTRIN	B-200	Trillion Btu
QTSIN	B-125	Trillion Btu
QWIIN	B-200	Trillion Btu

Model Variable	Equation	Units
REFCON	B-212	Trillion Btu
STEELCON	B-213	Trillion Btu

MODEL INPUT: *BCSC*

MODEL COMPONENT: Process/Assembly

DEFINITION: Energy savings coefficient at process step *s* for fuel *f* and vintage *v*

DISCUSSION:

The energy savings coefficients for the energy-intensive industries are assumed to be constant over the four Census regions. The coefficients for the food and kindred products, paper and allied products, glass and glass products, hydraulic cement, bulk chemicals, blast furnace and basic steel products, and primary aluminum industries were obtained from Arthur D. Little. These coefficients are determined through Relative Energy Intensity (REI) for both old and new plants. Relative Energy Intensity is defined as the ratio of energy use in a new or advanced process compared to the 1988 old plant average energy use which has been normalized to one. Regression analyses were performed to create a log-linear plot of REI versus time. The following equation is estimated by ADL in natural logarithms.

$$\ln(REI) = \beta \ln(t) \tag{A-1}$$

The intercept is assumed to be zero. The slope of the resulting linear plot of REI against time, or the coefficient β, is the energy savings coefficient. There is a separate coefficient for each process step, however the coefficients are the same for all fuels used at a particular process step. The coefficients for the TPCs are listed in Table E-13, Appendix E.

For the non-energy-intensive and non-manufacturing industries, the coefficients are based on regressions on NEA data and output from the 1990 Macroeconomic model.

SOURCES:

Decision Analysis Corporation and Arthur D. Little, "Industrial Model: Selected Process Flows Revised Final Report," prepared for EIA under Contract No. DE-AC01-92EI21946, Subtask 2B, Vienna, VA, April 26, 1993.

U. S. Department of Commerce, Office of Business Analysis, *National Energy Accounts*, PB89-187918, February 1989.

MODEL PARAMETER: *BELAS*

MODEL COMPONENT: Process/Assembly

DEFINITION: Own price elasticity at process step *s* for fuel *f* for old vintage and the cross price elasticity at process step *s* for fuel *f* and fuel *t* for old vintage

DISCUSSION:

The cross price elasticities for the energy intensive industries are zero for all process steps and fuels. The cross price elasticities for the non-manufacturing and non-energy-intensive industries were obtained through a series of regressions. The regressions were based on data from NEA and outputs from the 1990 Macroeconomic model. The resulting parameter estimates are the cross price elasticities. The price elasticity for steam was obtained using the elasticity from the fuel that had the largest boiler share in the BSC component by the four Census regions.

SOURCE:

U. S. Department of Commerce, Office of Business Analysis, *National Energy Accounts*, PB89-187918, February 1989.

MODEL INPUT: *BSSHR*

MODEL COMPONENT: Boiler/Steam/Cogeneration

DEFINITION: Share of total fuel consumption in the BSC component for fuel *f*

DISCUSSION:

The boiler shares for all industries are derived from the ADL Industrial Model Baseline Database energy consumption. The quantity of each fuel consumed by industry and region in the BSC component is divided by total energy consumption in the BSC component to determine the boiler share of each fuel. There is no BSC component for the following industries: coal mining, oil and gas mining, construction, glass and glass products, hydraulic cement, and primary aluminum. Therefore, this variable does not exist for these industries.

SOURCES:

Decision Analysis Corporation of Virginia and Arthur D. Little, "Industrial Model: Baseline Database Final Report," prepared for EIA under Contract No. DE-AC01-92EI21946, Subtask 1, Vienna VA, January 15, 1993, Appendix G.

Energy Information Administration, Manufacturing Energy Consumption Survey: Consumption of Energy 1988, DOE/EIA-0512(88), May 1991.

MODEL INPUT: *BSSHRCL*

MODEL COMPONENT: Boiler/Steam/Cogeneration

DEFINITION: Cross price elasticity for steam coal with fuel f

DISCUSSION:

Price elasticities for boiler use were obtained from an article in Energy Economics by Considine. The price elasticities were obtained from a linear logit form of a stationary fuel combustion model. This model is given in the following equation.

$$w_i = \frac{e^{f_i}}{\sum_{j=1}^{n} e^{f_j}} \tag{A-2}$$

where:

$$f_i = \eta_i + \sum_{j=1}^{n} \varphi_{ij} lnP_j \tag{A-3}$$

The price elasticities are found by differentiating the estimated linear logit model. Cross price elasticities are given by the following equation.

$$E_{ik} = w_j + \varphi_{ik} - \sum_{j=1}^{n} w_j \varphi_{jk} \tag{A-4}$$

There is no BSC component in the coal mining, oil and gas mining, construction, glass and glass products, hydraulic cement, and primary aluminum industries, therefore this variable does not exist for those industries. In the industrial model, the cross elasticity of steam coal with natural gas is assumed to be zero.

SOURCE:

Considine, Timothy J., "Separability, functional form and regulatory policy in models of interfuel substitution," Energy Economics, April 1989, p. 82-94.

MODEL INPUT: *BSSHRE*

MODEL COMPONENT: Boiler/Steam/Cogeneration

DEFINITION: Own price elasticity for fuel *f*

DISCUSSION:

Price elasticities for boiler use were obtained from an article in Energy Economics by Considine. The price elasticities were obtained from a linear logit form of a stationary fuel combustion model. This model is given in the following equation.

$$w_i = \frac{e^{f_i}}{\sum_{j=1}^{n} e^{f_j}} \tag{A-5}$$

where:

$$f_i = \eta_i + \sum_{j=1}^{n} \varphi_{ij} lnP_j \tag{A-6}$$

The price elasticities are found by differentiating the estimated linear logit model. Own price elasticities are given by the following equation.

$$E_{ii} = w_i - 1 + \varphi_{ii} - \sum_{j=1}^{n} w_j \varphi_{ji} \tag{A-7}$$

There is no BSC component in the coal mining, oil and gas mining, construction, glass and glass products, hydraulic cement, and primary aluminum industries, therefore this variable does not exist for those industries.

SOURCE:

Considine, Timothy J., "Separability, functional form and regulatory policy in models of interfuel substitution," Energy Economics, April 1989, p. 82-94.

MODEL INPUT: *BSSHRNG*

MODEL COMPONENT: Boiler/Steam/Cogeneration

DEFINITION: Cross price elasticity for natural gas with fuel *f*

DISCUSSION:

Price elasticities for boiler use were obtained from an article in Energy Economics by Considine. The price elasticities were obtained from a linear logit form of a stationary fuel combustion model. This model is given in the following equation.

$$w_i = \frac{e^{f_i}}{\sum_{j=1}^{n} e^{f_i}} \quad \textbf{(A-8)}$$

where:

$$f_i = \eta_i + \sum_{j=1}^{n} \varphi_{ij} lnP_j \quad \textbf{(A-9)}$$

The price elasticities are found by differentiating the estimated linear logit model. Cross price elasticities are given by the following equation.

$$E_{ik} = w_j + \varphi_{ik} - \sum_{j=1}^{n} w_j \varphi_{jk} \quad \textbf{(A-10)}$$

There is no BSC component in the coal mining, oil and gas mining, construction, glass and glass products, hydraulic cement, and primary aluminum industries, therefore this variable does not exist for those industries. In the industrial model, the cross elasticity of natural gas with steam coal is assumed to be zero.

SOURCE:

Considine, Timothy J., "Separability, functional form and regulatory policy in models of interfuel substitution," Energy Economics, April 1989, p. 82-94.

MODEL INPUT: *BSSHROIL*

MODEL COMPONENT: Boiler/Steam/Cogeneration

DEFINITION: Price elasticity for oil crossed with fuel *f*

DISCUSSION:

Price elasticities for boiler use were obtained from an article in Energy Economics by Considine. The price elasticities were obtained from a linear logit form of a stationary fuel combustion model. This model is given in the following equation.

$$w_i = \frac{e^{f_i}}{\sum_{j=1}^{n} e^{f_j}} \tag{A-11}$$

where:

$$f_i = \eta_i + \sum_{j=1}^{n} \varphi_{ij} lnP_j \tag{A-12}$$

The price elasticities are found by differentiating the estimated linear logit model. Cross price elasticities are given by the following equation.

$$E_{ik} = w_j + \varphi_{ik} - \sum_{j=1}^{n} w_j \ \varphi_{jk} \tag{A-13}$$

There is no BSC component in the coal mining, oil and gas mining, construction, glass and glass products, hydraulic cement, and primary aluminum industries, therefore this variable does not exist for those industries.

SOURCE:

Considine, Timothy J., "Separability, functional form and regulatory policy in models of interfuel substitution," Energy Economics, April 1989, p. 82-94.

MODEL INPUT: *BYPCSC*

MODEL COMPONENT: Process/Assembly

DEFINITION: Byproduct technology possibility curve (TPC) coefficient for byproduct *b* at process step *s* and vintage *v*

DISCUSSION:

The byproduct TPC coefficients are zero for all byproducts currently considered. It only applies to the paper and allied products industry.

SOURCE:

Decision Analysis Corporation and Arthur D. Little, "Industrial Model: Selected Process Flows Revised Final Report," prepared for EIA under Contract No. DE-AC01-92EI21946, Subtask 2B, Vienna, VA, April 26, 1993.

MODEL INPUT: *BYPINT*

MODEL COMPONENT: Process/Assembly

DEFINITION: Byproduct rate of production for byproduct *b* at process step *s* and vintage *v*

DISCUSSION:

The rate of production for each byproduct is calculated similarly to the calculation of unit energy consumption (UEC) for fuels used in the PA component. The total 1988 byproduct energy consumed in the BSC component is determined from the ADL Industrial Model Baseline Database. The total byproduct energy consumed is then divided by the 1988 value of output to obtain the UEC or rate of production for byproducts. Byproduct production in the paper and allied products industry includes pulping liquor produced in the kraft pulping process step and wood from the wood prep process step. Estimates of these two byproducts are obtained from *1988 Manufacturing Energy Consumption Survey* (MECS). The production obtained from MECS is then divided by the total physical throughput to the particular process step to determine the rate of production. The total byproduct production from blast furnaces and coke ovens must be shared out to the two process steps based on the physical throughput obtained from ADL.

SOURCES:

Decision Analysis Corporation of Virginia and Arthur D. Little, "Industrial Model: Baseline Database Final Report," prepared for EIA under Contract No. DE-AC01-92EI21946, Subtask 1, Vienna VA, January 15, 1993.

Energy Information Administration, Manufacturing Energy Consumption Survey: Consumption of Energy, 1988, DOE/EIA-0512(88), Washington, D.C., May 1991.

Decision Analysis Corporation and Arthur D. Little, "Industrial Model: Selected Process Flows Revised Final Report," prepared for EIA under Contract No. DE-AC01-92EI21946, Subtask 2B, Vienna, VA, April 26, 1993.

MODEL INPUT: *BYSINT*

MODEL COMPONENT: Boiler/Steam/Cogeneration

DEFINITION: Intensity for byproduct *b* consumed in the BSC component

DISCUSSION:

The intensity for byproducts consumed in the BSC component was obtained from the Department of Energy.

SOURCE:

Department of Energy, "Industrial Energy Productivity Project - Final Report," Generic Energy Services, DOE/CS/40151-1, Vol. 7 of 9, February 1983.

MODEL INPUT: *CAPREG*

MODEL COMPONENT: Boiler/Steam/Cogeneration

DEFINITION: Existing or planned capacity for cogeneration for use *u* in Census region *r* using fuel *f* in year *y*

DISCUSSION:

The existing or planned capacity for cogeneration was obtained from EIA-867 data.

SOURCE:

Energy Information Administration, EIA-867, Survey of Independent Power Producers Database.

MODEL INPUT: *CUMOUT88*

MODEL COMPONENT:

DEFINITION: Cumulative output through the year 1988

DISCUSSION:

Cumulative output was from NEA data (1958 - 1985) and output DRI (1986 - 1988).

SOURCES:

U. S. Department of Commerce, Office of Business Analysis, *National Energy Accounts*, PB89-187918, February 1989.

DRI, Inc., Data Series I/O-US/0293/Series.

MODEL INPUT: *EINTER*

MODEL COMPONENT: Process/Assembly

DEFINITION: Intercept at process step *s* for fuel *f* and vintage *v*

DISCUSSION:

Initial estimates of the intercept term are calculated based on initial UEC estimates and TPC coefficients. A series of regressions run by ADL determined the TPC coefficients (see the discussion of the variable *BCSC*). The resulting line of Relative Energy Intensity (REI) versus time has the TPC coefficient as the slope. The intercept of the regression line is used to calculate the variable *EINTER*. The regression equation solved by ADL is the following.

$$REI = \alpha + \beta t \tag{A-14}$$

Since the REI is defined as the ratio of the current year's UEC to the UEC for 1988, the above equation may be written as follows.

$$\log\left[\frac{UEC_t}{UEC_{88}}\right] = \alpha + \beta t \tag{A-15}$$

Upon solving the above equation for UEC_t, the following equation emerges.

$$UEC_t = UEC_{88} \; x \; e^{\alpha} \; x \; e^{\beta t} \tag{A-16}$$

The initial intercept estimate is the following part of the equation above.

$$EINTER = UEC_{88} \ x \ e^{\alpha} \qquad \textbf{(A-17)}$$

SOURCE:

Decision Analysis Corporation and Arthur D. Little, "Industrial Model: Selected Process Flows Revised Final Report," prepared for EIA under Contract No. DE-AC01-92EI21946, Subtask 2B, Vienna, VA, April 26, 1993.

MODEL INPUT: *EMISSCONTROLFAC*

MODEL COMPONENT:

DEFINITION: Emission control factor for pollutant *p* using fuel *f*

DISCUSSION:

Emission factors for all pollutants except CO_2 and total carbon were derived from EPA emissions factors. Carbon emission factors were obtained from (EIA).

SOURCE:

Energy Information Administration, "Emissions Greenhouse Gases: 1985 - 1990", DOE/EIA-0573 (Washington, D.C., September 1993).

MODEL INPUT: *ENBINT*

MODEL COMPONENT: Buildings

DEFINITION: Unit energy consumption (UEC) for fuel *f* used in building end use *e*

DISCUSSION:

There is no building energy use in the non-manufacturing industries due to lack of information, therefore, there is no unit energy consumption for these industries. For the manufacturing industries, the unit energy consumption for buildings is determined in the following manner. Total electricity consumption for buildings for lighting and air conditioning is provided by ADL. Percents of total electricity consumption for each end use are based on a study by Halger, Bailley & Company. Several assumptions were made to estimate energy use from this study. In particular, information was not available for the tobacco industry, so it was assumed to be similar to the food industry. Building energy use for the furniture industry was assumed to be similar to energy use in the lumber industry. Consumption of natural gas in buildings was determined from the 1985 energy consumption data from an ISTUM-2 run made by Energy and Environmental Analysis, Inc. Consumption of steam in buildings was determined through the following procedure:

1. Total fuel consumption for space heating is obtained using the percent shares from the Halger, Bailley study and total fuel consumption from MECS.
2. The ADL Industrial Model Baseline Database natural gas consumption estimate is subtracted from the total fuel consumption calculated above, resulting in the fuel consumption necessary to generate steam.
3. Using boiler efficiencies provided by ADL, the steam consumption is estimated.

The unit energy consumption is then calculated by dividing the consumption of each fuel for lighting and HVAC by an EIA estimate of 1988 employment for the industry. The UECs are calculated on a national basis and assumed to be constant for each region.

SOURCES:

Decision Analysis Corporation of Virginia and Arthur D. Little, "Industrial Model: Baseline Database Final Report," prepared for EIA under Contract No. DE-AC01-92EI21946, Subtask 1, Vienna VA, January 15, 1993, Appendix E.

Halger, Bailley & Company, "Industrial Buildings Energy Use," prepared for Department of Energy, Office of Buildings and Community Systems, March 1987.

Energy Information Administration, Manufacturing Energy Consumption Survey: Consumption of Energy 1988, DOE/EIA-0512(88), May 1991.

Energy and Environmental Analysis, Inc., "Industrial Energy Productivity Project - Final Report", prepared for the Department of Energy, DOE/CS/40151 (nine volumes), February 1983.

MODEL INPUT: *ENPINT*

MODEL COMPONENT: Process/Assembly

DEFINITION: Unit energy consumption (UEC) at process step *s* for fuel *f* and vintage *v*

DISCUSSION:

The UECs for the non-energy-intensive and non-manufacturing industries are obtained from ADL estimates. For the energy intensive industries, UECs are derived for each process step as well as for each fuel. The total unit energy consumption for each process step for each of the energy intensive industries is determined from ADL estimates and 1988 value of output. ADL provides estimates of UEC for electricity, steam, and direct fuels fired. The total consumption in the PA component is obtained for each industry and fuel from the ADL Industrial Model Baseline Database. The UEC for direct fuels fired is then shared out between the fuels consumed at each process step based on the ADL Industrial Model Baseline Database.

$$ENPINT_{v,f,s} = ENPINTLAG_{v,f,s} \quad \textbf{(A-18)}$$

where:

$ENPINT_{v,f,s}$	=	Unit energy consumption of fuel *f* at process step *s* for vintage *v*, and
$ENPINTLAG_{v,f,s}$	=	Lagged unit energy consumption of fuel *f* at process step *s* for vintage *v*.

$$ENPINT_{v,f,s} = EINTER_{v,f,s} \ x \ CSCCUR_{v,f,s} \quad \textbf{(A-19)}$$

where:

$ENPINT_{v,f,s}$	=	Unit energy consumption of fuel *f* at process step *s* for vintage *v*,

$EINTER_{v,f,s}$	=	Intercept at process step *s* for fuel *f* for vintage *v*, and
$CSCCUR_{v,f,s}$	=	Current energy savings at process step *s* for fuel *f* for vintage *v*.

The unit energy consumption is calculated at the national level, and is assumed to be constant for all Census regions. The initial UEC estimates are assumed equal for both old and new vintage. UEC estimates are measured in kWh/ton for electricity and in MMBtu/ton for all other fuels.

<u>**SOURCES:**</u>

Decision Analysis Corporation and Arthur D. Little, "Industrial Model: Selected Process Flows Revised Final Report," prepared for EIA under Contract No. DE-AC01-92EI21946, Subtask 2B, Vienna, VA, April 26, 1993.

Decision Analysis Corporation of Virginia and Arthur D. Little, "Industrial Model: Baseline Database Final Report," prepared for EIA under Contract No. DE-AC01-92EI21946, Subtask 1, Vienna VA, January 15, 1993.

MODEL INPUT: *ENSINT*

MODEL COMPONENT: Boiler/Steam/Cogeneration

DEFINITION: Intensity for fuel *f* consumed in the BSC component

DISCUSSION:

Intensity for fuels consumed in the BSC component were obtained from the Department of Energy.

SOURCE:

Department of Energy, "Industrial Energy Productivity Project - Final Report," Generic Energy Services, DOE/CS/40151-1, Vol. 7 of 9, February 1983.

MODEL INPUT: *GEN90*

MODEL COMPONENT: Boiler/Steam/Cogeneration

DEFINITION: 1990 generation of electricity

DISCUSSION:

Generation of electricity in 1990 was obtained from EIA-867 data.

SOURCE:

Energy Information Administration, EIA-867, Survey of Independent Power Producers Database.

MODEL INPUT: *GENEQPHTRT*

MODEL COMPONENT: Boiler/Steam/Cogeneration

DEFINITION: Heat rate for cogeneration of electricity by prime mover *m*

DISCUSSION:

Heat rates are assumed to be constant for all industries and all regions. Heat rates change based on the prime mover. For combustion turbines, including gas turbines and combined cycles, the heat rate is assumed to be 14,000 Btu/kWh. Internal combustion engines have a heat rate of 11,000 Btu/kWh. Steam turbines have a heat rate of 25,000 Btu/Kwh. Renewables, including wind turbines, solar and hydropower, are assumed to have a heat rate of 0 Btu/kWh.

SOURCE:

Decision Analysis Corporation of Virginia and Arthur D. Little, "Industrial Model: Baseline Database Final Report," prepared for EIA under contract No. DE-AC01-92EI21946, Task 92-016, Subtask 1, Vienna VA, January 15, 1993, p. 32.

MODEL INPUT: *GENEQPSHR*

MODEL COMPONENT: Boiler/Steam/Cogeneration

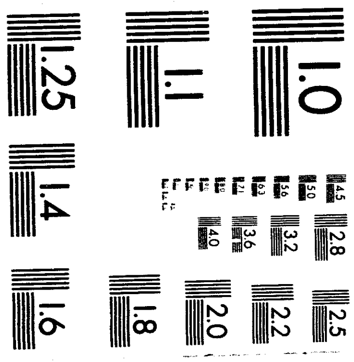
DEFINITION: Share of cogeneration for prime mover *m*

DISCUSSION:

The share of cogeneration by prime mover was obtained from EIA-867 data.

SOURCE:

Energy Information Administration, EIA-867, Survey of Independent Power Producers Database.


1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0
4.5
5.0
5.6

3 of 5

MODEL INPUT: *GENEQPSTEFF*

MODEL COMPONENT: Boiler/Steam/Cogeneration

DEFINITION: Efficiency of cogeneration for prime mover *m*

DISCUSSION:

The efficiency for internal combustion engines and combustion turbines is 74 percent for all industries. The efficiencies for steam turbines and renewables are 0.

SOURCE:

ADL, Facsimile, February 8, 1993.

MODEL INPUT: *GENUTIL*

MODEL COMPONENT: Boiler/Steam/Cogeneration

DEFINITION: Capacity utilization for cogeneration

DISCUSSION:

Capacity utilization data was obtained from EIA-867 data.

SOURCE:

Energy Information Administration, EIA-867, Survey of Independent Power Producers Database.

MODEL INPUT: *GSTEAM*

MODEL COMPONENT: Boiler/Steam/Cogeneration

DEFINITION: Steam demand coefficient for cogeneration regressions

DISCUSSION:

The steam demand coefficient was estimated through a system of simultaneous linear regressions. The following equation was estimated from pooled EIA-867 data over the years 1989, 1990, and 1991.

$$LN(GEN) = \alpha + \beta \times LN(STEAM) \qquad \textbf{(A-20)}$$

The resulting coefficient, β, is the steam demand coefficient. Data for generation was obtained from the EIA-867 database. Data for steam demand was determined from 1988 MECS. The same coefficient is used for each industry and region.

SOURCES:

Energy Information Administration, EIA-867, Survey of Independent Power Producers Database.

Energy Information Administration, Manufacturing Energy Consumption Survey: Consumption of Energy 1988, DOE/EIA-0512(88), May 1991.

MODEL INPUT: *IDVAL*

MODEL COMPONENT: Process/Assembly

DEFINITION: Units of value of production

DISCUSSION:

A value of one for *IDVAL* indicates that the input data for value of production is in physical units. A value of two indicates that the value of production is in dollar units. The following industries have *IDVAL* equal to 1: paper and allied products, glass and glass products, hydraulic cement, blast furnaces and basic steel products, and primary aluminum.

MODEL INPUT: *INDDIR*

DEFINITION: Industry code

DISCUSSION:

The following table shows the industry codes used by the Industrial model.

Industry Code	Industry Name	SIC Code
	Non-Manufacturing	
01	Agricultural Production - Crops	01
02	Other Agriculture including livestock	02 - 09
03	Coal Mining	12
04	Oil and Gas Mining	13
05	Metal and Other Non-Metallic Mining	10, 14
06	Construction	15, 16, 17
	Manufacturing	
07	Food and Kindred Products	20
08	Tobacco Products	21
09	Textile Mill Products	22
10	Apparel and Other Textile Products	23
11	Lumber and Wood Products	24
12	Furniture and Fixtures	25
13	Paper and Allied Products	26
14	Printing and Publishing	27
15	Bulk Chemicals	281, 282, 286, 287
19	Other Chemicals and Allied Products	283, 284, 285, 289
20	Petroleum Refining	291
21	Asphalt and Miscellaneous Coal Products	2911

22	Rubber and Miscellaneous Plastics Products	30
23	Leather and Leather Products	31
24	Glass and Glass Products	321, 322, 323
25	Cement, Hydraulic	324
26	Other Stone, Clay, and Glass Products	325, 326, 327, 328, 329
27	Blast Furnace and Basic Steel Products	331, 332
28	Primary Aluminum	3334, 3341, 3353, 3354, 3355
29	Other Primary Metals	333 - 336, 339, with the above exceptions
30	Fabricated Metals Products	34
31	Industrial Machinery	35
32	Electronic and Other Electric Equipment	36
33	Transportation Equipment	37
34	Instruments and Related Products	38
35	Miscellaneous Manufacturing	39

MODEL INPUT: *INDSTEPNAME*

MODEL COMPONENT: Process/Assembly

DEFINITION: Step name for process step *s*

DISCUSSION:

The following process steps are modeled in the Industrial model.

Industry	Process Step
Food and Kindred Products	
	Direct Heating
	Hot Water and Steam
	Refrigeration and Freezing
	Other Electric Use
Paper and Allied Products	
	Papermaking
	Bleaching
	Waste Fibers Pulping
	Mechanical Pulping
	Semi-Chemical Pulping
	Kraft Pulping
	Wood Preparation
Bulk Chemicals	

	Electrolytic
	Other Electric
	Direct Fuels
	Steam
	Feedstocks
Glass and Glass Products	
	Post-Forming
	Forming
	Melting/Recycled
	Melting/Virgin
	Batch Prep/Recycled
	Batch Prep/Virgin
Hydraulic Cement	
	Finish Grinding
	Dry Process
	Wet Process
Blast Furnace and Basic Steel Products	
	Cold Rolling
	Hot Rolling
	Ingot Casting

	Continuous Casting
	Blast Furnace/Open Hearth
	Blast Furnace/Basic Oxygen Furnace
	Electric Arc Furnace
	Coke Ovens
Primary Aluminum	
	Aluminum Smelting

SOURCE:

Decision Analysis Corporation and Arthur D. Little, "Industrial Model: Selected Process Flows Revised Final Report," prepared for EIA under Contract No. DE-AC01-92EI21946, Subtask 2B, Vienna, VA, April 26, 1993.

MODEL INPUT: *ITYPE*

MODEL COMPONENT: Process/Assembly

DEFINITION: Equation type for fuel *f* at process step *s*

DISCUSSION:

The equation type determines what method to use to calculate updated UECs. Equation type one assumes the UECs are constant. Equation type two is an econometrically estimated equation. Equation type three corresponds to the technology possibility curves. The non-energy-intensive industries, with a few exceptions, utilize an econometric equation, or equation type two, to estimate UECs. The energy intensive industries, with the exception of the feedstock process step in the bulk chemicals industry, use equation type 3 developed by ADL. The feedstock process step uses equation type one to estimate UEC.

MODEL INPUT: *OGEN*

MODEL COMPONENT: Boiler/Steam/Cogeneration

DEFINITION: Electricity generation for own use coefficient

DISCUSSION:

The electricity generation for own use coefficient was obtained from simultaneous regressions on EIA-867 data for the years 1989 through 1991. A regression relating total generation to steam demand was estimated, then the following equation was estimated for own use generation.

$$LN(OWN) = \alpha + \beta \times LN(GEN) \qquad \textbf{(A-21)}$$

The resulting slope coefficient, β, is the own use coefficient.

SOURCE:

Energy Information Administration, EIA-867, Survey of Independent Power Producers Database.

MODEL INPUT: *OWN90*

MODEL COMPONENT: Boiler/Steam/Cogeneration

DEFINITION: 1990 Electricity generation for own use

DISCUSSION:

1990 generation for own use was obtained from EIA-867 data.

SOURCE:

Energy Information Administration, EIA-867, Survey of Independent Power Producers Database.

MODEL INPUT: *PHDRAT*

MODEL COMPONENT: Process/Assembly

DEFINITION: 1990 production either in physical units or dollar value

DISCUSSION:

PHDRAT is in dollar units for the non-energy-intensive industries, and in physical units for the energy intensive industries except for the food and chemical industries, which are expressed in dollar value of output. Data for the non-energy-intensive industries are expressed in 1987 dollars inflated from 1982 million dollars using PCIO price deflators.

For the industries expressing value of output in physical units, data was obtained from various trade journals. Data for the paper, aluminum, and iron and steel industries were obtained from Business Statistics 1963-1991. Data for the cement industry was obtained from the Minerals Yearbook.

SOURCES:

Business Statistics 1963-1991, p. 110, 113, and 126.

Minerals Yearbook, U.S. Department of the Interior, Bureau of Mines, Volume II.

MODEL INPUT: *PRODFLOW*

MODEL COMPONENT: Process/Assembly

DEFINITION: Fraction of throughput to process step s linked through link l for vintage v

DISCUSSION:

For the non-energy-intensive industries, the fraction of throughput is one since each non-energy-intensive industry is assumed to consist of only one process step linked to the consumer. For the energy intensive industries, the fraction of throughput to each process step is determined by examining detailed process flows of each industry. All process steps linked to final consumption have a throughput fraction of one since the total amount emerging from the process step is passed directly to the final consumption. In the food and kindred products industry, each step is linked only to the final consumption, therefore the fraction of throughput to each process step through its only link is one. For all other energy intensive industries, if the current step has only one link, then the total amount of throughput at the current process step is divided by the total amount of throughput at the previous step to get fraction of throughput. If the current step is linked to several steps, then the fraction of throughput is determined by dividing the amount of throughput at the current step by the sum of throughput to all steps linked to the current step. Data on physical throughput to each process step is obtained from ADL estimates.

SOURCE:

Decision Analysis Corporation and Arthur D. Little, "Industrial Model: Selected Process Flows Revised Final Report," prepared for EIA under Contract No. DE-AC01-92EI21946, Task 92-016, Subtask 2B, Vienna, VA, April 1993.

MODEL INPUT: *PRODRETR*

MODEL COMPONENT: Process/Assembly

DEFINITION: Retirement rate at process step *s*

DISCUSSION:

Retirement rates were obtained from the Bureau of the Census. Unpublished data from the Survey of Plant Capacity from 1977 to 1988 was used to develop retirement rates.

SOURCE:

Bureau of the Census, Survey of Plant Capacity unpublished data.

MODEL INPUT: $STEMCUR_{90}$

MODEL COMPONENT: Boiler/Steam/Cogeneration

DEFINITION: Initial steam demand

DISCUSSION:

Initial steam demand for 1990 is obtained from *1988 Manufacturing Energy Consumption Survey* (MECS) for each industry and region.

SOURCE:

Energy Information Administration, Manufacturing Energy Consumption Survey: Consumption of Energy 1988, DOE/EIA-0512(88), May 1991.

MODEL INPUT: *SULFURCONT*

MODEL COMPONENT:

DEFINITION: Sulfur content of fuel *f*

DISCUSSION:

Sulfur contents are not currently calculated in the model. Therefore, all values are set to one for all fuels.

MODEL INPUT: *UNCONTEMISSFACT*

MODEL COMPONENT:

DEFINITION: Uncontrolled emission factor for pollutant *p* using fuel *f*

DISCUSSION:

Uncontrolled emission factors for all pollutants except CO_2 and total carbon were derived from EPA emissions factors. Carbon emission factors were obtained EIA (1993).

SOURCE:

Energy Information Administration, "Emissions Greenhouse Gases: 1985 - 1990", DOE/EIA-0573 (Washington, D.C., September 1993).

Appendix B. Mathematical Representation of Model Algorithms

Introduction

This appendix presents the subroutine flow diagrams for the Industrial Sector Model and a detailed mathematical description of the industrial model. The diagrams depict the relation between the main modules and the various submodules of the model. The Industrial Sector Model has three main subroutines: IND, ISEAM, and MODCAL. All the other subroutines are called from these subroutines.

Equations are presented for each subroutine according to each of the three model components, as well as miscellaneous equations. Table B-1 provides the location of each equation by providing equations found in each subroutine.

Figure B-1. Main Industrial Subroutine - IND

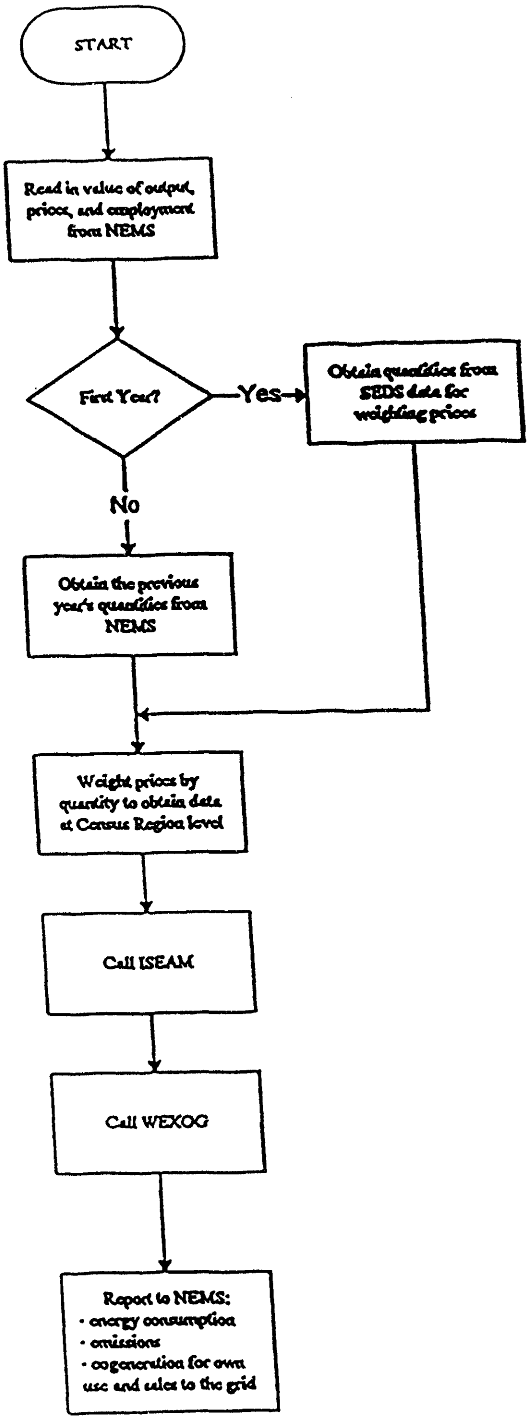


Figure B-2. Subroutine ISEAM

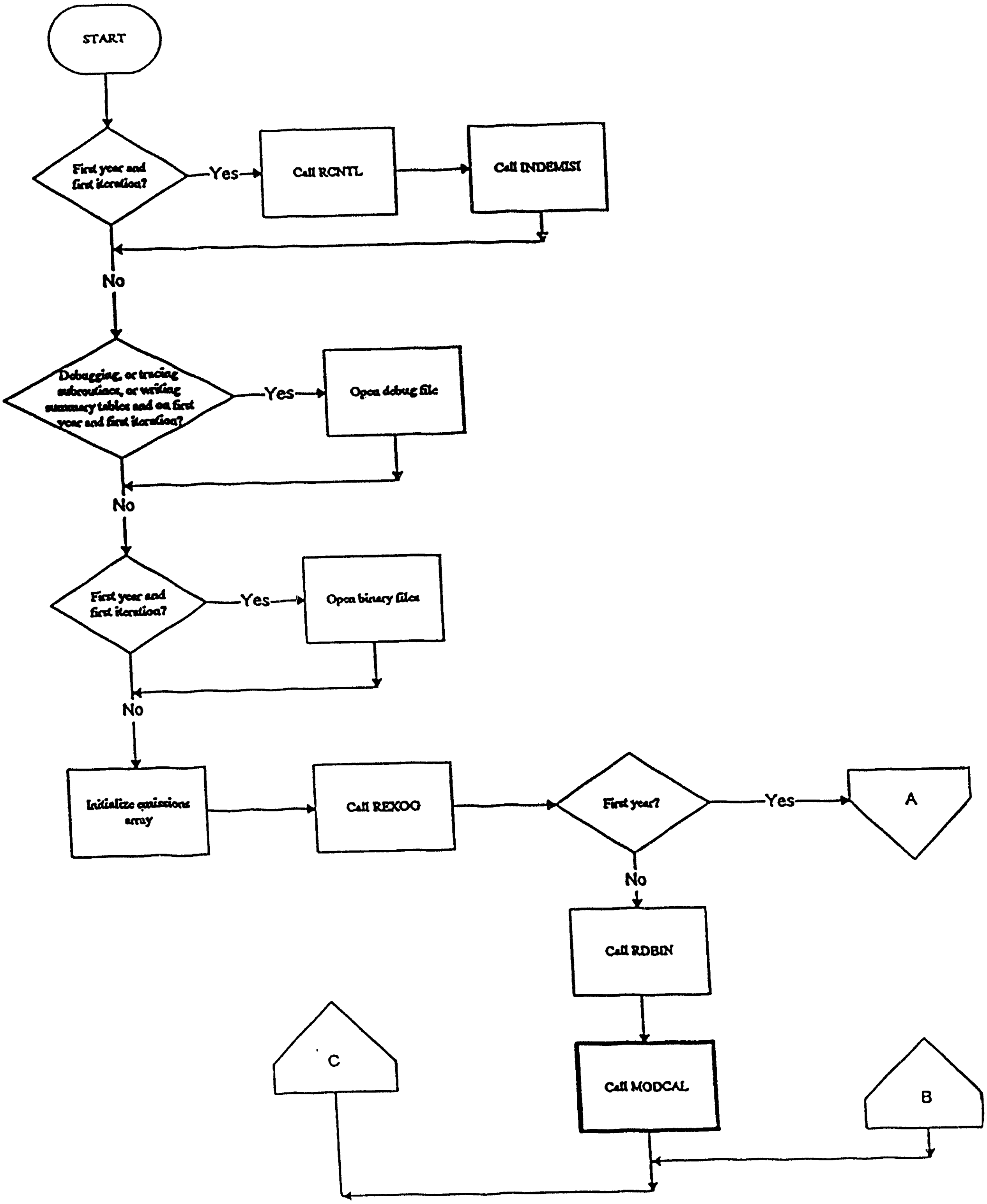


Figure B-2. Subroutine ISEAM, cont.

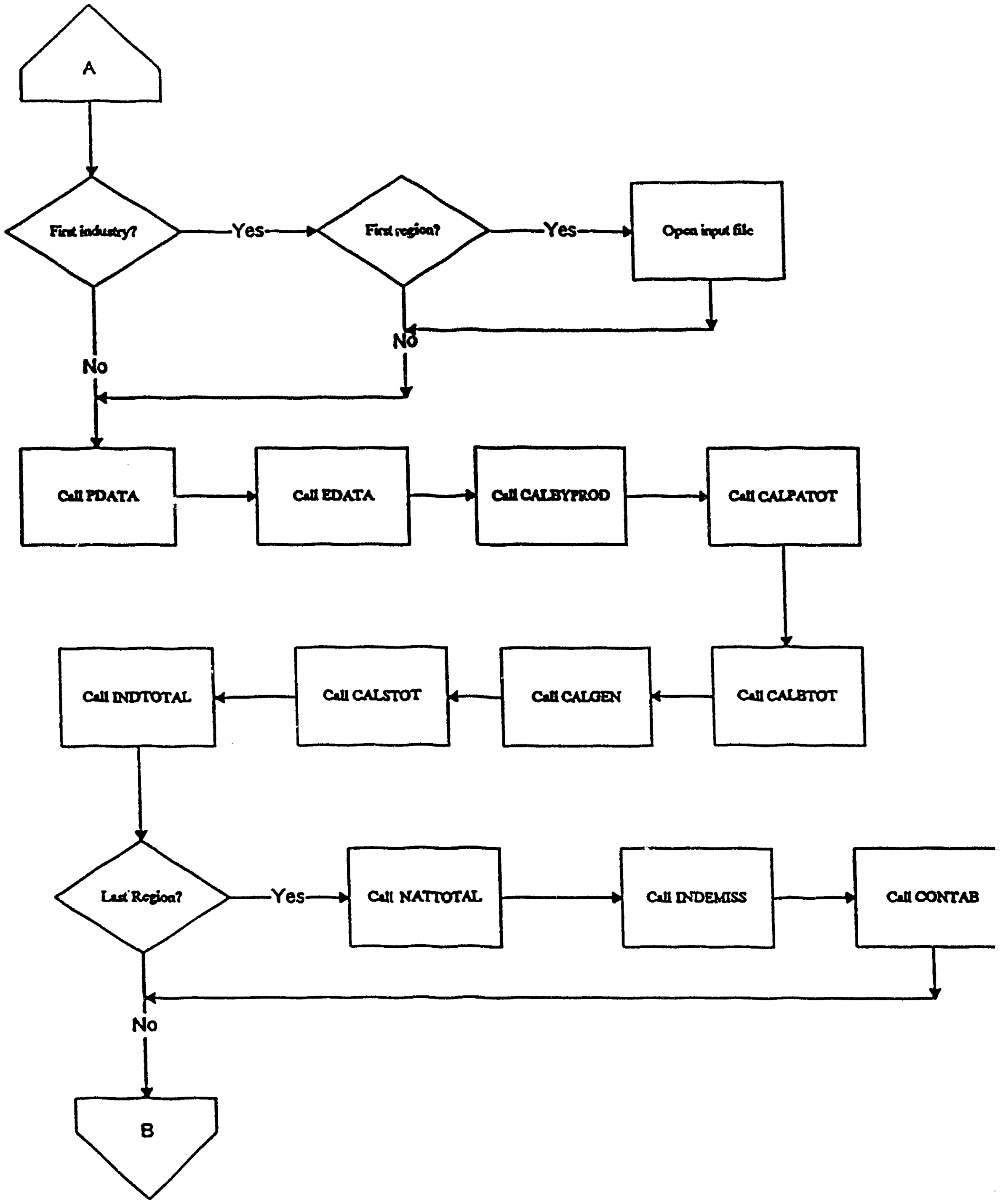


Figure B-2. Subroutine ISEAM, cont.

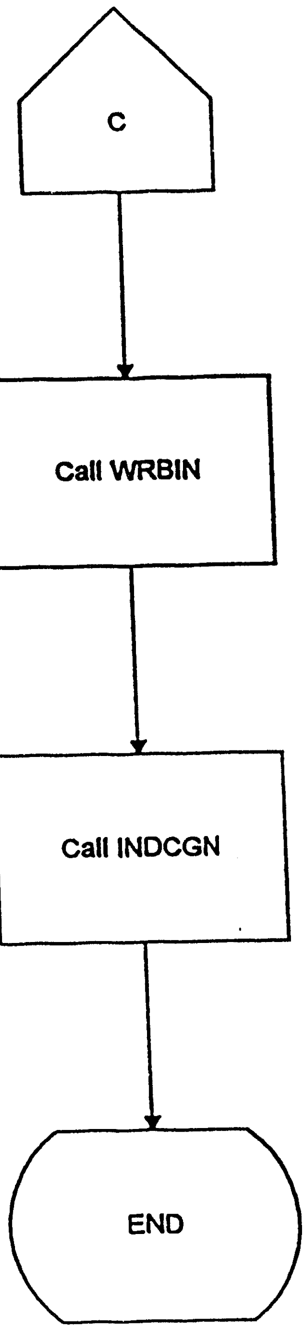


Figure B-3. Subroutine MODCAL

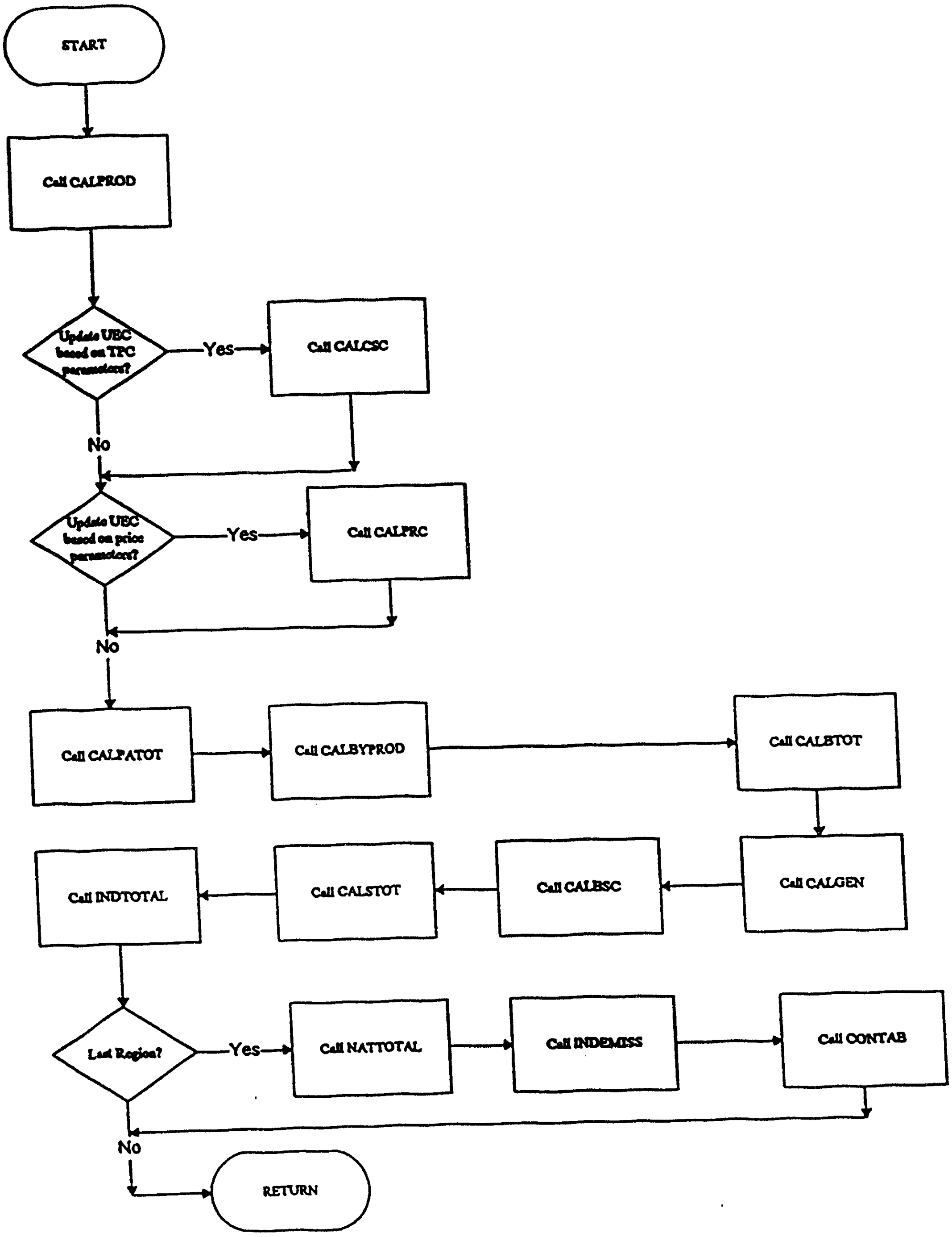


Table B-1. Equation locations

Subroutine	Equation
CALBSC	B-98 to B-99
CALBTOT	B-1 to B-2
CALBYPROD	B-129 to B-138
CALCSC	None
CALCSC1	B-33
CALCSC2	B-34 to B-36
CALCSC3	B-37 to B-58
CALGEN	B-62 to B-73
CALINTER	B-61
CALPATOT	B-3 to B-14
CALPRC	None
CALPRC1	None
CALPRC2	B-59 to B-60
CALPRC3	None
CALPROD	B-15 to B-32
CALSTOT	B-74 to B-87
CONTAB	B-160 to B-178
EDATA	None
FUELBOIL	B-88 to B-97
IBSEDS	B-226 to B-229
IND	B-122 to B-125
INDCGN	B-100 to B-121

INDEMISI	None
INDEMISS	B-154 to B-159
INDTOTAL	B-139 to B-147
ISEAM	None
MODCAL	None
NATTOTAL	B-148 to B-153
PDATA	B-230 to B-235
RCNTL	None
RDBIN	None
REXOG	B-126 to B-128
SUMTAB	B-179
WEXOG	B-180 to B-225
WRBIN	None
WRQTY	None

BUILDINGS

CALBTOT

Calculate energy consumption in buildings

$$ENBQTY_{e,f} = EMPLX_{i,r} \times ENBINT_{e,f} \tag{B-1}$$

where:

$ENBQTY_{e,f}$	=	Consumption of fuel f for building end use e,
$EMPLX_{i,r}$	=	Employment for industry i in Census region r, and
$ENBINT_{e,f}$	=	Unit energy consumption of fuel f for building end use e.

$$ENBQTY_{total,f} = \sum_{e=1}^{2} ENBQTY_{e,f} \tag{B-2}$$

where:

$ENBQTY_{total,f}$	=	Consumption of fuel f for all building end uses, and
$ENBQTY_{e,f}$	=	Consumption of fuel f for building end use e.

PROCESS/ASSEMBLY

CALPATOT

For the construction industry, calculate consumption of asphalt and road oil for years after 1990.

$$ENPQTY_{v,asp,s} = ENPINT_{v,asp,s} \times PRODZERO_{v,s} + 0.4 \times (PRODCUR_{v,s} - PRODZERO_{v,s}) \qquad \text{(B-3)}$$

where:

$ENPQTY_{v,asp,s}$	=	Consumption of asphalt and road oil at process step s for vintage v,
$ENPINT_{v,asp,s}$	=	Unit energy consumption of asphalt and road oil at process step s for vintage v,
$PRODZERO_{v,s}$	=	1990 production at process step s for vintage v, and
$PRODCUR_{v,s}$	=	Production at process step s for vintage v.

For the bulk chemical industry and the natural gas feedstock process step, the following equations are used after 1990.

$$ENPQTY_{v,ngf,s} = ENPINT_{v,ngf,s} \times PRODZERO_{v,s} + 0.25 \times (PRODCUR_{v,s} - PRODZERO_{v,s}) \qquad \text{(B-4)}$$

where:

$ENPQTY_{v,ngf,s}$	=	Consumption of natural gas feedstock at process step s for vintage v,
$ENPINT_{v,ngf,s}$	=	Unit energy consumption of natural gas feedstock at process s step for vintage v,
$PRODZERO_{v,s}$	=	1990 production at process step s for vintage v, and
$PRODCUR_{v,s}$	=	Production at process step s for vintage v.

For liquid petroleum gas and petrochemical feedstocks the following is used.

$$ENPQTY_{v,f,fd} = ENPINT_{v,f,fd} \times PRODZERO_{v,fd} + 0.8 \times (PRODCUR_{v,fd} - PRODZERO_{v,fd}) \quad \text{(B-5)}$$

where:

$ENPQTY_{v,f,fd}$	=	Consumption of fuel f at the feedstock process step for vintage v,
$ENPINT_{v,f,fd}$	=	Unit energy consumption of fuel f at the feedstock process step for vintage v,
$PRODZERO_{v,fd}$	=	1990 production at the feedstock process step for vintage v, and
$PRODCUR_{v,fd}$	=	Production at the feedstock process step for vintage v.

For all other fuels and process steps, calculate energy consumption

$$ENPQTY_{v,f,s} = PRODCUR_{v,s} \times ENPINT_{v,f,s} \quad \text{(B-6)}$$

where:

$ENPQTY_{v,f,s}$	=	Consumption of fuel f at process step s for vintage v,
$PRODCUR_{v,s}$	=	Production at process step s for vintage v, and
$ENPINT_{v,f,s}$	=	Unit energy consumption of fuel f at process step s for vintage v.

$$ENPQTY_{total,f,s} = \sum_{v=1}^{3} ENPQTY_{v,f,s} \quad \text{(B-7)}$$

where:

$ENPQTY_{total,f,s}$ = Consumption of fuel f at process step s for all vintages, and

$ENPQTY_{v,f,s}$ = Consumption of fuel f at process step s for vintage v.

Convert to trillion Btu. For electricity use the following equation.

$$ENPQTY_{v,elec,s} = \frac{ENPQTY_{v,elec,s}\ x\ 3412.0}{10^6} \qquad \textbf{(B-8)}$$

where:

$ENPQTY_{v,elec,s}$ = Consumption of electricity at process step s for vintage v,

3412.0 = Conversion factor, 3412.0 Btu per kilowatthour, and

10^6 = Conversion factor to convert from MMBtu to trillion Btu.

For all other fuels use the following

$$ENPQTY_{v,f,s} = \frac{ENPQTY_{v,f,s}}{10^6} \qquad \textbf{(B-9)}$$

where:

$ENPQTY_{v,f,s}$ = Consumption of fuel f at process step s for vintage v, and

10^6 = Conversion factor to convert from MMBtu to trillion Btu.

$$ENPQTY_{v,total,s} = \sum_{f=1}^{IFMAX_s} ENPQTY_{v,f,s} \tag{B-10}$$

where:

$ENPQTY_{v,total,s}$	=	Consumption of all fuels at process step s for vintage v,
$IFMAX_s$	=	Number of fuels consumed at process step s, and
$ENPQTY_{v,f,s}$	=	Consumption of fuel f at process step s for vintage v.

Sum energy consumption for main fuels, intermediate fuels, and renewable fuels.

$$ENPMQTY_f = \sum_{s=1}^{MPASTP} ENPQTY_{total,f,s} \tag{B-11}$$

where:

$ENPMQTY_f$	=	Consumption of main fuel f in the PA component,
$MPASTP$	=	Number of process steps, and
$ENPQTY_{total,f,s}$	=	Consumption of fuel f at process step s for all vintages.

$$ENPIQTY_f = \sum_{s=1}^{MPASTP} ENPQTY_{total,f,s} \tag{B-12}$$

where:

$ENPIQTY_f$ = Consumption of intermediate fuel f in the PA component,

$MPASTP$ = Number of process steps, and

$ENPQTY_{total,f,s}$ = Consumption of fuel f at process step s for all vintages.

$$ENPRQTY_f = \sum_{s=1}^{MPASTP} ENPQTY_{total,f,s} \quad \textbf{(B-13)}$$

where:

$ENPRQTY_f$ = Consumption of renewable fuel f in the PA component,

$MPASTP$ = Number of process steps, and

$ENPQTY_{total,f,s}$ = Consumption of fuel f at process step s for all vintages.

For the blast furnace and basic steel products industry at process step 8 (coke ovens), use the following equation:

$$ENPMQTY_{coke} = ENPIQTY_{coke} - \left[PRODCUR_{total,co} \; x \; \frac{24.8}{10^6} \right] \quad \textbf{(B-14)}$$

where:

$ENPMQTY_{coke}$ = Consumption of coke imports in the PA component,

$ENPIQTY_{coke}$ = Consumption of coke in the PA component,

$PRODCUR_{total,co}$ = Production at the coke oven process step for all vintages, and

$24.8/10^6$ = Conversion factor, where there are 24.8 MMBtu per short ton of coke converted to trillion Btu.

CALPROD

For the manufacturing industries, the following equations are used to retire old and mid vintage production.

$$PRODCUR_{old,s} = \left[PRODCUR_{old,s} + IDLCAP_{old,s}\right] x \ (1 - PRODRETR_s) \qquad \textbf{(B-15)}$$

where:

$PRODCUR_{old,s}$ = Existing production at process step s for old vintage,

$IDLCAP_{old,s}$ = Idle production for process step s for old vintage, and

$PRODRETR_s$ = Retirement rate at process step s.

$$PRODCUR_{mid,s} = (PRODCUR_{mid,s} + PRODCUR_{new,s}) \ x \ (1 - PRODRETR_s) \qquad \textbf{(B-16)}$$

where:

$PRODCUR_{mid,s}$ = Existing production at process step s for mid vintage,

$PRODCUR_{new,s}$ = Production at process step s for new vintage, and

$PRODRETR_s$ = Retirement rate at process step s.

For the non-manufacturing industries, there is no retirement data.

$$PRODCUR_{old,s} = PRODCUR_{old,s} + IDLCAP_{old,s} \tag{B-17}$$

where:

$PRODCUR_{old,s}$	=	Existing production at process step s for old vintage, and
$IDLCAP_{old,s}$	=	Idle production for process step s for old vintage.

$$PRODCUR_{mid,s} = PRODCUR_{mid,s} + PRODCUR_{new,s} \tag{B-18}$$

where:

$PRODCUR_{mid,s}$	=	Existing production at process step s for mid vintage, and
$PRODCUR_{new,s}$	=	Production at process step s for new vintage.

If IDVAL = 1, then

$$PRODX_{i,r} = PHDRAT\ x\ PRODVX_{i,r} \tag{B-19}$$

where:

$PRODX_{i,r}$	=	Output in physical units for industry i in Census region r,
$PHDRAT$	=	Ratio of physical units to value of output, and
$PRODVX_{i,r}$	=	Value of output for industry i in Census region r.

If IDVAL = 2, then

$$PRODX_{i,r} = PRODVX_{i,r} \quad \textbf{(B-20)}$$

where:

$PRODX_{i,r}$	=	Output in dollar units for industry i in Census region r, and
$PRODVX_{i,r}$	=	Value of output for industry i in Census region r.

If process step is linked to final consumption then,

$$PRODCUR_{total,s} = PRODFLOW_{old,s,l} \; x \; PRODX_{i,r} \quad \textbf{(B-21)}$$

where:

$PRODCUR_{total,s}$	=	Production at process step s for all vintages,
$PRODFLOW_{old,s,l}$	=	Down-step throughput to process step s linked by link l for old vintage, and
$PRODX_{i,r}$	=	Value of output for industry i in Census region r.

If total current production is greater than production from old and middle vintage, then

$$PRODCUR_{new,s} = PRODCUR_{total,s} - PRODCUR_{old,s} - PRODCUR_{mid,s} \quad \textbf{(B-22)}$$

where:

$PRODCUR_{new,s}$	=	Production at process step s for new vintage,
$PRODCUR_{total,s}$	=	Total production at process step s for all vintages,

$PRODCUR_{old,s}$ = Existing production at process step s for old vintage, and

$PRODCUR_{mid,s}$ = Existing production at process step s for mid vintage.

If current production is equal to production from old and middle vintage, then $PRODCUR_{new,s}$ = 0.0, and $PRODCUR_{mid,s}$ is unaltered.

If current production is less than production from old and middle vintage, then $PRODCUR_{new,s}$ = 0.0 and

$$PRODCUR_{old,s} = PRODCUR_{old,s} - IDLCAP_{old,s} \qquad \textbf{(B-23)}$$

where:

$PRODCUR_{old,s}$ = Existing production at process step s for old vintage, and

$IDLCAP_{old,s}$ = Idle production for process step s for old vintage.

$$IDLCAP_{old,s} = PRODCUR_{old,s} + PRODCUR_{mid,s} - PRODCUR_{total,s} \qquad \textbf{(B-24)}$$

where:

$IDLCAP_{old,s}$ = Idle production for process step s for old vintage,

$PRODCUR_{old,s}$ = Existing production at process step s for old vintage,

$PRODCUR_{mid,s}$ = Existing production at process step s for mid vintage, and

$PRODCUR_{total,s}$ = Production at process step s for all vintages.

If $PRODCUR_{old,s}$ is less than 0, then

$$PRODCUR_{mid,s} = PRODCUR_{mid,s} + PRODCUR_{old,s} \tag{B-25}$$

where:

$PRODCUR_{mid,s}$	=	Existing production at process step s for mid vintage, and
$PRODCUR_{old,s}$	=	Existing production at process step s for old vintage.

If $PRODCUR_{mid,s}$ is less than 0, then $PRODCUR_{mid,s} = 0.0$.

If step is not linked to final consumption and there is no new production, then

$$PRODSUM_{new,s,l} = PRODCUR_{total,IP} \times PRODFLOW_{old,s,l} \tag{B-26}$$

where:

$PRODSUM_{new,s,l}$	=	Amount of throughput used at process step s through link l for new vintage,
$PRODCUR_{total,IP}$	=	Production at process step IP linked to process step s through link l for all vintages, and
$PRODFLOW_{old,s,l}$	=	Down-step throughput to process step s linked by link l for old vintage.

$$PRODCUR_{total,s} = PRODCUR_{total,s} + PRODSUM_{new,s,l} \tag{B-27}$$

where:

$PRODCUR_{total,s}$	=	Production at process step s for all vintages, and

$PRODSUM_{new,s,l}$	=	Amount of throughput used at process step s through link l for new vintage.

If link l is the last link for process step s, then $PRODCUR_{new,s}$ = 0.0. And,

$$PRODCUR_{old,s} = PRODCUR_{total,s} - PRODCUR_{mid,s} \tag{B-28}$$

where:

$PRODCUR_{old,s}$	=	Existing production at process step s for old vintage,
$PRODCUR_{total,s}$	=	Production at process step s for all vintages, and
$PRODCUR_{mid,s}$	=	Existing production at process step s for mid vintage.

If $PRODCUR_{old,s}$ is less than 0, then

$$PRODCUR_{mid,s} = PRODCUR_{mid,s} + PRODCUR_{old,s} \tag{B-29}$$

where:

$PRODCUR_{mid,s}$	=	Existing production at process step s for mid vintage, and
$PRODCUR_{old,s}$	=	Existing production at process step s for old vintage.

If $PRODCUR_{mid,s}$ is less than 0, then $PRODCUR_{mid,s}$ = 0.0.

If there is new production, then

$$PRODSUM_{new,s,l} = PRODCUR_{new,IP} \times PRODFLOW_{new,s,l} \qquad \text{(B-30)}$$

where:

$PRODSUM_{new,s,l}$ = Amount of throughput used at process step s through link l for new vintage,

$PRODCUR_{new,IP}$ = Production at process step IP linked to process step s through link l for new vintage, and

$PRODFLOW_{new,s,l}$ = Down-step throughput to process step s linked by link l for new vintage.

$$PRODCUR_{new,s} = PRODCUR_{new,s} + PRODSUM_{new,s,l} \qquad \text{(B-31)}$$

where:

$PRODCUR_{new,s}$ = Production at process step s for new vintage, and

$PRODSUM_{new,s,l}$ = Amount of throughput used at process step s through link l for new vintage.

If new production at the first process step is not zero, then

$$PRODCUR_{total,s} = PRODCUR_{old,s} + PRODCUR_{mid,s} + PRODCUR_{new,s} \qquad \text{(B-32)}$$

where:

$PRODCUR_{total,s}$ = Production at process step s for all vintages,

$PRODCUR_{old,s}$ = Existing production at process step s for old vintage,

$PRODCUR_{mid,s}$ = Existing production at process step s for mid vintage, and

$PRODCUR_{new,s}$ = Production at process step s for new vintage.

CALCSC1

Calculate UEC's

$$ENPINT_{v,f,s} = ENPINTLAG_{v,f,s} \tag{B-33}$$

where:

$ENPINT_{v,f,s}$ = Unit energy consumption of fuel f at process step s for vintage v, and

$ENPINTLAG_{v,f,s}$ = Lagged unit energy consumption of fuel f at process step s for vintage v.

CALCSC2

Calculate CSC's for old and new vintage. If $CUMOUT_{total,s}$ is less than or equal to zero, then $CSCCUR_{v,f,s}$ = 1.0, otherwise use the following equation.

$$CSCCUR_{v,f,s} = \left[CUMOUT_{total,s}\right]^{BCSC_{v,f,s}} \tag{B-34}$$

where:

$CSCCUR_{v,f,s}$ = Current energy savings at process step s for fuel f for vintage v,

$CUMOUT_{total,s}$ = Cumulative output, from 1958 through the lag of the current year, at process step s for all vintages, and

$BCSC_{v,f,s}$ = Energy savings coefficient at process step s for fuel f and vintage v.

Calculate the UEC's for old and new vintage.

$$ENPINT_{v,f,s} = EINTER_{v,f,s} \times CSCCUR_{v,f,s} \tag{B-35}$$

where:

$ENPINT_{v,f,s}$ = Unit energy consumption of fuel f at process step s for vintage v,

$EINTER_{v,f,s}$ = Intercept at process step s for fuel f for vintage v, and

$CSCCUR_{v,f,s}$ = Current energy savings at process step s for fuel f for vintage v.

For mid vintage use the following equation for UEC.

$$ENPINT_{mid,f,s} = \frac{SUMPINT_{f,s}}{CUMPROD_{new,s}} \tag{B-36}$$

where:

$ENPINT_{mid,f,s}$ = Unit energy consumption of fuel f at process step s for mid vintage,

$SUMPINT_{f,s}$ = Cumulative unit energy consumption of fuel f at process step s, and

$CUMPROD_{new,s}$ = Cumulative production at process step s for new vintage.

CALCSC3

Calculate CSC's for old and new vintage.

$$CSCCUR_{v,f,s} = e^{BCSC_{v,f,s} \times (CURIYR - 1)} \qquad \textbf{(B-37)}$$

where:

$CSCCUR_{v,f,s}$	=	Current energy savings at process step s for fuel f for vintage v,
$BCSC_{v,f,s}$	=	Energy savings coefficient at process step s for fuel f and vintage v, and
$CURIYR$	=	Current year index.

Calculate UEC's.

$$ENPINT_{v,f,s} = EINTER_{v,f,s} \times CSCCUR_{v,f,s} \qquad \textbf{(B-38)}$$

where:

$ENPINT_{v,f,s}$	=	Unit energy consumption of fuel f at process step s for vintage v,
$EINTER_{v,f,s}$	=	Intercept at process step s for fuel f for vintage v, and
$CSCCUR_{v,f,s}$	=	Current energy savings at process step s for fuel f for vintage v.

For the cold rolling process step for the blast furnace and basic steel products industry, use the following equations for new vintage UEC's.

Electric

$$ENPINT_{new,elec,s} = EINTER_{new,elec,s} \times CSCCUR_{new,elec,s} \times \frac{1}{0.20} \times \left[0.20 + \frac{(0.21 - 0.20) \times (CURIYR - 1)}{25}\right] \quad \text{(B-39)}$$

where:

$ENPINT_{new,elec,s}$	=	Unit energy consumption of electricity at process step s for new vintage,
$EINTER_{new,elec,s}$	=	Intercept at process step s for electricity for new vintage,
$CSCCUR_{new,elec,s}$	=	Current energy savings at process step s for electricity for new vintage, and
$CURIYR$	=	Current year index.

Natural Gas

$$ENPINT_{new,ng,s} = EINTER_{new,ng,s} \times CSCCUR_{new,ng,s} \times \frac{1}{0.38} \times \left[0.38 + \frac{(0.31 - 0.38) \times (CURIYR - 1)}{25}\right] \quad \text{(B-40)}$$

where:

$ENPINT_{new,ng,s}$	=	Unit energy consumption of natural gas at process step s for new vintage,
$EINTER_{new,ng,s}$	=	Intercept at process step s for natural gas for new vintage,
$CSCCUR_{new,ng,s}$	=	Current energy savings at process step s for natural gas for new vintage, and
$CURIYR$	=	Current year index.

Residual fuel

$$ENPINT_{new,res,s} = EINTER_{new,res,s} \times CSCCUR_{new,res,s} \times \frac{1}{0.007} \times \left[0.007 + \frac{(0.006 - 0.007) \times (CURIYR - 1)}{25}\right] \quad \text{(B-41)}$$

where:

$ENPINT_{new,res,s}$	=	Unit energy consumption of residual fuel at process step *s* for new vintage,
$EINTER_{new,res,s}$	=	Intercept at process step *s* for residual fuel for new vintage,
$CSCCUR_{new,res,s}$	=	Current energy savings at process step *s* for residual fuel for new vintage, and
$CURIYR$	=	Current year index.

Distillate

$$ENPINT_{new,dis,s} = EINTER_{new,dis,s} \times CSCCUR_{new,dis,s} \times \frac{1}{0.001} \times \left[0.001 + \frac{(0.0008 - 0.001) \times (CURIYR - 1)}{25}\right] \quad \textbf{(B-42)}$$

where:

$ENPINT_{new,dis,s}$	=	Unit energy consumption of distillate at process step *s* for new vintage,
$EINTER_{new,dis,s}$	=	Intercept at process step *s* for distillate for new vintage,
$CSCCUR_{new,dis,s}$	=	Current energy savings at process step *s* for distillate for new vintage, and
$CURIYR$	=	Current year index.

Liquid petroleum gas

$$ENPINT_{new,lpg,s} = EINTER_{new,lpg,s} \times CSCCUR_{new,lpg,s} \times \frac{1}{0.001} \times \left[0.001 + \frac{(0.0008 - 0.001) \times (CURIYR - 1)}{25}\right] \quad \textbf{(B-43)}$$

where:

$ENPINT_{new,lpg,s}$	=	Unit energy consumption of liquid petroleum gas at process step s for new vintage,
$EINTER_{new,lpg,s}$	=	Intercept at process step s for liquid petroleum gas for new vintage,
$CSCCUR_{new,lpg,s}$	=	Current energy savings at process step s for liquid petroleum gas for new vintage, and
$CURIYR$	=	Current year index.

Petroleum coke

$$ENPINT_{new,pc,s} = EINTER_{new,pc,s} \times CSCCUR_{new,pc,s} \times \frac{1}{0.0002} \times \left[0.0002 + \frac{(0.00016 - 0.0002) \times (CURIYR - 1)}{25}\right] \quad \textbf{(B-44)}$$

where:

$ENPINT_{new,pc,s}$	=	Unit energy consumption of petroleum coke at process step s for new vintage,
$EINTER_{new,pc,s}$	=	Intercept at process step s for petroleum coke for new vintage,
$CSCCUR_{new,pc,s}$	=	Current energy savings at process step s for petroleum coke for new vintage, and
$CURIYR$	=	Current year index.

Other petroleum

$$ENPINT_{new,pet,s} = EINTER_{new,pet,s} \times CSCCUR_{new,pet,s} \times \frac{1}{0.002} \times \left[0.002 + \frac{(0.0016 - 0.002) \times (CURIYR - 1)}{25}\right] \quad \textbf{(B-45)}$$

where:

$ENPINT_{new,pet,s}$	=	Unit energy consumption of other petroleum at process step s for new vintage,
$EINTER_{new,pet,s}$	=	Intercept at process step s for other petroleum for new vintage,
$CSCCUR_{new,pet,s}$	=	Current energy savings at process step s for other petroleum for new vintage, and
$CURIYR$	=	Current year index.

Steam

$$ENPINT_{new,st,s} = EINTER_{new,st,s} \times CSCCUR_{new,st,s} \times \frac{1}{0.41} \times \left[0.41 + \frac{(0.47 - 0.41) \times (CURIYR - 1)}{25}\right] \quad \textbf{(B-46)}$$

where:

$ENPINT_{new,st,s}$	=	Unit energy consumption of steam at process step s for new vintage,
$EINTER_{new,st,s}$	=	Intercept at process step s for steam for new vintage,
$CSCCUR_{new,st,s}$	=	Current energy savings at process step s for steam for new vintage, and
$CURIYR$	=	Current year index.

For the blast furnace process step in the blast furnace and basic steel products industry, use the following equations to calculate UEC's.

Natural Gas

$$ENPINT_{old,ng,s} = EINTER_{old,ng,s} \ x \ CSCCUR_{old,ng,s} \ x \ \frac{1}{0.06} \ x \left[0.06 + \frac{(0.26 - 0.06) \ x \ (CURIYR - 1)}{25}\right] \quad \textbf{(B-47)}$$

where:

$ENPINT_{old,ng,s}$	=	Unit energy consumption of natural gas at process step s for old vintage,
$EINTER_{old,ng,s}$	=	Intercept at process step s for natural gas for old vintage,
$CSCCUR_{old,ng,s}$	=	Current energy savings at process step s for natural gas for old vintage, and
$CURIYR$	=	Current year index.

$$ENPINT_{new,ng,s} = EINTER_{new,ng,s} \ x \ CSCCUR_{new,ng,s} \ x \ \frac{1}{0.07} \ x \left[0.07 + \frac{(0.36 - 0.07) \ x \ (CURIYR - 1)}{25}\right] \quad \textbf{(B-48)}$$

where:

$ENPINT_{new,ng,s}$	=	Unit energy consumption of natural gas at process step s for new vintage,
$EINTER_{new,ng,s}$	=	Intercept at process step s for natural gas for new vintage,
$CSCCUR_{new,ng,s}$	=	Current energy savings at process step s for natural gas for new vintage, and
$CURIYR$	=	Current year index.

Coke

$$ENPINT_{old,coke,s} = EINTER_{old,coke,s} \times CSCCUR_{old,coke,s} \times \frac{1}{0.77} \times \left[0.77 + \frac{(0.57 - 0.77) \times (CURIYR - 1)}{25}\right] \quad \textbf{(B-49)}$$

where:

$ENPINT_{old,coke,s}$	=	Unit energy consumption of coke at process step s for old vintage,
$EINTER_{old,coke,s}$	=	Intercept at process step s for coke for old vintage,
$CSCCUR_{old,coke,s}$	=	Current energy savings at process step s for coke for old vintage, and
$CURIYR$	=	Current year index.

$$ENPINT_{new,coke,s} = EINTER_{new,coke,s} \times CSCCUR_{new,coke,s} \times \frac{1}{0.82} \times \left[\frac{(0.00 - 0.82) \times (CURIYR - 1)}{25}\right] \quad \textbf{(B-50)}$$

where:

$ENPINT_{new,coke,s}$	=	Unit energy consumption of coke at process step s for new vintage,
$EINTER_{new,coke,s}$	=	Intercept at process step s for coke for new vintage,
$CSCCUR_{new,coke,s}$	=	Current energy savings at process step s for coke for new vintage, and
$CURIYR$	=	Current year index.

Steam Coal

$$ENPINT_{new,coal,s} = EINTER_{new,coal,s} \times CSCCUR_{new,coal,s} \times \frac{1}{0.01} \times \left[0.01 + \frac{(0.53 - 0.01) \times (CURIYR - 1)}{25}\right] \quad \text{(B-51)}$$

where:

$ENPINT_{new,coal,s}$	=	Unit energy consumption of steam coal at process step *s* for new vintage,
$EINTER_{new,coal,s}$	=	Intercept at process step *s* for steam coal for new vintage,
$CSCCUR_{new,coal,s}$	=	Current energy savings at process step *s* for steam coal for new vintage, and
$CURIYR$	=	Current year index.

For the dry process step in the hydraulic cement industry use the following equations to calculate UEC's.

Electricity

$$ENPINT_{new,elec,s} = EINTER_{new,elec,s} \times CSCCUR_{new,elec,s} \times \frac{1}{0.17}\left[0.17 + \frac{(0.21 - 0.17) \times (CURIYR - 1)}{25}\right] \quad \text{(B-52)}$$

where:

$ENPINT_{new,elec,s}$	=	Unit energy consumption of electricity at process step *s* for new vintage,
$EINTER_{new,elec,s}$	=	Intercept at process step *s* for electricity for new vintage,
$CSCCUR_{new,elec,s}$	=	Current energy savings at process step *s* for electricity for new vintage, and
$CURIYR$	=	Current year index.

Natural Gas

$$ENPINT_{new,ng,s} = EINTER_{new,ng,s} \times CSCCUR_{new,ng,s} \times \frac{1}{0.154}\left[0.154 + \frac{(0.147 - 0.154) \times (CURIYR - 1)}{25}\right] \quad \textbf{(B-53)}$$

where:

$ENPINT_{new,ng,s}$	=	Unit energy consumption of natural gas at process step *s* for new vintage,
$EINTER_{new,ng,s}$	=	Intercept at process step *s* for natural gas for new vintage,
$CSCCUR_{new,ng,s}$	=	Current energy savings at process step *s* for natural gas for new vintage, and
CURIYR	=	Current year index.

Steam Coal

$$ENPINT_{new,coal,s} = EINTER_{new,coal,s} \times CSCCUR_{new,coal,s} \times \frac{1}{0.53}\left[0.53 + \frac{(0.505 - 0.53) \times (CURIYR - 1)}{25}\right] \quad \textbf{(B-54)}$$

where:

$ENPINT_{new,coal,s}$	=	Unit energy consumption of steam coal at process step *s* for new vintage,
$EINTER_{new,coal,s}$	=	Intercept at process step *s* for steam coal for new vintage,
$CSCCUR_{new,coal,s}$	=	Current energy savings at process step *s* for steam coal for new vintage, and
CURIYR	=	Current year index.

Residual Fuel

$$ENPINT_{new,res,s} = EINTER_{new,res,s} \times CSCCUR_{new,res,s} \times \frac{1}{0.004}\left[0.004 + \frac{(0.0038 - 0.004) \times (CURIYR - 1)}{25}\right] \quad \text{(B-55)}$$

where:

$ENPINT_{new,res,s}$	=	Unit energy consumption of residual fuel at process step s for new vintage,
$EINTER_{new,res,s}$	=	Intercept at process step s for residual fuel for new vintage,
$CSCCUR_{new,res,s}$	=	Current energy savings at process step s for residual fuel for new vintage, and
$CURIYR$	=	Current year index.

Distillate Fuel

$$ENPINT_{new,dist,s} = EINTER_{new,dist,s} \times CSCCUR_{new,dist,s} \times \frac{1}{0.023}\left[0.023 + \frac{(0.022 - 0.023) \times (CURIYR - 1)}{25}\right] \quad \text{(B-56)}$$

where:

$ENPINT_{new,dist,s}$	=	Unit energy consumption of distillate fuel at process step s for new vintage,
$EINTER_{new,dist,s}$	=	Intercept at process step s for distillate fuel for new vintage,
$CSCCUR_{new,dist,s}$	=	Current energy savings at process step s for distillate fuel for new vintage, and
$CURIYR$	=	Current year index.

Other Petroleum

$$ENPINT_{new,pet,s} = EINTER_{new,pet,s} \times CSCCUR_{new,pet,s} \times \frac{1}{0.118}\left[0.118 + \frac{(0.112 - 0.118) \times (CURIYR - 1)}{25}\right] \quad \textbf{(B-57)}$$

where:

$ENPINT_{new,pet,s}$	=	Unit energy consumption of other petroleum at process step *s* for new vintage,
$EINTER_{new,pet,s}$	=	Intercept at process step *s* for other petroleum for new vintage,
$CSCCUR_{new,pet,s}$	=	Current energy savings at process step *s* for other petroleum for new vintage, and
$CURIYR$	=	Current year index.

Calculate UECs for middle vintage.

$$ENPINT_{mid,f,s} = \frac{SUMPINT_{f,s}}{CUMPROD_{new,s}} \quad \textbf{(B-58)}$$

where:

$ENPINT_{mid,f,s}$	=	Unit energy consumption of fuel *f* at process step *s* for middle vintage,
$SUMPINT_{f,s}$	=	Cumulative unit energy consumption of fuel *f* at process step *s*, and
$CUMPROD_{new,s}$	=	Cumulative production at process step *s* for new vintage.

CALPRC2

Calculate energy savings for old and new vintage.

$$PRCCUR_{v,f,s} = \prod_{t=1}^{11} \left[WPRC_t\right]^{BELAS_{v,f,s,t}} \quad \textbf{(B-59)}$$

where:

$PRCCUR_{v,f,s}$	=	Current energy savings based on price for fuel f at process step s for vintage v,
$WPRC_t$	=	Price for fuel t in 1987 dollars, and
$BELAS_{v,f,s,t}$	=	Own price elasticity at process step s for fuel f and cross price elasticity with fuel f and fuel t for vintage v.

Calculate UECs for old and new vintage.

$$ENPINT_{v,f,s} = ENPINT_{v,f,s} \times PRCCUR_{v,f,s} \quad \textbf{(B-60)}$$

where:

$ENPINT_{v,f,s}$	=	Unit energy consumption of fuel f at process step s for vintage v, and
$PRCCUR_{v,f,s}$	=	Current energy savings based on price for fuel f at process step s for vintage v.

CALINTER

Calculate the intercept for old and new vintage.

$$EINTER_{old,f,s} = \frac{ENPINT_{old,f,s}}{[CUMOUT88]^{BCSC_{old,f,s}} \times \prod_{t=1}^{11} [WPRC_t]^{BELAS_{old,f,s,t}}} \qquad \textbf{(B-61)}$$

where:

$EINTER_{old,f,s}$	=	Intercept at process step s for fuel f for old vintage,
$ENPINT_{old,f,s}$	=	Unit energy consumption of fuel f at process step s for old vintage,
$CUMOUT88$	=	Cumulative output through the year 1988,
$BCSC_{old,f,s}$	=	Energy savings coefficient at process step s for fuel f and old vintage,
$WPRC_t$	=	Price for fuel t in 1987 dollars, and
$BELAS_{old,f,s,t}$	=	Own price elasticity at process step s for fuel f for old vintage, and cross price elasticity at process step s for fuel f and fuel t for old vintage.

The intercept for new vintage equals the intercept for old vintage calculated above.

CALGEN

Calculate total electricity demand

$$ELDEM = ENPMQTY_{elec} + ENBQTY_{total,elec} \tag{B-62}$$

where:

$ELDEM$	=	Total electricity demand from process/assembly and buildings,
$ENPMQTY_{elec}$	=	Consumption of electricity in the PA component, and
$ENBQTY_{total,elec}$	=	Consumption of electricity for all building end uses.

Calculate total steam demand

$$STEMCUR = ENBQTY_{hvac,steam} + ENPIQTY_{steam} \tag{B-63}$$

where:

$STEMCUR$	=	Total steam demand,
$ENBQTY_{hvac,steam}$	=	Consumption of steam for HVAC, and
$ENPIQTY_{steam}$	=	Consumption of steam in the PA component.

Calculate the intercept if year is 1990.

$$GINTER = \ln\left[\frac{GEN90}{(STEMCUR)_{90}^{GSTEAM}}\right] \tag{B-64}$$

where:

$GINTER$	=	Intercept for electricity generation,
$GEN90$	=	1990 generation of electricity,
$STEMCUR_{90}$	=	Total steam demand for 1990, and
$GSTEAM$	=	Steam demand coefficient.

Calculate total US electricity generation for the industry.

$$ELGEN_{total} = e^{GINTER} \; x \; STEMCUR^{GSTEAM} \tag{B-65}$$

where:

$ELGEN_{total}$	=	Electricity generation from all prime movers,
$GINTER$	=	Intercept term for electricity generation,
$STEMCUR$	=	Total steam demand, and
$GSTEAM$	=	Steam demand coefficient.

Calculate capacity.

$$ELCAP = \frac{ELGEN_{total} \; x \; 10^9}{GENUTIL \; x \; 3412.0 \; x \; 365.25 \; x \; 24.0} \qquad \textbf{(B-66)}$$

where:

$ELCAP$	=	Capacity for electricity generation,
$ELGEN_{total}$	=	Electricity generation from all prime movers,
$GENUTIL$	=	Capacity utilization for cogeneration,
3412.0	=	Conversion factor, 3412.0 Btu per kilowatthour,
365.25	=	Number of days per year,
24.0	=	Number of hours per day, and
10^9	=	Conversion factor to convert to megawatts.

Calculate intercept for own use generation.

$$OINTER = \ln\left[\frac{OWN90}{(ELGEN_{total})^{OGEN}}\right] \qquad \textbf{(B-67)}$$

where:

$OINTER$	=	Intercept for own use generation,
$OWN90$	=	1990 electricity generation for own use,
$ELGEN_{total}$	=	Electricity generation from all prime movers, and
$OGEN$	=	Own use generation coefficient.

Calculate electricity generated for own use.

$$ELOWN = e^{OINTER} \times ELGEN_{total}^{OGEN} \qquad \text{(B-68)}$$

where:

$ELOWN$	=	Electricity generation for own use,
$OINTER$	=	Intercept for own use generation,
$ELGEN_{total}$	=	Electricity generation from all prime movers, and
$OGEN$	=	Own use generation coefficient.

Calculate electricity generated for sales.

$$ELSALE = ELGEN_{total} - ELOWN \qquad \text{(B-69)}$$

where:

$ELSALE$	=	Electricity generation for sales to the grid,
$ELGEN_{total}$	=	Electricity generation from all prime movers, and
$ELOWN$	=	Electricity generation for own use.

Calculate electricity generation by prime mover.

$$ELGEN_m = ELGEN_{total} \times GENEQPSHR_m \qquad \text{(B-70)}$$

where:

$ELGEN_m$	=	Electricity generation from prime mover m,
$ELGEN_{total}$	=	Electricity generation from all prime movers, and

$GENEQPSHR_m$ = Share of generation for prime mover m.

Electricity generation for own use (ELOWN), electricity generation for sales to the grid (ELSALE), and capacity for electricity generation (ELCAP) are totaled across industries for each region.[9]

$$ELOTOT_r = \sum_{i=1}^{INDMAX} ELOWN_{r,i} \;\; for \; r=1,...,4. \tag{B-71}$$

where:

$ELOTOT_r$ = Total industrial electricity generation for own use in Census region r,

$INDMAX$ = Number of industries, and

$ELOWN$ = Electricity generation for own use.

$$ELSTOT_r = \sum_{i=1}^{INDMAX} ELSALE_{r,i} \;\; for \; r=1,...,4. \tag{B-72}$$

where:

$ELSTOT_r$ = Total industrial electricity generation for sales to the grid in Census region r,

$INDMAX$ = Number of industries, and

$ELSALE$ = Electricity generation for sales to the grid.

[9]Notice that the variables are shown as indexed. Although the variables for the totals are subscripted, the non-total variables are not (they are shown that way as a convenience for this documentation). In the computer code, the individual values are computed for each industry and region combination and summed into the totals.

$$ELCTOT_r = \sum_{i=1}^{INDMAX} ELCAP_{r,i} \quad for\ r=1,...,4. \tag{B-73}$$

where:

$ELCTOT_r$	=	Capacity for industrial electricity generation in Census region *r*,
$INDMAX$	=	Number of industries, and
$ELCAP$	=	Capacity for electricity generation.

CALSTOT

Calculate fuel consumption from internal combustion engine and combustion turbine.

$$ICEFUEL = ELGEN_{ice}\ x\ \frac{GENEQPHTRT_{ice}}{3412.0} \tag{B-74}$$

where:

$ICEFUEL$	=	Fuel consumption for electricity generation from internal combustion engines,
$ELGEN_{ice}$	=	Electricity generation from internal combustion engines,
$GENEQPHTRT_{ice}$	=	Heat rate for internal combustion engines, and
3412.0	=	Conversion factor to convert from kWh to Btu.

$$GCTFUEL = ELGEN_{ct}\ x\ \frac{GENEQPHTRT_{ct}}{3412.0} \tag{B-75}$$

where:

$GCTFUEL$	=	Fuel consumption for electricity generation from combustion turbines,

$ELGEN_{ct}$	=	Electricity generation from combustion turbines,
$GENEQPHTRT_{ct}$	=	Heat rate for combustion turbines, and
3412.0	=	Conversion factor to convert from kWh to Btu.

Calculate steam generated for internal combustion engines and combustion turbines.

$$ICESTEAM = (ICEFUEL - ELGEN_{ice}) \times GENEQPSTEFF_{ice} \tag{B-76}$$

where:

$ICESTEAM$	=	Cogeneration of steam from internal combustion engines,
$ICEFUEL$	=	Fuel consumption for electricity generation from internal combustion engines,
$ELGEN_{ice}$	=	Electricity generation from internal combustion engines, and
$GENEQPSTEFF_{ice}$	=	Efficiency for internal combustion engines.

$$GCTSTEAM = (GCTFUEL - ELGEN_{ct}) \times GENEQPSTEFF_{ct} \tag{B-77}$$

where:

$GCTSTEAM$	=	Cogeneration of steam from combustion turbines,
$GCTFUEL$	=	Fuel consumption for electricity generation from combustion turbines,
$ELGEN_{ct}$	=	Electricity generation from combustion turbines, and
$GENEQPSTEFF_{ct}$	=	Efficiency for combustion turbines.

Calculate the steam generated from boilers.

$$BOILSTEAM = STEMCUR - (ICESTEAM + GCTSTEAM) \quad \textbf{(B-78)}$$

where:

$BOILSTEAM$	=	Steam generated from boilers,
$STEMCUR$	=	Total steam demand,
$ICESTEAM$	=	Cogeneration of steam from internal combustion engines, and
$GCTSTEAM$	=	Cogeneration of steam from combustion turbines.

Calculate the total fuel consumed for cogeneration by internal combustion engines, combustion turbines, and steam turbines.

$$CGFUEL_{coal,total,r} = STFUEL_{coal} \quad \textbf{(B-79)}$$

where:

$CGFUEL_{coal,total,r}$	=	Consumption of coal for cogeneration of electricity for all uses in Census region r, and
$STFUEL_{coal}$	=	Consumption of coal in steam turbines.

$$CGFUEL_{oil,total,r} = STFUEL_{oil} + ICEFUEL \quad \textbf{(B-80)}$$

where:

$CGFUEL_{oil,total,r}$	=	Consumption of distillate oil for cogeneration of electricity for all uses in Census region r,
$STFUEL_{oil}$	=	Consumption of distillate oil in steam turbines, and

ICEFUEL	=	Fuel consumption for electricity generation from internal combustion engines.

$$CGFUEL_{ng,total,r} = STFUEL_{ng} + GCTFUEL \qquad \textbf{(B-81)}$$

where:

$CGFUEL_{ng,total,r}$	=	Consumption of natural gas for cogeneration of electricity for all uses in Census region r,
$STFUEL_{ng}$	=	Consumption of natural gas in steam turbines, and
$GCTFUEL$	=	Fuel consumption for electricity generation from combustion turbines.

$$CGFUEL_{renew,total,r} = STFUEL_{bm} + STBYP_{bm} \qquad \textbf{(B-82)}$$

where:

$CGFUEL_{renew,total,r}$	=	Consumption of renewables for cogeneration of electricity for all uses in Census region r,
$STFUEL_{bm}$	=	Consumption of biomass in steam turbines, and
$STBYP_{bm}$	=	Consumption of byproduct biomass in steam turbines.

Calculate the amount of fuel consumed for cogeneration for own use and sales to the grid.

$$CGFUEL_{f,own,r} = CGFUEL_{f,total,r} \times \left[\frac{ELOWN}{ELGEN_{total}} \right] \qquad \textbf{(B-83)}$$

where:

$CGFUEL_{f,own,r}$	=	Consumption of fuel f for cogeneration of electricity for own use in Census region r,

$CGFUEL_{f,total,r}$	=	Consumption of fuel f for cogeneration of electricity for all uses in Census region r,
$ELOWN$	=	Electricity generation for own use, and
$ELGEN_{total}$	=	Electricity generation from all prime movers.

$$CGFUEL_{f,sales,r} = CGFUEL_{f,total,r} - CGFUEL_{f,own,r} \quad \text{(B-84)}$$

where:

$CGFUEL_{f,sales,r}$	=	Consumption of fuel f for cogeneration of electricity for sales to the grid in Census region r,
$CGFUEL_{f,total,r}$	=	Consumption of fuel f for cogeneration of electricity for all uses in Census region r, and
$CGFUEL_{f,own,r}$	=	Consumption of fuel f for cogeneration of electricity for own use in Census region r.

Calculate the total amount of fuel consumed for cogeneration for own use and sales to the grid.

$$CGFUEL_{total,u,r} = \sum_{f=1}^{4} CGFUEL_{f,u,r} \quad for\ u=1,2\ and\ r=1,..,4. \quad \text{(B-85)}$$

where:

$CGFUEL_{total,u,r}$	=	Consumption of all fuels for cogeneration of electricity for use u in Census region r, and
$CGFUEL_{f,u,r}$	=	Consumption of fuel f for cogeneration of electricity for use u in Census region r.

Calculate the US total amount of fuel f consumed for cogeneration for own use and sales to the grid.

$$CGFUEL_{f,u,total} = \sum_{r=1}^{4} CGFUEL_{f,u,r} \quad for\ f=1,...,4\ and\ u=1,2. \tag{B-86}$$

where:

$CGFUEL_{f,u,total}$	=	Consumption of fuel *f* for cogeneration of electricity for use *u* in all Census regions, and
$CGFUEL_{f,u,r}$	=	Consumption of fuel *f* for cogeneration of electricity for use *u* in Census region *r*.

Calculate the total industrial fuel consumption for cogeneration.

$$GENTOT_{f,u,r} = \sum_{i=1}^{INDMAX} CGFUEL_{f,u,r} \tag{B-87}$$

where:

$GENTOT_{f,u,r}$	=	Total consumption of fuel *f* for cogeneration of electricity for use *u* in Census region *r*,
INDMAX	=	Number of industries, and
$CGFUEL_{f,u,r}$	=	Consumption of fuel *f* for cogeneration of electricity for use *u* in Census region *r*.

FUELBOIL

$$AVGINT = \sum_{f=1}^{IFSMAX} BSSHR_f \times ENSINT_f \qquad \textbf{(B-88)}$$

where:

$AVGINT$	=	Average intensity,
$IFSMAX$	=	Number of fuels consumed in the BSC component,
$BSSHR_f$	=	Share of total fuel consumption in the BSC component for fuel f, and
$ENSINT_f$	=	Intensity of fuel f in the BSC component.

Calculate steam generated by byproduct fuels for main, intermediate, and renewable fuels.

$$BYPSTM = \sum_{f=1}^{IFSBYPM} \frac{BYPBSCM_f}{BYSINT_f} + \sum_{f=1}^{IFSBYPI} \frac{BYPBSCI_f}{BYSINT_f} + \sum_{f=1}^{IFSBYPR} \frac{BYPBSCR_f}{BYSINT_f} \qquad \textbf{(B-89)}$$

where:

$BYPSTM$	=	Amount of steam generated from all byproduct fuels,
$IFSBYPM$	=	Number of byproduct main fuels,
$BYPBSCM_f$	=	Byproduct consumption of main fuel f in the BSC component,
$BYSINT_f$	=	Intensity for byproduct fuel f consumed in the BSC component,
$IFSBYPI$	=	Number of byproduct intermediate fuels,
$BYPBSCI_f$	=	Byproduct consumption of intermediate fuel f in the BSC component,

IFSBYPR	=	Number of byproduct renewable fuels, and
$BYPBSCR_f$	=	Byproduct consumption of renewable fuel *f* in the BSC component.

Calculate the amount of steam to be generated from purchased fuels.

$$STEMCURF = STEMCUR - BYPSTM \tag{B-90}$$

where:

STEMCURF	=	Amount of steam to be generated from purchased fuels,
STEMCUR	=	Total steam demand, and
BYPSTM	=	Amount of steam generated from all byproduct fuels.

Calculate the total amount of fuel consumed to generate steam.

$$ENSQTY_f = STEMCURF \times AVGINT \times BSSHR_f \tag{B-91}$$

where:

$ENSQTY_f$	=	Consumption of fuel *f* to generate steam,
STEMCURF	=	Amount of steam to be generated from purchased fuels,
AVGINT	=	Average intensity, and
$BSSHR_f$	=	Share of total fuel consumption in the BSC component for fuel *f*.

$$ENSQTY_f = ENSQTY_f - ICEFUEL \tag{B-92}$$

where:

$ENSQTY_f$ = Consumption of fuel f to generate steam, and

$ICEFUEL$ = Fuel consumption for electricity generation from internal combustion engines.

$$ENSQTY_f = ENSQTY_f - GCTFUEL \tag{B-93}$$

where:

$ENSQTY_f$ = Consumption of fuel f to generate steam, and

$GCTFUEL$ = Fuel consumption for electricity generation from combustion turbines.

Calculate the amount of fuel consumed in steam turbines.

$$STFUEL_f = \left[\frac{ENSQTY_f}{\sum_{f=1}^{IFSMAX} ENSQTY_f + \sum_{f=1}^{IFSBYP} BYSQTY_f} \right] x \; ELGEN_{st} \; x \; \frac{GENEQPHTRT_{st}}{3412.0} \tag{B-94}$$

where:

$STFUEL_f$ = Consumption of fuel f in steam turbines,

$ENSQTY_f$ = Consumption of fuel f to generate steam,

$IFSMAX$ = Number of fuels consumed in the BSC component,

$IFSBYP$ = Number of byproduct fuels consumed in the BSC component,

$BYSQTY_f$ = Consumption of byproduct fuel f in the BSC component,

$ELGEN_{st}$ = Electricity generation from steam turbines,

$GENEQPHTRT_{st}$ = Heat rate for steam turbines, and

3412.0 = Conversion factor to convert from kilowatt hours to Btu.

$$STBYP_f = \left[\frac{BYSQTY_f}{\sum_{f=1}^{IFSMAX} ENSQTY_f + \sum_{f=1}^{IFSBYP} BYSQTY_f} \right] x \; ELGEN_{st} \; x \; \frac{GENEQPHTRT_{st}}{3412.0} \quad \textbf{(B-95)}$$

where:

$STBYP_f$ = Consumption of byproduct fuel f in steam turbines,

$BYSQTY_f$ = Consumption of byproduct fuel f in the BSC component,

$IFSBYP$ = Number of byproduct fuels consumed in the BSC component,

$IFSMAX$ = Number of fuels consumed in the BSC component,

$ENSQTY_f$ = Consumption of fuel f to generate steam,

$ELGEN_{st}$ = Electricity generation from steam turbines,

$GENEQPHTRT_{st}$ = Heat rate for steam turbines, and

3412.0 = Conversion factor to convert from kilowatt hours to Btu.

$$ENSQTY_f = ENSQTY_f + ICEFUEL \quad \textbf{(B-96)}$$

where:

$ENSQTY_f$ = Consumption of fuel f to generate steam, and

ICEFUEL	=	Fuel consumption for electricity generation from internal combustion engines.

$$ENSQTY_f = ENSQTY_f + GCTFUEL \qquad \textbf{(B-97)}$$

where:

$ENSQTY_f$	=	Consumption of fuel f to generate steam, and
GCTFUEL	=	Fuel consumption for electricity generation from combustion turbines.

CALBSC

Calculate boiler fuel shares.

$$BSSHR_f = \begin{matrix} BSSHRLAG_f \times \left[\dfrac{PRCX_{f,r}}{PRCXLAG_f}\right]^{BSSHRE_f} \times \left[\dfrac{PRCX_{ng,r}}{PRCXLAG_{ng}}\right]^{BSSHRNG_f} \\ \times \left[\dfrac{PRCX_{oil,r}}{PRCXLAG_{oil}}\right]^{BSSHROIL_f} \times \left[\dfrac{PRCX_{coal,r}}{PRCXLAG_{coal}}\right]^{BSSHRCL_f} \end{matrix} \qquad \textbf{(B-98)}$$

where:

$BSSHR_f$	=	Share of total fuel consumption in the BSC component for fuel f,
$BSSHRLAG_f$	=	Lagged boiler share for fuel f,
$PRCX_{f,r}$	=	Price for fuel f in Census region r,
$PRCXLAG_f$	=	Lagged price for fuel f,
$BSSHRE_f$	=	Own price elasticity for fuel f,

$BSSHRNG_f$	=	Cross price elasticity for natural gas with fuel *f*,
$BSSHROIL_f$	=	Cross price elasticity for oil with fuel *f*, and
$BSSHRCL_f$	=	Cross price elasticity for coal with fuel *f*.

$$BSSHR_f = \frac{BSSHR_f}{\sum_{f=1}^{IFSMAX} BSSHR_f} \qquad \textbf{(B-99)}$$

where:

$BSSHR_f$	=	Share of total fuel consumption in the BSC component for fuel *f*, and
$IFSMAX$	=	Number of fuels consumed in the BSC component.

INDCGN

$$ELCTOT_{total} = \sum_{r=1}^{4} ELCTOT_r \qquad \textbf{(B-100)}$$

where:

$ELCTOT_{total}$	=	Capacity for industrial electricity generation in all Census regions, and
$ELCTOT_r$	=	Capacity for industrial electricity generation in Census region *r*.

$$ELOTOT_{total} = \sum_{r=1}^{4} ELOTOT_r \qquad \textbf{(B-101)}$$

where:

$ELOTOT_{total}$ = Total industrial electricity generation for own use in all Census regions, and

$ELOTOT_r$ = Total industrial electricity generation for own use in Census region r.

$$ELSTOT_{total} = \sum_{r=1}^{4} ELSTOT_r \qquad \textbf{(B-102)}$$

where:

$ELSTOT_{total}$ = Total industrial electricity generation for sales to the grid in all Census regions, and

$ELSTOT_r$ = Total industrial electricity generation for sales to the grid in Census region r.

$$GENTOT_{f,u,total} = \sum_{r=1}^{4} GENTOT_{f,u,r} \qquad \textbf{(B-103)}$$

where:

$GENTOT_{f,u,total}$ = Total consumption of fuel f for cogeneration of electricity for use u in all Census regions, and

$GENTOT_{f,u,r}$ = Total consumption of fuel f for cogeneration of electricity for use u in Census region r.

For 1990 and 1991,

$$CAPREG_{r,y,t\text{-}fuel,total} = \sum_{f=1}^{4} CAPREG_{r,y,f,total} \qquad \textbf{(B-104)}$$

where:

$CAPREG_{r,y,t\text{-}fuel,total}$ = Existing or planned capacity for cogeneration of electricity for all uses in Census region r using all fuels in year y, and

$CAPREG_{r,y,f,total}$ = Existing or planned capacity for cogeneration of electricity for all uses in Census region r using fuel f in year y.

$$CAPD_{d,y,f,own,pl} = \left[\frac{ELOTOT_r}{ELOTOT_r + ELSTOT_r}\right] x\ CAPREG_{r,y,f,total}\ x\ DIVSHARE_d \qquad \textbf{(B-105)}$$

where:

$CAPD_{d,y,f,own,pl}$ = Existing or planned capacity for cogeneration of electricity for own use in Census division d using fuel f in year y,

$ELOTOT_r$ = Total industrial electricity generation for own use in Census region r,

$ELSTOT_r$ = Total industrial electricity generation for sales to the grid in Census region r,

$CAPREG_{r,y,f,total}$ = Existing or planned capacity for cogeneration of electricity for all uses in Census region r using fuel f in year y, and

$DIVSHARE_d$ = Electricity share for Census division d.

$$CAPD_{d,y,f,sales,pl} = \left[CAPREG_{r,y,f,total} - CAPREG_{r,y,f,own}\right] x\ DIVSHARE_d \qquad \textbf{(B-106)}$$

where:

$CAPD_{d,y,f,sales,pl}$ = Existing or planned capacity for cogeneration of electricity for sales to the grid in Census division d using fuel f in year y,

$CAPREG_{r,y,f,total}$ = Existing or planned capacity for cogeneration of electricity for all uses in Census region r using fuel f in year y,

$CAPREG_{r,y,f,own}$ = Existing or planned capacity for cogeneration of electricity for own use in Census region r using fuel f in year y, and

$DIVSHARE_d$ = Electricity share for Census division d.

If 1992 through 1996,

$$CAPD_{d,y,own,pl} = CAPD_{d,y-1,f,own,pl} + \left[\frac{ELOTOT_r}{ELOTOT_r + ELSTOT_r}\right] x\ CAPDIV_{d,y,f,total,pl} \qquad \textbf{(B-107)}$$

where:

$CAPD_{d,y,f,own,pl}$ = Existing or planned capacity for cogeneration of electricity for own use in Census division d using fuel f in year y,

$CAPD_{d,y-1,f,own,pl}$ = Existing or planned capacity for cogeneration of electricity for own use in Census division d using fuel f in year $y-1$,

$ELOTOT_r$ = Total industrial electricity generation for own use in Census region r,

$ELSTOT_r$ = Total industrial electricity generation for sales to the grid in Census region r, and

$CAPDIV_{d,y,f,total,pl}$ = Planned capacity for electricity generation for all uses in Census division d using fuel f in year y.

$$CAPD_{d,y,sales,pl} = CAPD_{d,y-1,sales,pl} + CAPDIV_{d,y,f,total,pl} - CAPDIV_{d,y,f,own,pl} \quad \textbf{(B-108)}$$

where:

$CAPD_{d,y,f,sales,pl}$	=	Existing or planned capacity for cogeneration of electricity for sales to the grid in Census division d using fuel f in year y,
$CAPD_{d,y\text{-}1,f,sales,pl}$	=	Existing or planned capacity for cogeneration of electricity for sales to the grid in Census division d using fuel f in year $y\text{-}1$,
$CAPDIV_{d,y,f,total,pl}$	=	Planned capacity for electricity generation for all uses in Census division d using fuel f in year y, and
$CAPDIV_{d,y,f,own,pl}$	=	Planned capacity for electricity generation for own use in Census division d using fuel f in year y.

Calculate fuel consumption for each census division.

$$DIVFUEL_{d,f,u} = GENTOT_{f,u,r} \; x \; DIVSHARE_d \quad \textbf{(B-109)}$$

where:

$DIVFUEL_{d,f,u}$	=	Consumption of fuel f for cogeneration of electricity for use u in Census division d,
$GENTOT_{f,u,r}$	=	Total consumption of fuel f for cogeneration of electricity for use u in Census region r, and
$DIVSHARE_d$	=	Electricity share for Census division d.

$$DIVFUEL_{d,total,u} = \sum_{f=1}^{4} DIVFUEL_{d,f,u} \quad \textbf{(B-110)}$$

where:

$DIVFUEL_{d,total,u}$ = Consumption of all fuels for cogeneration of electricity for use u in Census division d, and

$DIVFUEL_{d,f,u}$ = Consumption of fuel f for cogeneration of electricity for use u in Census division d.

$$DIVFUEL_{total,f,u} = \sum_{d=1}^{9} DIVFUEL_{d,f,u} \qquad \textbf{(B-111)}$$

where:

$DIVFUEL_{total,f,u}$ = Consumption of fuel f for cogeneration of electricity for use u in all Census divisions, and

$DIVFUEL_{d,f,u}$ = Consumption of fuel f for cogeneration of electricity for use u in Census division d.

$$CAPD_{total,y,total,u,pl} = \sum_{d=1}^{9} CAPD_{d,y,total,u,pl} \qquad \textbf{(B-112)}$$

where:

$CAPD_{total,y,total,u,pl}$ = Existing or planned capacity for cogeneration of electricity for use u in all Census divisions using all fuels in year y, and

$CAPD_{d,y,total,u,pl}$ = Existing or planned capacity for cogeneration of electricity for use u in Census division d using all fuels in year y.

Convert total generation to gigawatt hours and capacity to megawatts.
The following equation calculates electric generation for own use.

$$GENGWH_{d,f,own} = ELOTOT_r \times DIVSHARE_d \times \left[\frac{DIVFUEL_{d,f,own}}{DIVFUEL_{d,total,own}}\right] \times \frac{10^6}{3412.0} \quad \textbf{(B-113)}$$

where:

$GENGWH_{d,f,own}$ = Cogeneration of electricity for own use using fuel f in Census division d,

$ELOTOT_r$ = Total industrial electricity generation for own use in Census region r,

$DIVSHARE_d$ = Electricity share for Census division d,

$DIVFUEL_{d,f,own}$ = Consumption of fuel f for cogeneration of electricity for own use in Census division d,

$DIVFUEL_{d,total,own}$ = Consumption of all fuels for cogeneration of electricity for own use in Census division d, and

$10^6/3412.0$ = Conversion factor to convert trillion Btu to megawatts.

$$GENGWH_{d,f,sales} = ELSTOT_r \times DIVSHARE_d \times \left[\frac{DIVFUEL_{d,f,sales}}{DIVFUEL_{d,total,sales}}\right] \times \frac{10^6}{3412.0} \quad \textbf{(B-114)}$$

where:

$GENGWH_{d,f,sales}$ = Cogeneration of electricity for sales to the grid using fuel f in Census division d,

$ELSTOT_r$ = Total industrial electricity generation for sales to the grid in Census region r,

$DIVSHARE_d$ = Electricity share for Census division d,

$DIVFUEL_{d,f,sales}$ = Consumption of fuel f for cogeneration of electricity for sales to the grid in Census division d,

$DIVFUEL_{d,total,sales}$ = Consumption of all fuels for cogeneration of electricity for sales to the grid in Census division d, and

$10^6/3412.0$ = Conversion factor to convert trillion Btu to megawatts.

$$CAPGW_{d,f,own,pl} = ELCTOT_r \; x \left[\frac{ELOTOT_r}{ELOTOT_r + ELSTOT_r}\right] x \; DIVSHARE_d \; x \left[\frac{DIVFUEL_{d,f,own}}{DIVFUEL_{d,total,own}}\right] \quad \textbf{(B-115)}$$

where:

$CAPGW_{d,f,own,pl}$ = Existing or planned capacity for cogeneration of electricity for own use using fuel f in Census division d ,

$ELCTOT_r$ = Capacity for industrial electricity generation in Census region r,

$ELOTOT_r$ = Total industrial electricity generation for own use in Census region r,

$ELSTOT_r$ = Total industrial electricity generation for sales to the grid in Census region r,

$DIVSHARE_d$ = Electricity share for Census division d,

$DIVFUEL_{d,f,own}$ = Consumption of fuel f for cogeneration of electricity for own use in Census division d, and

$DIVFUEL_{d,total,own}$ = Consumption of all fuels for cogeneration of electricity for own use in Census division d.

$$CAPGW_{d,f,sales,pl} = \left\{ELCTOT_r \; x \left[\frac{ELSTOT_r}{ELOTOT_r + ELSTOT_r}\right]\right\} x \; DIVSHARE_d \; x \left[\frac{DIVFUEL_{d,f,sales}}{DIVFUEL_{d,total,sales}}\right] \quad \textbf{(B-116)}$$

where:

$CAPGW_{d,f,sales,pl}$	=	Existing or planned capacity for cogeneration of electricity for sales to the grid using fuel f in Census division d,
$ELCTOT_r$	=	Capacity for industrial electricity generation in Census region r,
$ELOTOT_r$	=	Total industrial electricity generation for own use in Census region r,
$ELSTOT_r$	=	Total industrial electricity generation for sales to the grid in Census region r,
$DIVSHARE_d$	=	Electricity share for Census division d,
$DIVFUEL_{d,f,sales}$	=	Consumption of fuel f for cogeneration of electricity for sales to the grid in Census division d, and
$DIVFUEL_{d,total,sales}$	=	Consumption of all fuels for cogeneration of electricity for sales to the grid in Census division d.

For 1990 through 1996,

$$CAPGW_{d,f,u,pl} = CAPD_{d,y,f,u,pl} \quad \text{(B-117)}$$

where:

$CAPGW_{d,f,u,pl}$	=	Existing or planned capacity for cogeneration of electricity for use u using fuel f in Census division d, and
$CAPD_{d,y,f,u,pl}$	=	Existing or planned capacity for cogeneration of electricity for use u in Census division d using fuel f in year y.

After 1996, if $CAPGW_{d,f,u,pl} > CAPGWLAG_{d,f,u,pl}$, then

$$CAPGW_{d,f,u,pl} = CAPD_{d,y-1,f,u,pl} + \left[CAPGW_{d,f,u,pl} - CAPGWLAG_{d,f,u,pl}\right] \quad \textbf{(B-118)}$$

where:

$CAPGW_{d,f,u,pl}$ = Planned capacity for cogeneration of electricity for use u using fuel f in Census division d,

$CAPD_{d,y-1,f,u,pl}$ = Existing or planned capacity for cogeneration of electricity for use u in Census division d using fuel f in year y-1,

$CAPGW_{d,f,u,pl}$ = Planned capacity for cogeneration of electricity for use u using fuel f in Census division d, and

$CAPGWLAG_{d,f,u,pl}$ = Lagged planned capacity for cogeneration of electricity for use u using fuel f in Census division d.

Otherwise,

$$CAPGW_{d,f,u,pl} = CAPD_{d,y-1,f,u,pl} \quad \textbf{(B-119)}$$

where:

$CAPGW_{d,f,u,pl}$ = Planned capacity for cogeneration of electricity for use u using fuel f in Census division d, and

$CAPD_{d,y-1,f,u,pl}$ = Existing or planned capacity for cogeneration of electricity for use u in Census division d using fuel f in year y-1.

$$GENGWH_{total,f,u} = \sum_{d=1}^{9} GENGWH_{d,f,u} \quad \textbf{(B-120)}$$

where:

$GENGWH_{total,f,u}$ = Cogeneration of electricity for use u using fuel f in all Census divisions, and

$GENGWH_{d,f,u}$ = Cogeneration of electricity for use u using fuel f in Census division d.

$$CAPGW_{total,f,u,status} = \sum_{d=1}^{9} CAPGW_{d,f,u,status} \qquad \text{(B-121)}$$

where:

$CAPGW_{total,f,u,status}$ = Planned or unplanned capacity for cogeneration of electricity for use u using fuel f in all Census divisions, and

$CAPGW_{d,f,u,status}$ = Planned or unplanned capacity for cogeneration of electricity for use u using fuel f in Census division d.

OTHER INDUSTRIAL MODEL EQUATIONS

IND

For the non-manufacturing industries, calculate value of output.

$$OUTIND_{i,d} = \frac{MC\_NMFGO_{d,i,y}}{10^3} \tag{B-122}$$

where:

$OUTIND_{i,d}$	=	Gross value of output for industry i in Census division d,
$MC\_NMFGO_{d,i,y}$	=	Gross value of output for non-manufacturing industry i in Census division d in year y, and
10^3	=	Conversion factor to convert million \$1987 to billion \$1987.

For the manufacturing industries, calculate va[illegible]tput.

$$OUTIND_{i,d} = \frac{MC\_MFGO_{d,i,y}}{10^3} \tag{B-123}$$

where:

$OUTIND_{i,d}$	=	Gross value of output for industry i in Census division d,
$MC\_MFGO_{d,i,y}$	=	Gross value of output for manufacturing industry i in Census division d in year y, and
10^3	=	Conversion factor to convert million \$1987 to billion \$1987.

If the year is 1990, regional prices are calculated by the following for electricity, similarly for the other fuels.

$$PRCX_{elec,r} = \frac{\sum_{d=1}^{NUM_r} DPRCX_{elec,d} \ x \ QSELIN_{d,1990}}{\sum_{d=1}^{NUM_r} QSELIN_{d,1990}} \tag{B-124}$$

where:

$PRCX_{elec,r}$	=	Price of electricity in Census region *r*,
NUM_r	=	Number of Census divisions in Census region *r*,
$DPRCX_{elec,d}$	=	Price of electricity in Census division *d*, and
$QSELIN_{d,1990}$	=	SEDS consumption of electricity in Census division *d* in 1990.

If the year is after 1990, regional prices are calculated by the following for electricity, similarly for other fuels.

$$PRCX_{elec,r} = \frac{\sum_{d=1}^{NUM_r} DPRCX_{elec,d} \ x \ QELIN_{d,y-1}}{\sum_{d=1}^{NUM_r} QELIN_{d,y-1}} \tag{B-125}$$

where:

$PRCX_{elec,r}$	=	Price of electricity in Census region *r*,
NUM_r	=	Number of Census divisions in Census region *r*,
$DPRCX_{elec,d}$	=	Price of electricity in Census division *d*, and

$QELIN_{d,y-1}$	=	Industrial consumption of electricity in Census division d in year y-1.

REXOG

Aggregate value of output to the regional level:

$$PRODVX_{i,r} = \sum_{d=1}^{NUM_r} OUTIND_{i,d} \tag{B-126}$$

where:

$PRODVX_{i,r}$	=	Value of output in dollar units for industry i in Census region r,
NUM_r	=	Number of Census divisions in Census region r, and
$OUTIND_{i,d}$	=	Gross value of output for industry i in Census division d.

Aggregate employment values to the regional level:

$$EMPLX_{i,r} = \sum_{d=1}^{NUM_r} EMPIND_{i,d} \tag{B-127}$$

where:

$EMPLX_{i,r}$	=	Employment for industry i in Census region r,
NUM_r	=	Number of Census divisions in Census region r, and
$EMPIND_{i,d}$	=	Employment for industry i in Census division d.

$$EMPLX_{i,r} = EMPLX_{i,r} \times 10^3 \quad \textbf{(B-128)}$$

where:

$EMPLX_{i,r}$	=	Employment for industry i in Census region r, and
10^3	=	Conversion factor to convert from millions to thousands.

CALBYPROD

Calculate the current TPC for byproducts for old and new vintage. Currently, only the paper and allied products industry has a TPC for byproducts. For all other industries, the UEC remains unchanged.

$$BYPCSCCUR_{v,f,s} = \left[\frac{PRODCUR_{total,s}}{PRODLAG_{total,s}}\right]^{BYPCSC_{v,f,s}} \quad \textbf{(B-129)}$$

where:

$BYPCSCCUR_{v,f,s}$	=	Current energy savings for byproduct fuel f at process step s for vintage v,
$PRODCUR_{total,s}$	=	Production at process step s for all vintages,
$PRODLAG_{total,s}$	=	Lagged production at process step s for all vintages, and
$BYPCSC_{v,f,s}$	=	Byproduct technology possibility curve coefficient for byproduct fuel f at process step s for vintage v.

Calculate the TPC for middle vintage.

$$BYPCSCCUR_{mid,f,s} = \frac{(PRODCUR_{new,s} \times BYPCSCCUR_{new,f,s}) + (PRODCUR_{mid,s} \times BYPCSCLAG_{mid,f,s})}{PRODCUR_{new,s} + PRODCUR_{mid,s}} \quad \textbf{(B-130)}$$

where:

$BYPCSCCUR_{mid,f,s}$	=	Current energy savings for byproduct fuel f at process step s for mid vintage,
$PRODCUR_{new,s}$	=	New production at process step s for new vintage,
$BYPCSCCUR_{new,f,s}$	=	Current energy savings for byproduct fuel f at process step s for new vintage,
$PRODCUR_{mid,s}$	=	Existing production at process step s for mid vintage, and
$BYPCSCLAG_{mid,f,s}$	=	Lagged energy savings for byproduct fuel f at process step s for middle vintage.

Calculate the rate of byproduct energy produced.

$$BYPINT_{v,f,s} = BYPINTLAG_{v,f,s} \times BYPCSCCUR_{v,f,s} \quad \textbf{(B-131)}$$

where:

$BYPINT_{v,f,s}$	=	Rate of byproduct energy production for byproduct fuel f at process step s for vintage v,
$BYPINTLAG_{v,f,s}$	=	Lagged rate of byproduct energy production for byproduct fuel f at process step s for vintage v, and
$BYPCSCCUR_{v,f,s}$	=	Current energy savings for byproduct fuel f at process step s for vintage v.

Calculate byproduct energy production.

$$BYPQTY_{v,f,s} = PRODCUR_{v,s} \times BYPINT_{v,f,s} \tag{B-132}$$

where:

$BYPQTY_{v,f,s}$	=	Byproduct energy production for byproduct fuel f at process step s for vintage v,
$PRODCUR_{v,s}$	=	Production at process step s for vintage v, and
$BYPINT_{v,f,s}$	=	Rate of byproduct energy production for byproduct fuel f at process step s for vintage v.

$$BYPQTY_{total,f,s} = \sum_{v=1}^{2} BYPQTY_{v,f,s} \tag{B-133}$$

where:

$BYPQTY_{total,f,s}$	=	Byproduct energy production for byproduct fuel f at process step s for all vintages, and
$BYPQTY_{v,f,s}$	=	Byproduct energy production for byproduct fuel f at process step s for vintage v.

$$BYPQTY_{v,f,s} = \frac{BYPQTY_{v,f,s}}{10^6} \tag{B-134}$$

where:

$BYPQTY_{v,f,s}$	=	Byproduct energy production for byproduct fuel f at process step s for vintage v, and
10^6	=	Conversion factor to convert to trillion Btu.

$$BYPQTY_{v,total,s} = \sum_{f=1}^{IFBYP_s} BYPQTY_{v,f,s} \quad \textbf{(B-135)}$$

where:

$BYPQTY_{v,total,s}$	=	Byproduct energy production for all byproduct fuels at process step s for vintage v,
$IFBYP_s$	=	Number of byproducts consumed at process step s, and
$BYPQTY_{v,f,s}$	=	Byproduct energy production for byproduct fuel f at process step s for vintage v.

Calculate byproduct energy production for main, intermediate, and renewable fuels.

$$ENBYPM_{f,v} = \sum_{s=1}^{MPASTP} BYPQTY_{v,f,s} \quad \textbf{(B-136)}$$

where:

$ENBYPM_{f,v}$	=	Byproduct energy production for main byproduct fuel f for vintage v,
$MPASTP$	=	Number of process steps, and
$BYPQTY_{v,f,s}$	=	Byproduct energy production for byproduct fuel f at process step s for vintage v.

$$ENBYPI_{f,v} = \sum_{s=1}^{MPASTP} BYPQTY_{v,f,s} \quad \textbf{(B-137)}$$

where:

$ENBYPI_{f,v}$	=	Byproduct energy production for intermediate byproduct fuel f for vintage v,

$MPASTP$	=	Number of process steps, and
$BYPQTY_{v,f,s}$	=	Byproduct energy production for byproduct fuel f at process step s for vintage v.

$$ENBYPR_{f,v} = \sum_{s=1}^{MPASTP} BYPQTY_{v,f,s} \tag{B-138}$$

where:

$ENBYPR_{f,v}$	=	Byproduct energy production for renewable byproduct fuel f for vintage v,
$MPASTP$	=	Number of process steps, and
$BYPQTY_{v,f,s}$	=	Byproduct energy production for byproduct fuel f at process step s for vintage v.

INDTOTAL

Calculate total consumption of electricity.

$$QTYMAIN_{elec,r} = ENPMQTY_{elec} + ENBQTY_{total,elec} - ELOWN \tag{B-139}$$

where:

$QTYMAIN_{elec,r}$	=	Consumption of purchased electricity in Census region r,
$ENPMQTY_{elec}$	=	Consumption of electricity in the PA component,
$ENBQTY_{elec}$	=	Consumption of electricity for all building end uses, and
$ELOWN$	=	Electricity generated for own use.

$$QTYMAIN_{ng,r} = ENPMQTY_{ng} + ENBQTY_{total,ng} + ENSQTY_{ng} \tag{B-140}$$

where:

$QTYMAIN_{ng,r}$ = Consumption of natural gas in Census region *r*,

$ENPMQTY_{ng}$ = Consumption of natural gas in the PA component,

$ENBQTY_{total,ng}$ = Consumption of natural gas for all building end uses, and

$ENSQTY_{ng}$ = Consumption of natural gas to generate steam.

For all other main fuels,

$$QTYMAIN_{f,r} = ENPMQTY_f + ENSQTY_f + BYPBSCM_f \tag{B-141}$$

where:

$QTYMAIN_{f,r}$ = Consumption of all other main fuels *f* in Census region *r*,

$ENPMQTY_f$ = Consumption of all other main fuels *f* in the PA component,

$ENSQTY_f$ = Consumption of all other main fuels *f* to generate steam, and

$BYPBSCM_f$ = Byproduct consumption of main fuel *f* from the BSC component.

$$QTYINTR_{steam,r} = ENPIQTY_{steam} + ENBQTY_{total,steam} \tag{B-142}$$

where:

$QTYINTR_{steam,r}$	=	Consumption of steam in Census region r,
$ENPIQTY_{steam}$	=	Consumption of steam in the PA component,
$ENBQTY_{total,ng}$	=	Consumption of steam for all building end uses,

For all other intermediate fuels,

$$QTYINTR_{f,r} = ENPIQTY_f + ENSQTY_f \qquad \textbf{(B-143)}$$

where:

$QTYINTR_{f,r}$	=	Consumption of all other intermediate fuels f in Census region r,
$ENPIQTY_f$	=	Consumption of all other intermediate fuels f in the PA component, and
$ENSQTY_f$	=	Consumption of all other intermediate fuels f to generate steam.

$$QTYRENW_{f,r} = ENPRQTY_f + ENSQTY_f + BYPBSCR_f \qquad \textbf{(B-144)}$$

where:

$QTYRENW_{f,r}$	=	Consumption of renewable fuel f in Census region r,
$ENPRQTY_f$	=	Consumption of renewable fuel f in the PA component,
$ENSQTY_f$	=	Consumption of renewable fuel f to generate steam, and
$BYPBSCR_f$	=	Byproduct consumption of renewable fuel f in the BSC component.

$$QTYMAIN_{total,r} = \sum_{f=1}^{22} QTYMAIN_{f,r} \tag{B-145}$$

where:

$QTYMAIN_{total,r}$ = Consumption of all main fuels in Census region r, and

$QTYMAIN_{f,r}$ = Consumption of main fuel f in Census region r.

$$QTYINTR_{total,r} = \sum_{f=1}^{6} QTYINTR_{f,r} \tag{B-146}$$

where:

$QTYINTR_{total,r}$ = Consumption of all intermediate fuels in Census region r, and

$QTYINTR_{f,r}$ = Consumption of intermediate fuel f in Census region r.

$$QTYRENW_{total,r} = \sum_{f=1}^{9} QTYRENW_{f,r} \tag{B-147}$$

where:

$QTYRENW_{total,r}$ = Consumption of all renewable fuels in Census region r, and

$QTYRENW_{f,r}$ = Consumption of renewable fuel f in Census region r.

NATTOTAL

$$QTYMAIN_{f,total} = \sum_{r=1}^{4} QTYMAIN_{f,r} \tag{B-148}$$

where:

$QTYMAIN_{f,total}$	=	Consumption of main fuel f in all Census regions, and
$QTYMAIN_{f,r}$	=	Consumption of main fuel f in Census region r.

$$QTYINTR_{f,total} = \sum_{r=1}^{4} QTYINTR_{f,r} \tag{B-149}$$

where:

$QTYINTR_{f,total}$	=	Consumption of intermediate fuel f in all Census regions, and
$QTYINTR_{f,r}$	=	Consumption of intermediate fuel f in Census region r.

$$QTYRENW_{f,total} = \sum_{r=1}^{4} QTYRENW_{f,r} \tag{B-150}$$

where:

$QTYRENW_{f,total}$	=	Consumption of renewable fuel f in all Census regions, and
$QTYRENW_{f,r}$	=	Consumption of renewable fuel f in Census region r.

Calculate total industrial consumption.

$$TQMAIN_{f,r} = \sum_{i=1}^{INDMAX} QTYMAIN_{i,f,r} \quad for\ f=1,...,4\ and\ r=1,..,4. \qquad \textbf{(B-151)}$$

where:

$TQMAIN_{f,r}$	=	Total consumption of main fuel f in Census region r,
$INDMAX$	=	Number of industries, and
$QTYMAIN_{i,f,r}$	=	Total consumption of main fuel f in Census region r in industry i.

$$TQINTR_{f,r} = \sum_{i=1}^{INDMAX} QTYINTR_{i,f,r} \quad for\ f=1,...,4\ and\ r=1,...,4. \qquad \textbf{(B-152)}$$

where:

$TQINTR_{f,r}$	=	Total consumption of intermediate fuel f in Census region r,
$INDMAX$	=	Number of industries, and
$QTYINTR_{i,f,r}$	=	Total consumption of intermediate fuel f in Census region r in industry i.

$$TQRENW_{f,r} = \sum_{i=1}^{INDMAX} QTYRENW_{i,f,r} \quad for\ f=1,...,4\ and\ r=1,...,4. \qquad \textbf{(B-153)}$$

where:

$TQRENW_{f,r}$	=	Total consumption of renewable fuel f in Census region r,
$INDMAX$	=	Number of industries, and

$QTYRENW_{i,f,r}$ = Total consumption of renewable fuel f in Census region r in industry i.

INDEMISS

Calculate emissions.

$$EMIRENW_{f,p,r} = QTYRENW_{f,r} \times UNCONTEMISSFACT_{f,p} \times EMISSCONTROLFAC_{f,p} \quad \text{(B-154)}$$

where:

$EMIRENW_{f,p,r}$ = Emissions of pollutant p from renewable fuel f in Census region r,

$QTYRENW_{f,r}$ = Consumption of renewable fuel f in Census region r,

$UNCONTEMISSFACT_{f,p}$ = Uncontrolled emission factor for pollutant p using fuel f, and

$EMISSCONTROLFAC_{f,p}$ = Emissions control factor for pollutant p using fuel f.

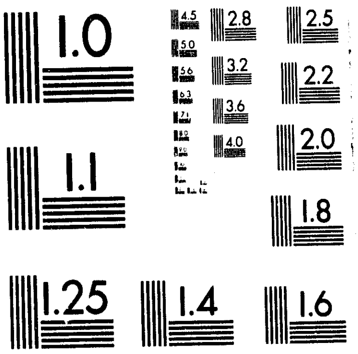
For emissions of SO_x use the following equation.

$$EMIRENW_{f,sox,r} = EMIRENW_{f,sox,r} \times SULFURCONT_f \quad \text{(B-155)}$$

where:

$EMIRENW_{f,sox,r}$ = Emissions of SOx from renewable fuel f in Census region r, and

$SULFURCONT_f$ = Sulfur content of fuel f.


1.0
4.5
2.8
2.5
5.0
3.2
2.2
5.6
6.3
3.6
2.0
4.0
1.1
1.8
1.25
1.4
1.6

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$$EMIRENW_{f,p,total} = \sum_{r=1}^{4} EMIRENW_{f,p,r} \quad \textbf{(B-156)}$$

where:

$EMIRENW_{f,p,total}$ = Emissions of pollutant p from renewable fuel f in all Census regions, and

$EMIRENW_{f,p,r}$ = Emissions of pollutant p from renewable fuel f in Census region r.

$$EMIRENW_{total,p,r} = \sum_{f=1}^{8} EMIRENW_{f,p,r} \quad \textbf{(B-157)}$$

where:

$EMIRENW_{total,p,r}$ = Emissions of pollutant p from all renewable fuels in Census region r, and

$EMIRENW_{f,p,r}$ = Emissions of pollutant p from renewable fuel f in Census region r.

$$TOTEMIS_{renw,p,r} = \sum_{f=1}^{8} EMIRENW_{f,p,r} \quad \textbf{(B-158)}$$

where:

$TOTEMIS_{renw,p,r}$ = Total emissions of pollutant p from renewables in Census region r, and

$EMIRENW_{f,p,r}$ = Emissions of pollutant p from renewable fuel f in Census region r.

Calculate emissions for total industrial sector.

$$TEMISR_{f,p,r} = \sum_{i=1}^{INDMAX} EMIRENW_{i,f,p,r} \quad for\ f=1,...,4, \quad p=1,...,8, \quad and\ r=1,...4. \qquad \textbf{(B-159)}$$

where:

$TEMISR_{f,p,r}$	=	Total emissions of pollutant p for renewable fuel f in Census region r,
$INDMAX$	=	Number of industries, and
$EMIRENW_{i,f,p,r}$	=	Emissions of pollutant p from renewable fuel f in Census region r in industry i.

CONTAB

Calculate consumption for heat and power.

$$TMANHP_f = \sum_{i=7}^{INDMAX} QTYMAIN_{f,i} \quad for\ f=1,...,NUM_{fg} \qquad \textbf{(B-160)}$$

where:

$TMANHP_f$	=	Total manufacturing consumption of fuel f for heat and power,
$INDMAX$	=	Number of industries,
NUM_{fg}	=	Number of fuels in fuel group fg, and
$QTYMAIN_{f,i}$	=	Total consumption of main fuel f in all Census regions for industry i.

$$TMANHP_{renw} = \sum_{i=7}^{INDMAX} \sum_{f=1}^{8} QTYRENW_{f,total} \qquad \textbf{(B-161)}$$

where:

$TMANHP_{renw}$	=	Total manufacturing consumption of renewables for heat and power,
$INDMAX$	=	Number of industries, and
$QTYRENW_{f,i}$	=	Consumption of renewable fuel f in all Census regions for industry i.

$$TREFCON_{elec} = \sum_{d=1}^{9} QELRF_{d,y} \qquad \textbf{(B-162)}$$

where:

$TREFCON_{elec}$	=	Total consumption of electricity from the petroleum refining industry, and
$QELRF_{d,y}$	=	Electricity consumed by petroleum refining industry for Census division d in year y.

Similarly for the other fuels.

$$TNONHP_{f} = \sum_{i=1}^{6} QTYMAIN_{f,i}, \quad for\ F=1,...,NUM_{Fg} \qquad \textbf{(B-163)}$$

where:

$TNONHP_{f}$	=	Total non-manufacturing consumption of main fuel f for heat and power,
NUM_{fg}	=	Number of fuels in fuel group fg, and

$QTYMAIN_{f,i}$	=	Consumption of main fuel f in all Census regions for non-manufacturing industry i.

Calculate consumption for miscellaneous feedstocks.

$$TMISCFD_f = \sum_{i=1}^{INDMAX} QTYMAIN_{f,i} \quad for\ f=1,...,NUM_{fg} \tag{B-164}$$

where:

$TMISCFD_f$	=	Total consumption of miscellaneous and feedstock fuel f,
$INDMAX$	=	Number of industries,
NUM_{fg}	=	Number of fuels in fuel group fg, and
$QTYMAIN_{f,i}$	=	Total consumption of main fuel f for all Census regions for industry i.

Calculate consumption for the food and kindred products industry.

$$TFOODCON_f = \sum_{f=1}^{NUM_{fg}} QTYMAIN_{f,total} \tag{B-165}$$

where:

$TFOODCON_f$	=	Total consumption of fuel f by the food and kindred products industry,
NUM_{fg}	=	Number of fuels in fuel group fg, and
$QTYMAIN_{f,total}$	=	Consumption of main fuel f for all Census regions.

$$TFOODCON_{renw} = \sum_{f=1}^{8} QTYRENW_{f,total} \tag{B-166}$$

where:

$TFOODCON_{renw}$ = Total consumption of renewables by the food and kindred products industry, and

$QTYRENW_{f,total}$ = Consumption of renewable fuel f for all Census regions.

Calculate consumption for the paper and allied products industry:

$$TPAPERCON_{f} = \sum_{f=1}^{NUM_{fg}} QTYMAIN_{f,total} \tag{B-167}$$

where:

$TPAPERCON_{f}$ = Total consumption of fuel f by the paper and allied products industry,

NUM_{fg} = Number of fuels in fuel group fg, and

$QTYMAIN_{f,total}$ = Consumption of main fuel f for all Census regions.

$$TPAPERCON_{renw} = \sum_{f=1}^{8} QTYRENW_{f,total} \tag{B-168}$$

where:

$TPAPERCON_{renw}$ = Total consumption of renewables by the paper and allied products industry, and

$QTYRENW_{f,total}$ = Consumption of renewable fuel f for all Census regions.

Calculate consumption for the bulk chemical industry:

$$TCHEMCON_f = \sum_{f=1}^{NUM_{fg}} QTYMAIN_{f,total} \qquad \textbf{(B-169)}$$

where:

$TCHEMCON_f$	=	Total consumption of fuel f by the bulk chemical industry,
NUM_{fg}	=	Number of fuels in fuel group fg, and
$QTYMAIN_{f,total}$	=	Consumption of main fuel f for all Census regions.

$$TCHEMCON_{renw} = \sum_{f=1}^{8} QTYRENW_{f,total} \qquad \textbf{(B-170)}$$

where:

$TCHEMCON_{renw}$	=	Total consumption of renewables by the bulk chemical industry, and
$QTYRENW_{f,total}$	=	Consumption of renewable fuel f for all Census regions.

Calculate consumption for the glass and glass products industry:

$$TGLASSCON_f = \sum_{f=1}^{NUM_{fg}} QTYMAIN_{f,total} \qquad \textbf{(B-171)}$$

where:

$TGLASSCON_f$	=	Total consumption of fuel f by the glass and glass products industry,

NUM_{fg}	=	Number of fuels in fuel group fg, and
$QTYMAIN_{f,total}$	=	Consumption of main fuel f for all Census regions.

$$TGLASSCON_{renw} = \sum_{f=1}^{8} QTYRENW_{f,total} \tag{B-172}$$

where:

$TGLASSCON_{renw}$	=	Total consumption of renewables by the glass and glass products industry, and
$QTYRENW_{f,total}$	=	Consumption of renewable fuel f for all Census regions.

Calculate consumption for the hydraulic cement industry:

$$TCEMENTCON_{f} = \sum_{f=1}^{NUM_{fg}} QTYMAIN_{f,total} \tag{B-173}$$

where:

$TCEMENTCON_{f}$	=	Total consumption of fuel f by the hydraulic cement industry,
NUM_{fg}	=	Number of fuels in fuel group fg, and
$QTYMAIN_{f,total}$	=	Consumption of main fuel f for all Census regions.

$$TCEMENTCON_{renw} = \sum_{f=1}^{8} QTYRENW_{f,total} \tag{B-174}$$

where:

$TCEMENTCON_{renw}$ = Total consumption of renewables by the hydraulic cement industry, and

$QTYRENW_{f,total}$ = Consumption of renewable fuel f for all Census regions.

Calculate consumption for the blast furnace and basic steel products industry:

$$TSTEELCON_f = \sum_{f=1}^{NUM_{fg}} QTYMAIN_{f,total} \quad \textbf{(B-175)}$$

where:

$TSTEELCON_f$ = Total consumption of fuel f by the blast furnace and basic steel products industry,

NUM_{fg} = Number of fuels in fuel group fg, and

$QTYMAIN_{f,total}$ = Consumption of main fuel f for all Census regions.

$$TSTEELCON_{renw} = \sum_{f=1}^{8} QTYRENW_{f,total} \quad \textbf{(B-176)}$$

where:

$TSTEELCON_{renw}$ = Total consumption of renewables by the blast furnace and basic steel products industry, and

$QTYRENW_{f,total}$ = Consumption of renewable fuel f for all Census regions.

Calculate consumption for the primary aluminum industry:

$$TALUMCON_f = \sum_{f=1}^{NUM_{fg}} QTYMAIN_{f,total} \qquad \textbf{(B-177)}$$

where:

$TALUMCON_f$	=	Total consumption of fuel f by the primary aluminum industry,
NUM_{fg}	=	Number of fuels in fuel group fg, and
$QTYMAIN_{f,total}$	=	Consumption of main fuel f for all Census regions.

$$TALUMCON_{renw} = \sum_{f=1}^{8} QTYRENW_{f,total} \qquad \textbf{(B-178)}$$

where:

$TALUMCON_{renw}$	=	Total consumption of renewables by the primary aluminum industry, and
$QTYRENW_{f,total}$	=	Consumption of renewable fuel f for all Census regions.

WEXOG

Calculate shares to share from Census regions to divisions:

$$FUELSHARE_{elec,d} = \frac{QSELIN_{d,1990}}{\sum_{d=1}^{NUM_r} QSELIN_{d,1990}} \qquad \textbf{(B-179)}$$

where:

$FUELSHARE_{elec,d}$ = Share of consumption for electricity in Census division d,

$QSELIN_{d,1990}$ = SEDS consumption of electricity in Census division d in 1990, and

NUM_r = Number of Census divisions in Census region r.

Similarly for the other fuels.

$$DSRENW_{f,d} = \frac{OUTIND_{13,d} + OUTIND_{11,d}}{\sum_{d=1}^{NUM_r} (OUTIND_{13,d} + OUTIND_{11,d})} \qquad \textbf{(B-180)}$$

where:

$DSRENW_{f,d}$ = Share of output for renewable fuel f in Census division d,

$OUTIND_{13,d}$ = Gross value of output for the paper and allied products industry in Census division d,

$OUTIND_{11,d}$ = Gross value of output for the lumber and wood products industry in Census division d, and

NUM_r = Number of Census divisions in Census region r.

$$DQMAIN_{f,d} = TQMAIN_{f,r} \ x \ FUELSHARE_{f,d} \qquad \textbf{(B-181)}$$

where:

$DQMAIN_{f,d}$ = Consumption of main fuel f in Census division d,

$TQMAIN_{f,r}$ = Total consumption of main fuel f in Census region r, and

$FUELSHARE_{f,d}$	=	Share of consumption of fuel f in Census division d.

$$DQRENW_{f,d} = TQRENW_{f,r} \times DSRENW_{f,d} \quad \text{(B-182)}$$

where:

$DQRENW_{f,d}$	=	Consumption of renewable fuel f in Census division d,
$TQRENW_{f,r}$	=	Total consumption of renewable fuel f in Census region r, and
$DSRENW_{f,d}$	=	Share of output for renewable fuel f in Census division d.

Calculate consumption values to benchmark:

$$BMAIN_{elec,d} = DQMAIN_{elec,d} + QELRF_{d,y} \quad \text{(B-183)}$$

where:

$BMAIN_{elec,d}$	=	Consumption of electricity in Census division d,
$DQMAIN_{elec,d}$	=	Consumption of electricity in Census division d, and
$QELRF_{d,y}$	=	Electricity consumed by petroleum refining industry in Census division d in year y.

$$BMAIN_{ng,d} = \left[\sum_{f=3}^{5} DQMAIN_{f,d}\right] + QNGRF_{d,y} + \sum_{u=1}^{2} CGOGQ_{d,y,ng,u} \quad \text{(B-184)}$$

where:

$BMAIN_{ng,d}$	=	Consumption of natural gas in Census division d,
$DQMAIN_{f,d}$	=	Consumption of natural gas fuel f in Census division d,

$QNGRF_{d,y}$ = Natural gas consumed by petroleum refining industry in Census division d in year y, and

$CGOGQ_{d,y,ng,u}$ = Consumption of natural gas from cogeneration of electricity for use u in enhanced oil recovery in Census division d in year y.

$$BMAIN_{coal,d} = DQMAIN_{coal,d} + QCLRF_{d,y} + COPRCLQ_{d,y} + COPRCLG_{d,y} + \sum_{u=1}^{2} CGOGQ_{d,y,coal,u} \quad \textbf{(B-185)}$$

where:

$BMAIN_{coal,d}$ = Consumption of coal in Census division d,

$DQMAIN_{coal,d}$ = Consumption of coal in Census division d,

$QCLRF_{d,y}$ = Coal consumed by petroleum refining industry in Census division d in year y,

$COPRCLQ_{d,y}$ = Supply of coal liquids in Census division d in year y,

$COPRCLG_{d,y}$ = Supply of coal gases in Census division d in year y, and

$CGOGQ_{d,y,coal,u}$ = Consumption of coal from cogeneration of electricity for use u in enhanced oil recovery in Census division d in year y.

For metallurgical coal, net coke imports, motor gasoline, asphalt and road oil, petrochemical feedstocks, and kerosene use the following equation.

$$BMAIN_{f,d} = DQMAIN_{f,d} \quad \textbf{(B-186)}$$

where:

$BMAIN_{f,d}$ = Consumption of fuel f in Census division d, and

$DQMAIN_{f,d}$ = Consumption of fuel f in Census division d,

$$BMAIN_{res,d} = DQMAIN_{res,d} + QRLRF_{d,y} + \sum_{u=1}^{2} CGOGQ_{d,y,res,u} \qquad \textbf{(B-187)}$$

where:

$BMAIN_{res,d}$ = Consumption of residual fuel in Census division d,

$DQMAIN_{res,d}$ = Consumption of residual fuel in Census division d,

$QRLRF_{d,y}$ = Residual fuel consumed by petroleum refining industry in Census division d in year y, and

$CGOGQ_{d,y,res,u}$ = Consumption of residual fuel from cogeneration of electricity for use u in enhanced oil recovery in Census division d in year y.

$$BMAIN_{dis,d} = DQMAIN_{dis,d} + QDSRF_{d,y} \qquad \textbf{(B-188)}$$

where:

$BMAIN_{dis,d}$ = Consumption of distillate in Census division d,

$DQMAIN_{dis,d}$ = Consumption of distillate in Census division d, and

$QDSRF_{d,y}$ = Distillate fuel consumed by petroleum refining industry in Census division d in year y.

$$BMAIN_{lpg,d} = \left[\sum_{f=12}^{13} DQMAIN_{f,d}\right] + QLGRF_{d,y} \qquad \textbf{(B-189)}$$

where:

$BMAIN_{lpg,d}$ = Consumption of liquid petroleum gas in Census division d,

$DQMAIN_{f,d}$	=	Consumption of liquid petroleum gas fuel f in Census division d, and
$QLGRF_{d,y}$	=	Liquid petroleum gas consumed by petroleum refining industry in Census division d in year y.

$$BMAIN_{sg,d} = DQMAIN_{sg,d} + QSGRF_{d,y} \qquad \textbf{(B-190)}$$

where:

$BMAIN_{sg,d}$	=	Consumption of still gas in Census division d,
$DQMAIN_{sg,d}$	=	Consumption of still gas in Census division d, and
$QSGRF_{d,y}$	=	Still gas consumed by petroleum refining industry in Census division d in year y.

$$BMAIN_{pc,d} = DQMAIN_{pc,d} + QPCRF_{d,y} \qquad \textbf{(B-191)}$$

where:

$BMAIN_{pc,d}$	=	Consumption of petroleum coke in Census division d,
$DQMAIN_{pc,d}$	=	Consumption of petroleum coke in Census division d, and
$QPCRF_{d,y}$	=	Petroleum coke consumed by petroleum refining industry in Census division d in year y.

$$BMAIN_{pet,d} = DQMAIN_{lube,d} + \left[\sum_{f=21}^{22} DQMAIN_{f,d}\right] + QOTRF_{d,y} \qquad \textbf{(B-192)}$$

where:

$BMAIN_{pet,d}$ = Consumption of other petroleum in Census division d,

$DQMAIN_{lube,d}$ = Consumption of lubes and waxes in Census division d,

$DQMAIN_{f,d}$ = Consumption of other petroleum fuel f in Census division d, and

$QOTRF_{d,y}$ = Other petroleum consumed by petroleum refining industry in Census division d in year y.

Calculate consumption for other industrial:

$$OTHIND_{f,d} = \left[BMAIN_{f,d} \times \frac{\sum_{y=1}^{MSEDYR} BENCHFAC_{f,d}}{2.0} \right] - BMAIN_{f,d} \quad \textbf{(B-193)}$$

where:

$OTHIND_{f,d}$ = Consumption of fuel f for "other industry" in Census division d,

$BMAIN_{f,d}$ = Consumption of fuel f in Census division d,

$MSEDYR$ = Index of SEDS years, and

$BENCHFAC_{f,d}$ = Benchmark factor for fuel f in Census division d.

Calculate benchmarked consumption values:

$$QELIN_{d,y} = BMAIN_{elec,d} + OTHIND_{elec,d} \tag{B-194}$$

where:

$QELIN_{d,y}$	=	Industrial consumption of electricity in Census division d in year y,
$BMAIN_{elec,d}$	=	Consumption of electricity in Census division d, and
$OTHIND_{elec,d}$	=	Consumption of electricity for "other industry" in Census division d.

Similarly for the other fuels:

$$QGFIN_{d,y} = \left[BMAIN_{ng,d} + OTHIND_{ng,d}\right] x \left[\frac{DQMAIN_{cng,d} + DQMAIN_{fds,d}}{BMAIN_{ng,d}}\right] \tag{B-195}$$

where:

$QGFIN_{d,y}$	=	Industrial consumption of core natural gas in Census division d in year y,
$BMAIN_{ng,d}$	=	Consumption of natural gas in Census division d,
$OTHIND_{ng,d}$	=	Consumption of natural gas for "other industry" in Census division d,
$DQMAIN_{ncng,d}$	=	Consumption of core natural gas in Census division d, and
$DQMAIN_{fds,d}$	=	Consumption of feedstock natural gas in Census division d.

$$QGIIN_{d,y} = (BMAIN_{ng,d} + OTHIND_{ng,d}) - QGFIN_{d,y} \tag{B-196}$$

where:

$QGIIN_{d,y}$ = Industrial consumption of non-core natural gas in Census division d in year y,

$BMAIN_{ng,d}$ = Consumption of natural gas in Census division d,

$OTHIND_{ng,d}$ = Consumption of natural gas for "other industry" in Census division d, and

$QGFIN_{d,y}$ = Industrial consumption of core natural gas in Census division d in year y.

$$QTPIN_{d,y} = \sum_{f=6}^{15} BMAIN_{f,d} + OTHIND_{f,d} \tag{B-197}$$

where:

$QTPIN_{d,y}$ = Consumption of total petroleum in Census division d in year y,

$BMAIN_{f,d}$ = Consumption of fuel f in Census division d, and

$OTHIND_{f,d}$ = Consumption of fuel f for "other industry" in Census division d.

$$QHOIN_{d,y} = DQRENW_{hydro,d} \tag{B-198}$$

where:

$QHOIN_{d,y}$ = Industrial consumption of hydropower in Census division d in year y, and

$DQRENW_{hydro,d}$ = Consumption of hydropower in Census division d.

Similarly for other renewables.

For biomass use the following equation:

$$QBMIN_{d,y} = \left[\sum_{f=2}^{3} DQRENW_{f,d}\right] + \left[\sum_{u=1}^{2} CGOGQ_{d,y,bm,u}\right] + QBMRF_{d,y} \qquad \textbf{(B-199)}$$

where:

$QBMIN_{d,y}$	=	Industrial consumption of biomass in Census division d in year y,
$DQRENW_{f,d}$	=	Consumption of renewable fuel f in Census division d,
$CGOGQ_{d,y,bm,u}$	=	Consumption of biomass from cogeneration of electricity for use u in enhanced oil recovery in Census division d in year y, and
$QBMRF_{d,y}$	=	Biomass consumed by petroleum refining industry in Census division d in year y.

$$QTRIN_{d,y} = QHOIN_{d,y} + QBMIN_{d,y} + QGEIN_{d,y} + QSTIN_{d,y} + QPVIN_{d,y} + QWIIN_{d,y} + QMSIN_{d,y} \qquad \textbf{(B-200)}$$

where:

$QTRIN_{d,y}$	=	Consumption of total renewables in Census division d in year y,
$QHOIN_{d,y}$	=	Consumption of hydropower in Census division d in year y,
$QBMIN_{d,y}$	=	Consumption of biomass in Census division d in year y,
$QGEIN_{d,y}$	=	Consumption of geothermal in Census division d in year y,
$QSTIN_{d,y}$	=	Consumption of solar thermal in Census division d in year y,

$QPVIN_{d,y}$	=	Consumption of photovoltaic in Census division d in year y,
$QWIIN_{d,y}$	=	Consumption of wind in Census division d in year y, and
$QMSIN_{d,y}$	=	Consumption of municipal solid waste in Census division d in year y.

Calculate NEMS cogeneration variables:

$$CGINDCAP_{d,y,f,u,pl} = CAPGW_{d,f,u,pl} + CGRECAP_{d,y,f,u,pl} + CGOGCAP_{d,y,f,u,pl} \quad \textbf{(B-201)}$$

where:

$CGINDCAP_{d,y,f,u,pl}$	=	Industrial planned capacity for cogeneration for use u using fuel f in Census division d in year y,
$CAPGW_{d,f,u,pl}$	=	Planned capacity for cogeneration of electricity for use u using fuel f in Census division d,
$CGRECAP_{d,y,f,u,pl}$	=	Refinery planned capacity for cogeneration for use u using fuel f in Census division d in year y.
$CGOGCAP_{d,y,f,u,pl}$	=	Oil and gas planned capacity for cogeneration for use u using fuel f in Census division d in year y.

$$CGINDGEN_{d,y,f,u} = GENGWH_{d,f,u} + CGREGEN_{d,y,f,u} + CGOGGEN_{d,y,f,u} \quad \textbf{(B-202)}$$

where:

$CGINDGEN_{d,y,f,u}$	=	Industrial cogeneration of electricity for use u using fuel f in Census division d in year y,
$GENGWH_{d,f,u}$	=	Cogeneration of electricity for use u using fuel f in Census division d,

$CGREGEN_{d,y,f,u}$	=	Refinery cogeneration of electricity for use u using fuel f in Census division d in year y, and
$CGOGGEN_{d,y,f,u}$	=	Oil and gas cogeneration of electricity for use u using fuel f in Census division d in year y.

$$CGINDQ_{d,y,f,u} = DIVFUEL_{d,f,u} + CGREQ_{d,y,f,u} + CGOGQ_{d,y,f,u} \qquad \textbf{(B-203)}$$

where:

$CGINDQ_{d,y,f,u}$	=	Industrial consumption of fuel f for cogeneration of electricity for use u in Census division d in year y,
$DIVFUEL_{d,f,u}$	=	Consumption of fuel f for cogeneration of electricity for use u in Census division d,
$CREGQ_{d,y,f,u}$	=	Consumption of fuel f from cogeneration of electricity for use u in refineries in Census division d in year y, and
$CGOGQ_{d,y,f,u}$	=	Consumption of fuel f from cogeneration of electricity for use u in enhanced oil recovery in Census division d in year y.

$$MANHP_{elec,y} = TMANHP_{elec} + QELRF_{total,y} \qquad \textbf{(B-204)}$$

where:

$MANHP_{elec,y}$	=	Consumption of electricity for manufacturing heat and power in year y,
$TMANHP_{elec}$	=	Total manufacturing consumption of electricity for manufacturing heat and power, and
$QELRF_{total,y}$	=	Electricity consumed by petroleum refining industry in year y.

$$NONHP_{f,y} = TNONHP_f + \sum_{u=1}^{2} CGOGQ_{total,y,f,u} \quad \textbf{(B-205)}$$

where:

$NONHP_{f,y}$ = Consumption of fuel f for non-manufacturing heat and power in year y,

$TNONHP_f$ = Total non-manufacturing consumption of fuel f for heat and power, and

$CGOGQ_{total,y,f,u}$ = Consumption of fuel f from cogeneration of electricity for use u in enhanced oil recovery in all Census divisions in year y.

$$MISCFD_{f,y} = TMISCFD_f \quad \textbf{(B-206)}$$

where:

$MISCFD_{f,y}$ = Consumption of miscellaneous fuels and feedstocks f in year y, and

$TMISCFD_f$ = Total consumption of miscellaneous fuels and feedstocks f.

$$FOODCON_{f,y} = TFOODCON_f \quad \textbf{(B-207)}$$

where:

$FOODCON_{f,y}$ = Consumption of fuel f by the food and kindred products industry in year y, and

$TFOODCON_f$ = Total consumption of fuel f by the food and kindred products industry.

$$PAPERCON_{f,y} = TPAPERCON_f \tag{B-208}$$

where:

$PAPERCON_{f,y}$ = Consumption of fuel f by the paper and allied products industry in year y, and

$TPAPERCON_f$ = Total consumption of fuel f by the paper and allied products industry in year y.

$$CHEMCON_{f,y} = TCHEMCON_f \tag{B-209}$$

where:

$CHEMCON_{f,y}$ = Consumption of fuel f by the bulk chemical industry in year y, and

$TCHEMCON_f$ = Total consumption of fuel f by the bulk chemical industry.

$$GLASSCON_{f,y} = TGLASSCON_f \tag{B-210}$$

where:

$GLASSCON_{f,y}$ = Consumption of fuel f by the glass and glass products industry in year y, and

$TGLASSCON_f$ = Total consumption of fuel f by the glass and glass products industry.

$$CEMENTCON_{f,y} = TCEMENTCON_f \tag{B-211}$$

where:

$CEMENTCON_{f,y}$	=	Consumption of fuel f by the hydraulic cement industry in year y, and
$TCEMENTCON_f$	=	Total consumption of fuel f by the hydraulic cement industry.

$$REFCON_{f,y} = TREFCON_f \tag{B-212}$$

where:

$REFCON_{f,y}$	=	Consumption of fuel f by the petroleum refining industry in year y, and
$TREFCON_f$	=	Total consumption of fuel f by the petroleum refining industry.

$$STEELCON_{f,y} = TSTEELCON_f \tag{B-213}$$

where:

$STEELCON_{f,y}$	=	Consumption of fuel f by the blast furnace and basic steel products industry in year y, and
$TSTEELCON_f$	=	Total consumption of fuel f by the blast furnace and basic steel products industry.

$$ALUMCON_{f,y} = TALUMCON_f \quad \textbf{(B-214)}$$

where:

$ALUMCON_{f,y}$	=	Consumption of fuel f by the primary aluminum industry in year y, and
$TALUMCON_f$	=	Total consumption of fuel f by the primary aluminum industry.

$$DEMIMAIN_{f,p,d} = \left[BMAIN_{f,d} + OTHIND_{f,d}\right] \times UNCONTEMISSFACT_{f,p} \times EMISSCONTROLFAC_{f,p} \quad \textbf{(B-215)}$$

where:

$DEMIMAIN_{f,p,d}$	=	Emissions of pollutant p from main fuel f in Census division d,
$BMAIN_{f,d}$	=	Consumption of main fuel f in Census division d,
$OTHIND_{f,d}$	=	Consumption of fuel f from "other industry" in Census division d,
$UNCONTEMISSFACT_{f,p}$	=	Uncontrolled emission factor for pollutant p using fuel f, and
$EMISSCONTROLFAC_{f,p}$	=	Emissions control factor for pollutant p using fuel f.

$$DEMIMAIN_{ng,p,d} = (BMAIN_{ng,d} + OTHIND_{ng,d}) - (BENCHFAC_{ng,d} \times DQMAIN_{ng,d}) + (BENCHFAC_{ng,d} \times QLPIN_{d,y} \times UNCONTEMISSFACT_{cng,p} \times EMISSCONTROLFAC_{cng,p}) + (BENCHFAC_{ng,d} \times DQMAIN_{ng,d} \times UNCONTEMISSFACT_{fng,p} \times EMISSCONTROLFAC_{fng,p}) \quad \textbf{(B-216)}$$

where:

$DEMIMAIN_{ng,p,d}$	=	Emissions of pollutant p from natural gas in Census division d,
$BMAIN_{ng,d}$	=	Consumption of natural gas feedstocks in Census division d,
$OTHIND_{ng,d}$	=	Consumption of natural gas feedstocks from other industry in Census division d,
$BENCHFAC_{ng,d}$	=	Benchmark factor for natural gas feedstocks in Census division d,
$DQMAIN_{ng,d}$	=	Consumption of natural gas feedstocks in Census division d,
$QLPIN_{d,y}$	=	Industrial consumption of lease and plant natural gas in Census division d in year y,
$UNCONTEMISSFACT_{cng,p}$	=	Uncontrolled emission factor for pollutant p using core natural gas,
$EMISSCONTROLFAC_{cng,p}$	=	Emissions control factor for pollutant p using core natural gas,
$UNCONTEMISSFACT_{fng,p}$	=	Uncontrolled emission factor for pollutant p using feedstock natural gas, and
$EMISSCONTROLFAC_{fng,p}$	=	Emissions control factor for pollutant p using feedstock natural gas.

$$DEMIMAIN_{lpg,p,d} = \Big((BMAIN_{lpg,d} + OTHIND_{lpg,d}) - (BENCHFAC_{lpg,d} \times DQMAIN_{lpg,d}\Big) \times \Big(UNCONTEMISSFACT_{lpghp,p} \times EMISSCONTROLFAC_{lpghp,p}\Big) + (BENCHFAC_{lpg,d} \times DQMAIN_{lpg,d} \times UNCONTEMISSFACT_{lpgf,p} \times EMISSCONTROLFAC_{lpgf,p}) \quad \text{(B-217)}$$

where:

$DEMIMAIN_{lpg,p,d}$	=	Emissions of pollutant p from liquid petroleum gas in Census division d,
$BMAIN_{lpg,d}$	=	Consumption of liquid petroleum gas in Census division d,
$OTHIND_{lpg,d}$	=	Consumption of liquid petroleum gas from "other industry" in Census division d,
$BENCHFAC_{lpg,d}$	=	Benchmark factor for liquid petroleum gas in Census division d,
$DQMAIN_{lpg,d}$	=	Consumption of liquid petroleum gas in Census division d,
$UNCONTEMISSFACT_{lpghp,p}$	=	Uncontrolled emission factor for pollutant p using liquid petroleum gas for heat and power,
$EMISSCONTROLFAC_{lpghp,p}$	=	Emissions factor for pollutant p using liquid petroleum gas for heat and power,
$UNCONTEMISSFACT_{lpgf,p}$	=	Uncontrolled emission factor for pollutant p using liquid petroleum gas for feedstocks, and
$EMISSCONTROLFAC_{lpgf,p}$	=	Emissions factor for pollutant p using liquid petroleum gas for feedstocks.

For emissions of SO_x the following equation is used.

$$DEMIMAIN_{f,p,d} = DEMIMAIN_{f,p,d} \times SULFURCONT_f \quad \textbf{(B-218)}$$

where:

$DEMIMAIN_{f,p,d}$	=	Emissions of pollutant p from main fuel f in Census division d, and
$SULFURCONT_f$	=	Sulfur content of fuel f.

$$DEMIRENW_{f,p,d} = TEMISR_{f,p,r} \times DSRENW_{f,d} \qquad \text{(B-219)}$$

where:

$DEMIRENW_{f,p,d}$	=	Emissions of pollutant p from renewable fuel f in Census division d,
$TEMISR_{f,p,r}$	=	Total emissions of pollutant p from renewable fuel f in Census region r, and
$DSRENW_{f,d}$	=	Share of output of renewable fuel f in Census division d.

$$EMINCX_{f,p,d,y} = \sum_{f=1}^{NUM_{fg}} DEMIMAIN_{f,p,d} \qquad \text{(B-220)}$$

where:

$EMINCX_{f,p,d,y}$	=	Emissions of pollutant p from fuel f in Census division d in year y,
NUM_{fg}	=	Number of fuels in fuel group fg, and
$DEMIMAIN_{f,p,d}$	=	Emissions of pollutant p from main fuel f in Census division d.

$$EMINCX_{renw,p,d,y} = \sum_{f=1}^{8} DEMIRENW_{f,p,d} \qquad \text{(B-221)}$$

where:

$EMINCX_{renw,p,d,y}$	=	Emissions of pollutant p from renewables in Census division d in year y, and
$DEMIRENW_{f,p,d}$	=	Emissions of pollutant p from renewable fuel f in Census division d.

$$EMINCX_{f,p,total,y} = \sum_{d=1}^{9} EMINCX_{f,p,d,y} \qquad \textbf{(B-222)}$$

where:

$EMINCX_{f,p,total,y}$	=	Emissions of pollutant p from fuel f all Census divisions in year y,
$EMINCX_{f,p,d,y}$	=	Emissions of pollutant p from fuel f in Census division d in year y,

$$EMINC_{f,p,y} = \frac{EMINCX_{f,p,total,y}}{10^6} \qquad \textbf{(B-223)}$$

where:

$EMINC_{f,p,y}$	=	Industrial emissions of pollutant p from fuel f in year y,
$EMINCX_{f,p,total,y}$	=	Emissions of pollutant p from fuel f in all Census divisions in year y, and
10^6	=	Conversion factor to convert to million metric tons.

$$EMINCC_{d,p,y} = \frac{\sum_{f=1}^{4} EMINCX_{f,p,d,y}}{10^6} \qquad \textbf{(B-224)}$$

where:

$EMINCC_{d,p,y}$	=	Industrial emissions of pollutant p in Census division d in year y,
$EMINCX_{f,p,d,y}$	=	Emissions of pollutant p from fuel f in Census division d in year y, and
10^6	=	Conversion factor to convert to million metric tons.

IBSEDS

Calculate benchmark factors.

$$BENCHFAC_{f,d} = \frac{SEDSIND_{f,d}}{BMAIN_{f,d}} \qquad \textbf{(B-225)}$$

where:

$BENCHFAC_{f,d}$	=	Benchmark factor for fuel f in Census division d,
$SEDSIND_{f,d}$	=	SEDS consumption of fuel f in Census division d, and
$BMAIN_{f,d}$	=	Consumption of main fuel f in Census division d.

$$BENCHFAC_{bm,d} = \frac{BIOFUELS_d}{\sum_{f=2}^{3} DQRENW_{f,d}} \qquad \textbf{(B-226)}$$

where:

$BENCHFAC_{bm,d}$	=	Benchmark factor for biomass in Census division d,
$BIOFUELS_d$	=	Consumption of biofuels in Census division d, and

$DQRENW_{f,d}$ = Consumption of renewable fuel f in Census division d.

$$OTHIND_{f,d} = [BENCHFAC_{f,d} \times BMAIN_{f,d}] - BMAIN_{f,d} \qquad \textbf{(B-227)}$$

where:

$OTHIND_{f,d}$ = Consumption of fuel f for "other industry" in Census division d,

$BMAIN_{f,d}$ = Consumption of main fuel f in Census division d, and

$BENCHFAC_{f,d}$ = Benchmark factor for fuel f in Census division d.

$$OTHIND_{f,total} = \sum_{d=1}^{9} OTHIND_{f,d} \qquad \textbf{(B-228)}$$

where:

$OTHIND_{f,total}$ = Consumption of fuel f for "other industry" all Census divisions, and

$OTHIND_{f,d}$ = Consumption of fuel f for "other industry" in Census division d.

PDATA

$$PHDRAT = \frac{PHDRAT}{PRODVX_{i,r}} \qquad \textbf{(B-229)}$$

where:

$PHDRAT$ = Ratio of physical units to value of output, and

$PRODVX_{i,r}$ = Value of output for industry i in Census region r.

If IDVAL = 1, then

$$PRODX_{i,r} = PHDRAT \times PRODVX_{i,r} \tag{B-230}$$

where:

$PRODX_{i,r}$ = Output in physical units for industry i in Census region r,

$PHDRAT$ = Ratio of physical units to value of output, and

$PRODVX_{i,r}$ = Value of output for industry i in Census region r.

If IDVAL = 2, then

$$PRODX_{i,r} = PRODVX_{i,r} \tag{B-231}$$

where:

$PRODX_{i,r}$ = Output in dollar units for industry i in Census region r, and

$PRODVX_{i,r}$ = Value of output for industry i in Census region r.

If process step s is linked to final consumption, then use the following equation:

$$PRODCUR_{total,s} = PRODFLOW_{old,s,l} \times PRODX_{i,r} \tag{B-232}$$

where:

$PRODCUR_{total,s}$	=	Production at process step s for all vintages,
$PRODFLOW_{old,s,l}$	=	Down-step throughput to process step s linked by link l for old vintage, and
$PRODX_{i,r}$	=	Output for industry i in Census region r.

If process step is linked to some other step, then use the following equation:

$$PRODSUM_{s,l} = PRODFLOW_{old,s,l} \times PRODCUR_{total,s} \qquad \textbf{(B-233)}$$

where:

$PRODSUM_{s,l}$	=	Amount of throughput used at process step s through link l,
$PRODFLOW_{old,s,l}$	=	Down-step throughput to process step s linked by link l for old vintage, and
$PRODCUR_{total,s}$	=	Production at process step s through link l for all vintages.

$$PRODCUR_{total,s} = \sum_{l=1}^{NTMAX_s} PRODSUM_{s,l} \qquad \textbf{(B-234)}$$

where:

$PRODCUR_{total,s}$	=	Production at process step s for all vintages,
$NTMAX_s$	=	Number of links at process step s, and

$PRODSUM_{s,l}$ = Amount of throughput used at process step s through link l.

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Appendix D. Model Abstract

Model Name:

Industrial Demand Model

Model Acronym:

None

Description:

The Industrial Demand Model is based upon economic and engineering relationships that model industrial sector energy consumption at the nine Census division level of detail. The seven most energy intensive industries are modeled at the detailed process step level and 25 other industries are modeled at a less detailed level. The industrial model incorporates three components: buildings, process and assembly, and boiler, steam, and cogeneration. The model estimates consumption of 22 main fuels, 6 intermediate fuels, and 8 renewable fuels.

Purpose of the Model:

As a component of the National Energy Modeling System integrated forecasting tool, the industrial model generates mid-term forecasts of industrial sector energy consumption. The industrial model facilitates policy analysis of energy markets, technological development, environmental issues, and regulatory development as they impact industrial sector energy consumption.

Most Recent Model Update:

November 1993.

Part of another Model?

National Energy Modeling System (NEMS)

Model Interfaces:

Receives inputs from the Electricity Market Module, Oil and Gas Market Module, Renewable Fuels Module, Macroeconomic Activity Module, and Petroleum Market Module.

Official Model Representative:

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Energy Demand Analysis Branch
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Washington, DC 20585

Telephone: (202) 586-1420

Documentation:

Model Documentation Report: Industrial Sector Model of the National Energy Modeling System, December 1993.

Archive Media and Installation Manual(s):

As of this writing, the model has not been officially archived. The model will be archived on IBM 3090 mainframe magnetic tape storage as part of the National Energy Modeling System production runs used to generate the Annual Energy Outlook 1994.

Energy System Described:

Domestic industrial sector energy consumption

Coverage:

- Geographic: Nine Census divisions: New England, Mid Atlantic, East North Central, West North Central, South Atlantic, East South Central, West South Central, Mountain, and Pacific.
- Time Unit/Frequency: Annual, 1990 through 2010

Modeling Features:

- Structure: 26 manufacturing and 6 nonmanufacturing industries. The manufacturing industries are further subdivided into the energy intensive and non-energy-intensive industries.

- Each industry is modelled as three separate but interrelated components consisting of the process/assembly component (PA), the buildings component (BLD), and the boiler/steam/cogeneration component (BSC).

- Modeling Technique: Ordinary least-squares with log transformations is used for the nonmanufacturing and non-energy-intensive manufacturing industries. The energy intensive industries are modeled through the use of a detailed process flow accounting procedure.

Non-DOE Input Sources:

National Energy Accounts

Major Industrial Power Plant Database

Historical Dollar Value of Output in the Industrial Sector

DOE Input Sources:

Form EI-867: Survey of Independent Power Producers

- Electricity generation, total and by prime mover
- Electricity generation for own use and sales
- Capacity utilization

Manufacturing Energy Consumption Survey 1988, May 1991

State Energy Data System 1991, May 1993

Computing Environment:

- Hardware Used: IBM 3090
- Operating System: MVS
- Language/Software Used: VS FORTRAN, Ver 2.05

- Memory Requirement: 437K
- Storage Requirement: Model has not yet been archived. It will require an as-yet undetermined number of tracks of an IBM 3380 disk pack.
- Estimated Run Time: 1.1 minutes for a 1990-2010 run in non-iterating NEMS mode on an IBM 3090.
- Special Features: None.

Independent Expert Reviews Conducted:

None.

Status of Evaluation Efforts by Sponsor:

None.

Appendix E. Data Quality and Estimation

Introduction

The NEMS Industrial Demand Model develops forecasts of industrial sector energy consumption based on the data elements as detailed in Appendix A of this report. This Appendix provides the initial values and sources for the input data, and the estimation methods, results, and quality of the parameter estimates. References are also provided at the end of the Appendix for the quality of the Manufacturing Energy Consumption Survey (MECS 1988) and the Non-Utility Power Producer Report (EIA-867).

Table E-1. Building Component UEC (Trillion Btu/Thousand People Employed)

		Building Use and Energy Source			
		Lighting	HVAC		
SIC	Industry	Elec. UEC	Elec UEC	Nat. Gas UEC	Steam UEC
20	Food & Kindred Products	0.009	0.006	0.013	0.062
21	Tobacco	0.007	0.005	0.000	0.071
22	Textiles	0.017	0.014	0.005	0.033
23	Apparel	0.001	0.002	0.005	0.009
24	Lumber	0.002	0.006	0.000	0.031
25	Furniture	0.001	0.002	0.002	0.030
26	Pulp & Paper	0.054	0.008	0.002	0.096
27	Printing	0.001	0.008	0.002	0.016
281, 282, 286, 287	Bulk Chemicals	0.037	0.018	0.002	0.118
283, 284, 285, 289	Other Chemicals	0.002	0.001	0.002	0.002
2911	Petroleum Refining	0.156	0.074	0.036	0.123
295, 299	Other Petroleum	0.002	0.001	0.001	0.001
30	Rubber	0.005	0.015	0.002	0.013
31	Leather	0.003	0.003	0.000	0.035
321, 322, 323	Glass and Glass Products	0.148	0.084	0.030	0.000
324	Hydraulic Cement	0.010	0.006	0.000	0.000
325, 326, 327, 328, 329	Other	0.005	0.003	0.002	0.000
331,332, etc.	Blast Furnaces & Basic Steel	0.788	0.374	0.957	1.231
3334, 3341, etc.	Primary Aluminum	0.053	0.025	0.000	0.007
333-336, 339	Other Primary Metals	0.003	0.001	0.000	0.004
34	Fabricated Metals	0.006	0.005	0.012	0.030
35	Industrial Machinery	0.006	0.012	0.000	0.014
36	Electronic Equipment	0.006	0.017	0.001	0.011
37	Transportation Equipment	0.010	0.007	0.003	0.037

Table E-1. Building Component UEC (Trillion Btu/Thousand People Employed)

		Building Use and Energy Source			
		Lighting	HVAC		
SIC	Industry	Elec. UEC	Elec UEC	Nat. Gas UEC	Steam UEC
38	Instruments	0.004	0.014	0.001	0.027
39	Miscellaneous Manufacturing	0.003	0.003	0.007	0.011

Source: [30].

Table E-2.A. Non-Manufacturing Sector PA Component UEC (Trillion Btu/Billion 1987$ Output)

SIC	Census Region	Elec	Ngas	Resid	Dist	Liq Gas	Motor Gas	Coal	Coke&Br	Other	Total	Steam
1 Agri-Crops	1	1.116	0.369	0.000	4.656	0.643	0.764	0.002	0.000	0.133	6.434	0.162
	2	1.116	0.369	0.000	4.656	0.643	0.764	0.002	0.000	0.133	6.434	0.162
	3	1.116	0.369	0.000	4.656	0.643	0.764	0.002	0.000	0.133	6.434	0.162
	4	1.116	0.369	0.000	4.656	0.643	0.764	0.002	0.000	0.133	6.434	0.162
2-9 Agri-Other	1	0.320	0.119	0.000	1.335	0.185	0.219	0.000	0.000	0.041	1.860	0.042
	2	0.320	0.119	0.000	1.335	0.185	0.219	0.000	0.000	0.041	1.860	0.042
	3	0.320	0.119	0.000	1.335	0.185	0.219	0.000	0.000	0.041	1.860	0.042
	4	0.320	0.119	0.000	1.335	0.185	0.219	0.000	0.000	0.041	1.860	0.042
12 Coal Mining	1	1.973	3.596	0.117	0.376	0.051	0.055	0.277	0.000	0.000	4.472	0.000
	2	1.973	3.596	0.117	0.376	0.051	0.055	0.277	0.000	0.000	4.472	0.000
	3	1.973	3.596	0.117	0.376	0.051	0.055	0.277	0.000	0.000	4.472	0.000
	4	1.973	3.596	0.117	0.376	0.051	0.055	0.277	0.000	0.000	4.472	0.000
13 Oil&Gas Mining	1	1.754	10.739	0.377	1.235	0.172	0.175	0.909	0.000	0.014	13.607	0.698
	2	1.754	10.739	0.377	1.235	0.172	0.175	0.909	0.000	0.014	13.607	0.698
	3	1.754	10.739	0.377	1.235	0.172	0.175	0.909	0.000	0.014	13.607	0.698
	4	1.754	10.739	0.377	1.235	0.172	0.175	0.909	0.000	0.014	13.607	0.698
10,14 Metal Mining	1	5.572	13.033	0.425	1.384	0.193	0.198	0.826	0.000	0.000	16.054	0.272
	2	5.572	13.033	0.425	1.384	0.193	0.198	0.826	0.000	0.000	16.054	0.272
	3	5.572	13.033	0.425	1.384	0.193	0.198	0.826	0.000	0.000	16.054	0.272
	4	5.572	13.033	0.425	1.384	0.193	0.198	0.826	0.000	0.000	16.054	0.272
15,16,17 Construction	1	0.174	0.164	0.047	0.485	0.013	0.112	0.000	0.000	1.069	1.890	0.000
	2	0.174	0.164	0.047	0.485	0.013	0.112	0.000	0.000	1.069	1.890	0.000
	3	0.174	0.164	0.047	0.485	0.013	0.112	0.000	0.000	1.069	1.890	0.000
	4	0.174	0.164	0.047	0.485	0.013	0.112	0.000	0.000	1.069	1.890	0.000

Source: [30].

Table E-2.B. Non-Energy-Intensive Manufacturing Sector PA Component UEC (Trillion Btu/Billion 1987$ Output)

SIC	Census Region	Elec	Ngas	Resid	Dist	Liq Gas	Coal	Coke&Br	Total Other	Steam	Total Consump.	Bfg/Cog	Waste Gas	Pet Coke	Pulp Liq.	Wood	Byprod.	Total Byprod.
21 Tobacco	1	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3	0.150	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22 Textiles	1	0.653	0.296	0.189	0.077	0.045	0.000	0.000	0.108	1.395	2.764	0.011	0.000	0.000	0.000	0.011	0.000	0.022
	2	0.477	0.282	0.001	0.002	0.009	0.000	0.912	0.000	0.602	2.285	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3	1.625	0.379	0.053	0.042	0.016	0.000	0.005	0.090	1.597	3.807	0.009	0.000	0.000	0.000	0.009	0.000	0.019
	4	0.781	0.364	0.000	0.009	0.005	0.000	0.000	0.000	0.776	1.935	0.000	0.000	0.000	0.000	0.000	0.000	0.000
23 Apparel	1	0.152	0.087	0.018	0.019	0.000	0.000	0.000	0.000	0.041	0.318	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.259	0.152	0.000	0.007	0.000	0.011	0.000	0.001	0.050	0.480	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3	0.396	0.097	0.003	0.004	0.000	0.026	0.000	0.009	0.049	0.584	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	4	0.100	0.026	0.000	0.000	0.000	0.000	0.000	0.000	0.007	0.132	0.000	0.000	0.000	0.000	0.000	0.000	0.000
24 Lumber	1	0.572	0.235	0.064	0.293	0.000	0.000	0.000	0.214	1.410	2.788	0.000	0.000	0.000	0.000	0.192	0.000	0.192
	2	0.718	0.213	0.061	0.123	0.000	0.025	0.000	0.173	1.204	2.516	0.000	0.000	0.000	0.000	0.155	0.000	0.155
	3	1.496	0.194	0.024	0.151	0.000	0.010	0.000	0.674	3.109	5.660	0.000	0.000	0.000	0.000	0.606	0.000	0.606
	4	0.700	0.111	0.019	0.137	0.000	0.000	0.000	0.669	2.940	4.576	0.000	0.000	0.000	0.000	0.601	0.000	0.601
25 Furniture	1	0.321	0.449	0.021	0.033	0.002	0.000	0.000	0.005	0.055	0.886	0.000	0.000	0.000	0.000	0.001	0.000	0.001
	2	0.455	0.744	0.002	0.014	0.001	0.000	0.000	0.004	0.060	1.281	0.000	0.000	0.000	0.000	0.001	0.000	0.001
	3	0.670	0.376	0.011	0.042	0.003	0.000	0.000	0.029	0.135	1.265	0.000	0.000	0.000	0.000	0.004	0.000	0.004
	4	0.192	0.000	0.000	0.000	0.000	0.000	0.000	0.003	0.009	0.203	0.000	0.000	0.000	0.000	0.000	0.000	0.000
27 Printing	1	0.273	0.088	0.002	0.011	0.016	0.000	0.000	0.019	0.000	0.409	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.686	0.463	0.001	0.001	0.015	0.000	0.000	0.011	0.000	1.177	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3	0.782	0.219	0.004	0.002	0.014	0.000	0.000	0.014	0.000	1.035	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	4	0.363	0.128	0.000	0.001	0.033	0.000	0.000	0.000	0.000	0.526	0.000	0.000	0.000	0.000	0.000	0.000	0.000
Chem., Other 283,284,285,289	1	0.010	0.034	0.042	0.045	-0.000	0.000	0.000	0.054	0.083	0.268	0.000	0.032	0.000	0.000	0.000	0.003	0.035
	2	0.022	0.112	0.023	0.010	-0.000	0.000	0.000	0.028	0.275	0.470	0.000	0.016	0.000	0.000	0.000	0.002	0.018
	3	0.059	0.956	0.053	0.046	-0.000	0.000	0.000	0.761	1.373	3.247	0.000	0.445	0.000	0.000	0.000	0.049	0.493
	4	0.029	0.118	0.004	0.016	-0.000	0.000	0.000	0.027	0.128	0.322	0.000	0.016	0.000	0.000	0.000	0.002	0.017
Misc Refining	1	0.068	0.029	0.011	0.294	0.000	0.051	0.000	0.591	0.262	1.305	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.069	0.029	0.005	0.148	0.000	0.037	0.000	0.526	0.207	1.021	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3	0.261	0.441	0.002	0.172	0.000	0.047	0.000	2.948	1.026	4.897	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	4	0.243	0.140	0.014	0.308	0.000	0.000	0.000	2.608	0.728	4.041	0.000	0.000	0.000	0.000	0.000	0.000	0.000
30 Rubber	1	0.885	0.222	0.019	0.067	0.018	0.000	0.000	0.023	0.667	1.900	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2	1.068	0.515	0.010	0.006	0.063	0.000	0.000	0.012	0.845	2.519	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3	1.227	0.460	0.029	0.018	0.012	0.000	0.000	0.027	0.930	2.703	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	4	0.639	0.253	0.003	0.007	0.011	0.000	0.000	0.000	0.375	1.287	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table E-2.B. Non-Energy-Intensive Manufacturing Sector PA Component UEC (Trillion Btu/Billion 1987$ Output)

SIC	Census Region	Elec	Ngas	Resid	Dist	Liq Gas	Coal	Coke&Br	Total Other	Steam	Total Consump.	Bfg/Cog	Waste Gas	Pet Coke	Pulp Liq.	Wood	Byprod.	Total Byprod.
31 Leather	1	0.185	0.339	0.139	0.071	0.000	0.131	0.000	0.000	0.004	0.869	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.477	0.493	0.058	0.038	0.033	0.053	0.000	0.003	0.003	1.157	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3	0.704	0.000	0.012	0.010	0.000	0.000	0.000	0.007	0.000	0.733	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	4	0.307	0.868	0.000	0.000	0.000	0.000	0.000	0.000	0.002	1.177	0.000	0.000	0.000	0.000	0.000	0.000	0.000
SC&G, Other 325,326,327,328,329	1	0.485	3.381	0.355	0.159	0.074	0.310	0.029	0.096	0.577	5.465	0.000	0.000	0.000	0.000	0.044	0.011	0.056
	2	0.513	3.204	0.014	0.151	0.060	0.758	0.000	0.233	0.553	5.486	0.000	0.000	0.000	0.000	0.108	0.028	0.136
	3	0.635	4.199	0.232	0.208	0.110	0.573	0.000	0.130	0.711	6.798	0.000	0.000	0.000	0.000	0.060	0.016	0.076
	4	0.474	2.439	0.044	0.109	0.144	0.566	0.073	0.114	0.419	4.381	0.000	0.000	0.000	0.000	0.053	0.014	0.067
Prim. Metals, Other 333-336,339	1	0.211	0.794	0.009	0.052	0.000	0.000	0.244	0.037	0.292	1.640	0.000	0.000	0.000	0.000	0.000	0.026	0.026
	2	0.372	1.742	0.009	0.037	0.000	0.000	1.014	0.083	0.589	3.846	0.000	0.000	0.000	0.000	0.000	0.058	0.056
	3	0.354	0.840	0.009	0.026	0.000	0.000	0.296	0.029	0.291	1.845	0.000	0.000	0.000	0.000	0.000	0.020	0.020
	4	0.614	0.688	0.001	0.047	0.000	0.000	0.100	0.014	0.194	1.658	0.000	0.000	0.000	0.000	0.000	0.010	0.010
34 Fab Metals	1	0.505	0.855	0.027	0.066	0.035	0.005	0.008	0.021	0.183	1.703	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.670	0.947	0.011	0.008	0.029	0.023	0.006	0.024	0.188	1.906	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3	0.654	0.754	0.001	0.011	0.027	0.003	0.010	0.014	0.126	1.600	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	4	0.533	0.574	0.000	0.007	0.022	0.000	0.000	0.067	0.113	1.316	0.000	0.000	0.000	0.000	0.000	0.000	0.000
35 Ind Machinery	1	0.348	0.230	0.020	0.032	0.007	0.000	0.000	0.000	0.103	0.740	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.388	0.535	0.000	0.010	0.016	0.000	0.003	0.005	0.193	1.149	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3	0.321	0.238	0.001	0.013	0.013	0.000	0.000	0.008	0.063	0.657	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	4	0.268	0.355	0.000	0.001	0.004	0.000	0.000	0.011	0.075	0.715	0.000	0.000	0.000	0.000	0.000	0.000	0.000
36 Electronics	1	0.333	0.218	0.020	0.019	0.018	0.000	0.004	0.009	0.100	0.720	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.276	0.328	0.005	0.001	0.010	0.000	0.000	0.007	0.116	0.742	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3	0.310	0.233	0.002	0.004	0.012	0.000	0.000	0.000	0.075	0.636	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	4	0.282	0.108	0.000	0.001	0.009	0.000	0.000	0.000	0.026	0.426	0.000	0.000	0.000	0.000	0.000	0.000	0.000
37 Transportation	1	0.330	0.242	0.101	0.053	0.007	0.002	0.000	0.014	0.080	0.828	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.245	0.233	0.008	0.005	0.006	0.003	0.023	0.014	0.047	0.583	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3	0.276	0.190	0.016	0.008	0.007	0.000	0.000	0.013	0.028	0.539	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	4	0.244	0.138	0.001	0.003	0.003	0.000	0.000	0.007	0.015	0.412	0.000	0.000	0.000	0.000	0.000	0.022	0.022
38 Instruments	1	0.445	0.174	0.022	0.024	0.001	0.000	0.000	0.037	0.174	0.876	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.631	0.428	0.004	0.005	0.003	0.000	0.000	0.000	0.062	1.132	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3	0.732	0.304	0.001	0.004	0.004	0.000	0.000	0.000	0.043	1.088	0.000	0.000	0.000	0.000	0.000	0.031	0.031
	4	0.634	0.247	0.000	0.001	0.000	0.000	0.000	0.053	0.032	0.967	0.000	0.000	0.000	0.000	0.000	0.000	0.000
39 Misc. Mfg.	1	0.252	0.508	0.018	0.034	0.013	0.000	0.000	0.001	0.088	0.913	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	2	0.386	0.460	0.000	0.020	0.000	0.000	0.000	0.000	0.060	0.926	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	3	0.753	0.000	0.007	0.003	0.052	0.000	0.000	0.075	0.017	0.907	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	4	0.185	0.112	0.000	0.000	0.000	0.000	0.000	0.000	0.011	0.308	0.000	0.000	0.000	0.000	0.000	0.000	0.000

Table E-3. Food and Kindred Product Industry End-Use Flow (Trillion Btu/Billion 1987$ Output)

End-Use Flows	Elec	Nat Gas	Resid	Dist	Other Petro.	LPG	Coal+Coke	Steam	Byproduct
Direct Heating	0.0	0.373	0.017	0.018	0.022	0.005	0.023	0.0	0.030
Hot Water & Steam	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.236	0.0
Refrig & Freezing	0.081	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Electric	0.392	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Source: [31].

Table E-4. Pulp and Paper Industry UEC (Energy Use/Ton of Pulp)

Process Step	Flow MMTons	Elec Kwh/ton	Nat Gas MMBtu/ton	Distillate MMBtu/ton	Resid MMBtu/ton	Other Petro. MMBtu/ton	LPG MMBtu/ton	Coal MMBtu/ton	Steam MMBtu/ton	Wood MMBtu/ton	Pulping Liquor MMBtu/ton
Wood Preparation	58.0	117.23	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.92	0.0
Pulping											
Waste Fibers	17.95	351.70	0.0	0.0	0.0	0.0	0.0	0.0	1.6	0.0	0.0
Mechanical	7.5	1494.0	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.0	0.0
Semi-Mechanical	4.1	410.0	0.0	0.0	0.0	0.0	0.0	0.0	6.0	0.0	0.0
Kraft	46.5	410.0	1.194	0.02	0.174	0.029	0.041	0.005	12.8	0.039	17.98
Bleaching	33.64	87.92	0.0	0.0	0.0	0.0	0.0	0.0	6.4	0.0	0.0
Papermaking, Converting, and Misc.	76.0	468.93	0.318	0.005	0.46	0.008	0.011	0.001	7.5	0.010	0.0

Source: [31].

Table E-5. Bulk Chemical Industry End-Use Flow (Trillion Btu/Billion 1987$ Output)

End-Use Flows	Elec	Nat Gas	Resid	Dist	Other Petro.	LPG	Coal	Steam
Electrolytic/Electrothermal Use	1.166	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Other Electricity Use	3.616	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Direct Fuel Use	0.0	4.281	0.301	0.039	0.105	0.009	0.026	0.0
Steam Use	0.0	0.0	0.0	0.0	0.0	0.0	0.0	6.391

Source: [31].

Table E-6. Glass and Glass Product Industry UEC (Energy Use/Ton of Product)

Process Step	Elec Kwh/ton	Nat Gas MMBtu/ton	Resid MMBtu/ton	Dist MMBtu/ton	Other Petro. MMBtu/ton	Coal MMBtu/ton
Batch Preparation	61.547	0.0	0.0	0.0	0.0	0.0
Melting/Refining	52.755	8.371	0.192	0.624	0.086	0.326
Forming	342.907	0.480	0.011	0.036	0.005	0.019
Post-Forming	26.377	2.040	0.047	0.152	0.021	0.080

Source: [31].

Table E-7. Hydraulic Cement Industry UEC (Energy Use/Ton of Product)

Process Step	Elec Kwh/ton	Nat Gas MMBtu/ton	Resid MMBtu/ton	Dist MMBtu/ton	Other Petro. MMBtu/ton	Coal MMBtu/ton
Portland Cement						
Wet Process	216.882	1.376	0.037	0.207	1.051	4.729
Dry Process	190.504	0.949	0.026	0.143	0.724	3.259
Finish Grinding	67.409	0.0	0.0	0.0	0.0	0.0

Source: [31].

Table E-8. Blast Furnace and Basic Steel Products Industry UEC (Energy Use/Ton of Product)

Unit Process	Flow MMtons	Electricity	Steam	Coal	Coke	Natural Gas(1)	Fuel Oil(1)	Waste Gases (2)	Misc.(3)
Coke Ovens	28.9	0.10	0.80	38.6		0.26	0.01	-2.76	-3.78
Iron and Steel Making (4)									
Open Hearth/Blast Furnace	5.1	0.11	0.77	0.06		4.50	1.79	-1.34	0.10
Blast Furnace/BOF	57.9	0.20	1.28	0.91	11.90	0.85	0.31	-2.25	-0.05
Electric Arc Furnace	36.9	2.13	0.00	0.00		0.00	0.00	0.00	0.00
Casting/Primary Breakdown									
Continuous Casting	57.6	0.09	0.01	0.00		0.30	0.00	0.00	0.00
Ingot Casting/Primary Rolling	37.3	0.11	0.03	0.00		1.66	0.00	0.09	0.00
Hot Rolling	83.8	0.35	0.02	0.00		2.50	0.02	0.09	0.00
Cold Rolling and Finishing	29.2	0.79	1.61	0.00		1.75	0.05	0.44	0.00

Note: Natural gas makes up 93% of purchased gas and liquid fuels.

(1) Purchased natural gas and liquid fuels.
(2) Net waste gas use: input-output.
(3) Includes tar and pitch, light oils, and coke breeze.
(4) Energy values for coke accounted for by coal used in coke ovens.

Source: [31].

Table E-9. Primary Aluminum Industry UEC (Energy Use/Ton of Product)

Process Step	Elec Kwh/ton	Nat Gas MMBtu/ton	Other Petro. MMBtu/ton	Coal MMBtu/ton
Aluminum Smelting	15,457.209	3.546	2.054	0.370

Source: [31].

Table E-10. BSC Fuel Component Shares

SIC	Industry	Census Region	Ngas	Resid	Dist	Liq Gas	Coal	Coke&Br	Total Other		Total Consump.
20	Food	1	0.556	0.151	0.133	0.010	0.102	0.000	0.047	0.000	1.000
		2	0.531	0.038	0.011	0.006	0.381	0.000	0.033	0.000	1.000
		3	0.583	0.080	0.068	0.000	0.110	0.000	0.160	0.000	1.000
		4	0.474	0.076	0.039	0.029	0.135	0.000	0.247	0.000	1.000
21	Tobacco	1	0.075	0.054	0.025	0.000	0.846	0.000	0.000	0.000	1.000
		2	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		3	0.075	0.054	0.025	0.000	0.846	0.000	0.000	0.000	1.000
		4	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
22	Textile	1	0.461	0.361	0.060	0.031	0.038	0.000	0.048	0.000	1.000
		2	0.979	0.003	0.004	0.014	0.000	0.000	0.000	0.000	1.000
		3	0.508	0.086	0.028	0.010	0.333	0.000	0.035	0.000	1.000
		4	0.982	0.000	0.013	0.006	0.000	0.000	0.000	0.000	1.000
23	Apparel	1	0.551	0.225	0.216	0.005	0.000	0.000	0.003	0.000	1.000
		2	0.782	0.000	0.061	0.051	0.097	0.000	0.009	0.000	1.000
		3	0.515	0.030	0.042	0.085	0.237	0.000	0.092	0.000	1.000
		4	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
24	Lumber	1	0.502	0.018	0.335	0.051	0.000	0.000	0.094	0.000	1.000
		2	0.498	0.018	0.154	0.149	0.101	0.000	0.079	0.000	1.000
		3	0.435	0.007	0.181	0.044	0.038	0.000	0.295	0.000	1.000
		4	0.336	0.007	0.222	0.040	0.000	0.000	0.396	0.000	1.000
25	Furniture	1	0.341	0.147	0.200	0.054	0.000	0.000	0.013	0.245	1.000
		2	0.517	0.012	0.079	0.043	0.178	0.000	0.009	0.163	1.000
		3	0.114	0.029	0.099	0.045	0.119	0.000	0.030	0.564	1.000
		4	0.000	0.000	0.000	0.089	0.000	0.000	0.046	0.865	1.000
26	Paper	1	0.187	0.634	0.027	0.000	0.127	0.000	0.025	0.000	1.000
		2	0.333	0.039	0.010	0.000	0.606	0.000	0.013	0.000	1.000
		3	0.388	0.138	0.011	0.000	0.408	0.000	0.055	0.000	1.000
		4	0.538	0.182	0.009	0.000	0.214	0.000	0.058	0.000	1.000
27	Printing	1	0.527	0.030	0.217	0.000	0.000	0.000	0.226	0.000	1.000
		2	0.940	0.004	0.009	0.000	0.000	0.000	0.047	0.000	1.000
		3	0.820	0.047	0.027	0.000	0.000	0.000	0.106	0.000	1.000
		4	0.967	0.000	0.033	0.000	0.000	0.000	0.000	0.000	1.000

Table E-10. BSC Fuel Component Shares, cont.

SIC	Industry	Census Region	Ngas	Resid	Dist	Liq Gas	Coal	Coke&Br	Total Other		Total Consump.
281,282 286,287	Bulk Chem	1	0.401	0.305	0.041	0.002	0.053	0.000	0.187	0.012	1.000
		2	0.501	0.064	0.003	0.000	0.392	0.000	0.037	0.002	1.000
		3	0.659	0.023	0.002	0.002	0.148	0.002	0.153	0.010	1.000
		4	0.823	0.016	0.009	0.002	0.093	0.000	0.054	0.003	1.000
283,284 285,289	OtherChem	1	0.332	0.306	0.125	0.000	0.108	0.000	0.087	0.042	1.000
		2	0.315	0.049	0.008	0.000	0.609	0.000	0.013	0.006	1.000
		3	0.553	0.023	0.007	0.000	0.309	0.000	0.072	0.035	1.000
		4	0.716	0.017	0.027	0.000	0.201	0.000	0.026	0.013	1.000
295,299	Asph, Coal & Misc	1	0.068	0.126	0.000	0.000	0.283	0.000	0.523	0.000	1.000
		2	0.085	0.065	0.000	0.000	0.259	0.000	0.590	0.000	1.000
		3	0.263	0.006	0.000	0.000	0.067	0.000	0.664	0.000	1.000
		4	0.118	0.055	0.000	0.000	0.000	0.000	0.827	0.000	1.000
30	Rubber	1	0.468	0.177	0.099	0.001	0.218	0.000	0.022	0.016	1.000
		2	0.849	0.068	0.007	0.002	0.058	0.000	0.010	0.006	1.000
		3	0.691	0.193	0.019	0.000	0.064	0.000	0.019	0.013	1.000
		4	0.938	0.044	0.017	0.001	0.000	0.000	0.000	0.000	1.000
31	Leather	1	0.209	0.537	0.108	0.000	0.146	0.000	0.000	0.000	1.000
		2	0.463	0.340	0.088	0.000	0.091	0.000	0.017	0.000	1.000
		3	0.000	0.509	0.166	0.000	0.000	0.000	0.325	0.000	1.000
		4	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000
321,322 323	Glass&Glass Prods.	1	0.692	0.112	0.047	0.000	0.145	0.000	0.004	0.000	1.000
		2	0.612	0.004	0.042	0.000	0.333	0.000	0.009	0.000	1.000
		3	0.678	0.058	0.048	0.000	0.212	0.000	0.004	0.000	1.000
		4	0.612	0.017	0.039	0.000	0.326	0.000	0.006	0.000	1.000
324	Hydraulic Cement	1	0.150	0.049	0.063	0.000	0.738	0.000	0.000	0.000	1.000
		2	0.070	0.001	0.030	0.000	0.899	0.000	0.000	0.000	1.000
		3	0.112	0.019	0.050	0.000	0.820	0.000	0.000	0.000	1.000
		4	0.072	0.004	0.029	0.000	0.896	0.000	0.000	0.000	1.000

Table E-10. BSC Fuel Component Shares, cont.

SIC	Industry	Census Region	Ngas	Resid	Dist	Liq Gas	Coal	Coke&Br	Total Other		Total Consump.
325,326 327,328 329	Other SCG	1	0.744	0.079	0.039	0.000	0.131	0.000	0.007	0.000	1.000
		2	0.651	0.003	0.034	0.000	0.297	0.000	0.015	0.000	1.000
		3	0.722	0.041	0.040	0.000	0.190	0.000	0.007	0.000	1.000
		4	0.653	0.012	0.032	0.000	0.293	0.000	0.010	0.000	1.000
331,332	Blast Furn&Basic Steel	1	0.405	0.101	0.074	0.000	0.331	0.057	0.032	0.000	1.000
		2	0.391	0.045	0.023	0.000	0.406	0.104	0.032	0.000	1.000
		3	0.422	0.100	0.037	0.000	0.347	0.068	0.025	0.000	1.000
		4	0.754	0.027	0.143	0.000	0.000	0.050	0.026	0.000	1.000
3334,3341 3353,3354	Primary Aluminum	1	0.897	0.008	0.022	0.000	0.065	0.000	0.009	0.000	1.000
		2	0.898	0.003	0.007	0.000	0.082	0.000	0.009	0.000	1.000
		3	0.909	0.007	0.011	0.000	0.066	0.000	0.006	0.000	1.000
		4	0.970	0.001	0.025	0.000	0.000	0.000	0.004	0.000	1.000
333-336 339	Other Primary Metals	1	0.744	0.062	0.060	0.000	0.105	0.000	0.028	0.000	1.000
		2	0.780	0.030	0.020	0.000	0.140	0.000	0.030	0.000	1.000
		3	0.776	0.062	0.030	0.000	0.110	0.000	0.021	0.000	1.000
		4	0.899	0.011	0.075	0.000	0.000	0.000	0.015	0.000	1.000
34	Fab Metals	1	0.701	0.087	0.136	0.000	0.033	0.000	0.042	0.000	1.000
		2	0.747	0.034	0.017	0.000	0.155	0.000	0.047	0.000	1.000
		3	0.891	0.004	0.034	0.001	0.029	0.000	0.042	0.000	1.000
		4	0.756	0.000	0.025	0.001	0.000	0.000	0.219	0.000	1.000
35	Ind Machinery	1	0.461	0.202	0.228	0.003	0.107	0.000	0.000	0.000	1.000
		2	0.565	0.002	0.037	0.003	0.387	0.000	0.006	0.000	1.000
		3	0.779	0.012	0.152	0.008	0.023	0.000	0.027	0.000	1.000
		4	0.955	0.000	0.013	0.002	0.000	0.000	0.030	0.000	1.000
36	Electronic	1	0.525	0.169	0.225	0.000	0.039	0.000	0.043	0.000	1.000
		2	0.670	0.033	0.010	0.000	0.256	0.000	0.032	0.000	1.000
		3	0.742	0.026	0.063	0.000	0.169	0.000	0.000	0.000	1.000
		4	0.962	0.000	0.038	0.001	0.000	0.000	0.000	0.000	1.000

Table E-10. BSC Fuel Component Shares, cont.

SIC	Industry	Census Region	Ngas	Resid	Dist	Liq Gas	Coal	Coke&Br	Total Other		Total Consump.
37	Transportation	1	0.290	0.304	0.149	0.000	0.235	0.000	0.022	0.000	1.000
		2	0.469	0.042	0.026	0.000	0.427	0.000	0.037	0.000	1.000
		3	0.653	0.137	0.065	0.000	0.085	0.000	0.060	0.000	1.000
		4	0.868	0.014	0.046	0.000	0.011	0.000	0.061	0.000	1.000
38	Instruments	1	0.125	0.151	0.040	0.003	0.676	0.000	0.005	0.000	1.000
		2	0.863	0.071	0.024	0.043	0.000	0.000	0.000	0.000	1.000
		3	0.871	0.021	0.027	0.081	0.000	0.000	0.000	0.000	1.000
		4	0.958	0.000	0.006	0.000	0.000	0.000	0.036	0.000	1.000
39	Misc Mfg	1	0.585	0.110	0.103	0.000	0.201	0.000	0.001	0.000	1.000
		2	0.773	0.000	0.088	0.000	0.139	0.000	0.000	0.000	1.000
		3	0.000	0.238	0.043	0.000	0.000	0.000	0.719	0.000	1.000
		4	1.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	1.000

Source: [30].

Table E-11. Boiler Fuel Share Elasticities

	Petroleum	Natural Gas	Steam Coal
Petroleum	-0.33	0.05	0.17
Natural Gas	0.04	-0.47	0.00
Steam Coal	0.63	0.00	-1.01

Source: [95].

Table E-12. Advanced and State-of-The-Art Technologies

Pulp and Paper

Wood preparation: savings over current technology - 16%
- Whole Tree Debarking/Chipping*
- Chip Screening Equipment*

State-Of-The-Art Technologies (Energy Savings by Process Step)

Chemical Technologies (Kraft, Sulfite):	- Continuous Digesters - Batch Digesters - Radar Displacement Heating - Sunds Defibrator Cold Blow and Extended Delignification - EKONO's White Liquor Impregnation - Anthraquinone Pulping - Alkaline Sulfite Anthraquinone (ASOQ) and Neutral Sulfite Anthraquinone (NSAQ) Pulping - Tampella Recovery System - Advanced Black Liquor Evaporator - Process Controls System
Mechanical and Semi-Mechanical Technologies:	- Pressurized Groundwood (PGW) - PGW-Plus - Thermo-Refiner Mechanical Pulping - Heat Recovery in TMP* - Cyclotherm System for Heat Recovery* - Chemimechanical Pulping - Chemi-Thermomechanical Pulping (CTMP) - Process Control System
Semi-Chemical Technologies:	- See Chemical and Mechanical S-O-A technologies above
Waste Paper Pulping Technologies:	- Advanced pulping - Advanced De-inking

Bleaching Oxygen Predelignification Technologies:	- Oxygen Bleaching - Displacement Bleaching - Bio-bleaching
Papermaking Technologies:	- Extended Nip Press* - Hot Pressing - IR Moisture Profiling* - Reduced Air Requirement* - Waste Heat Recovery* - Process Control System*

* Potential for retrofit

Advanced Technologies

Wood Preparation:	Total Savings Over Average S-O-A technologies are foreseen to be modest. Most of the energy savings that can be achieved in the future are in the use of computer control, more efficient electric motors/drives, etc. Assume REI's to decrease by 0.5% per year.
Chemical (Kraft/Sulfite) Technologies:	Technology Introduction: 2005-2015 - Non-Sulfur Chemimechanical (NSCM) Pulping - Advanced Alcohol Pulping - Biological Pulping - Ontario Paper Co (OPCO) Process - Black Liquor Concentration* - Black Liquor Heat Recovery* - Black Liquor Gasification*
Mechanical Technologies:	Technology Introduction: 2005-2015 - Advanced Chemical/Thermal Treatment - Non-sulfur Chemimechanical (NSCM) - OPCO Process
Semi-Chemical Technologies:	Technology Introduction: 2005-2015

- OPCO Process
- NSCM Process
- Waste Pulping - Improvements in steam use, computer control, etc., assumed to decrease REI by 0.2% per year

Bleaching Technologies:

Technology Introduction: 2005-2015
- Ozone Bleaching
- NO_2/O_2 Bleaching
- Biobleaching

Papermaking Technologies:

Technology Introduction: 2005-2015
- High-Consistency Forming*
- Advances in Wet Pressing·
- Press Drying*
- Impulse Drying*
- Air Radio-Frequency-Assisted (ARFA) Drying*

* Potential for retrofit

Glass and Glass Product Industry

State-Of-The-Art Technologies (Energy Savings by Process Step)

Batch Preparation Technologies:

- Computerized Weighing, Mixing, and Charging

Melting/Refining Technologies:

Total savings over average currer technologies: 21-27%
- Chemical Boosting
- Oxygen Enriched Combustion Air*
- Automatic Tap Charging Transformers for Electric Melters
- Sealed-in Burner Systems*
- Dual-Depth Melter
- Chimney Block Regenerator

Refractories
- Reduction of Regenerator Air Leakage*
- Recuperative Burners*

Forming
Post Forming
Technologies:

- Emhart Type 540 Forehearth
- EH-F 400 Series Forehearth
- Forehearth High-Pressure Gas Firing System
- Lightweighting*

* Potential for retrofit

Advanced Technologies

Batch Preparation Technologies:

No advanced technologies identified

Melting/Refining Technologies:

Technology Introduction: 1995-2010
- Direct Coal Firing
- Submerged Burner Combustion
- Coal-Fired Hot Gas Generation*
- Advanced Glass Melter
- Batch Liquefaction
- Molybdenum-Lined Electric Melter
- Ultrasonic Bath Agitation/Refining*
- Excess Heat Extraction from Regenerators
- Thermochemical Recuperator
- Sol-Gel Process
- Furnace Insulation Materials*
- Pressure Swing Adsorption Oxygen Generator*
- Hollow Fiber Membrane Air Separation Process*

* Potential for retrofit

Forming
Post-Forming

Technology Introduction: 1995-2010
- Mold Design*
- Mold Cooling Systems
- Automatic Gob Control
- Improved Glass Strengthening Techniques*
- Improved Protective Coatings*

* Potential for retrofit

Hydraulic Cement Industry

State-Of-The-Art Technologies **(Energy Savings by Process Step)**

Dry Process Technologies:

- Roller Mills*
- High-Efficiency Classifiers*
- Grinding Media and Mill Linings*
- Waste Heat Drying*
- Kiln Feed Slurry Dewatering*
- Dry-Preheater/Precalciner Kilns
- Kiln Radiation and Infiltration Losses*
- Kiln Internal Efficiency Enhancement*
- Waste Fuels*
- Controlled Particle Size Distribution Cement
- High-Pressure Roller Press
- Finish Mill Internals, Configuration, and Operation
- Grinding Aids*

Imports - Finish Grinding Technologies:

- High-Efficiency Classifiers*
- Controlled Particle Size Distribution Cement*
- High Pressure Roller Press
- Roller Mills*
- Finish Mill Internals, Configuration, and Operation
- Grinding Aids*

* Potential for retrofit

Advanced Technologies

Dry Process Technologies:	Technology Introduction: 1997-2013 - Autogenous Mills - Differential Grinding - Sensors and Controls* - Fluidized-Bed Drying - Stationary Clinkering Systems - All-Electric Kilns - Sensors for On-Line Analysis* - Advanced Kiln Control* - Catalyzed, Low-Temperature Calcination - Alkali Specification Modification* - Cone Crushers* - Advanced (Non-Mechanical) Comminution - Modifying Fineness Specifications* - Blended Cements* - Advanced Waste Combustion
Imports - Finish Grinding	Technology Introduction: 1997-2013 - Sensors and Controls* - Cone Crushers* - Advanced (Non-Mechanical) Comminution - Modifying Fineness Specifications* - Blended Cements*

* Potential for retrofit

Iron and Steel Industry

State-Of-The-Art Technologies	**(Energy Savings by Process Step)**
Cokemaking Technologies:	- Dry Quenching of Coke* - Carbonization Control

- Programmed Heating
- Wet Quenching of Coke with Energy Recovery*
- Sensible Heat Recovery of Off-Gases*

Ironmaking Technologies:

Blast Furnace
- Coal Injection*
- Water-Cooling
- Movable Throat Armor*
- Top Gas Pressure Recovery*
- Hot Stove Waste Heat Recovery*
- Insulation of Cold Blast Main*
- Recovery of BF Gas Released During Charging
- Slag Waste Heat Recovery*
- Paul Wurth Top*
- External Desulfurization - injection of calcium carbide or mag-coke as a desulfurizing reagent*
- Midrex/HBI

Steelmaking Technologies:

Basic Oxygen Furnace
- Gas Recovery in Combination with Sensible Heat Recovery*
- Two working vessels concept*
- Combined Top and Bottom Oxygen Blowing*
- In-Process Control (Dynamic) of Temp and Carbon Content*

Electric Arc Furnace
- DC Arc Furnaces*
- Ultra-High Power (UHP)*
- Computerization*
- Bottom Tap Vessels*
- Water-Cooled Furnace Panels and Top*
- Water-Cooled Electrode Sections*
- Oxy-Fuel Burners*
- Long Arc Foamy Slag Practice*
- Material Handling Practices*

Induction Furnaces*

Energy Optimizing Furnaces*

Scrap-Preheating*

Ladle Drying and Preheating*

Injection Steelmaking (ladle metallurgy)
- Vacuum Arc Decarburization*
- Argon Stirring*

Specialty Steelmaking Processes
- Electroslag Remelting (ESR)*
- Argon-Oxygen Decarburization (AOD)*
- Vacuum Induction Melting (VIM)*
- Electron Beam Melting (EBM)*
- Vacuum Arc Remelting (VAR)*

Steelcasting Technologies:

- Modern Casters*
- Thin Slab Casting
- Slab Heat Recovery*
- Soaking Pit Utilization and Pit Vacant Time*

Steelforming (rolling) Technologies:

Hot charging

Preheating Furnaces
- Improved Insulation*
- Waste Heat Recovery and Air Preheating*
- Waste Heat Recovery and Fuel Gas Preheating*
- Increased Length of the Preheating Furnace
- Waste Heat Boilers
- Evaporative Cooling of Furnace Skids

Direct Rolling
- Leveling Furnace*

- The Coil Box*
- Covered Delay Table*

Pickling - Insulated Floats*

Annealing
- Air Preheating*
- Fuel Gas Preheating*
- Combustion Control*

Continuous Annealing

Continuous Cold Rolling

* Potential for retrofit

Advanced Technologies

Ironmaking Technologies:	- PLASMARED - COREX - Direct Iron Ore Smelting (AISI) - HiSmelt - Fastmet - Iron Carbode Route - KR Process - Iron ore reduction/steelmaking (AISI)
Direct Steelmaking Technologies:	PLASMAMELT INRED ELRED Foster Wheeler - Tetronics Expand Processive Plasma Process
Steelmaking Technologies:	- Scrap Preheating* - Energy Optimizing Furnace (EOF)

- Modern Electric Arc Furnace with Continuous Charging/Scrap Preheating
- Modern Basic Oxygen Furnace
  - Injection of Carbonaceous Fuels
  - Increased Scrap Use
- Ladle Drying and Preheating*
- Injection Steelmaking

Steelcasting Technologies:

- Horizontal Continuous Caster*
- Near Net Shapecasting*
- Direct Strip Casting*
- Ultra Thin Strip Casting*
- Spray Casting

Hot/Cold Rolling:

- Direct Rolling
- Continuous Cold Rolling and Finishing
- In Line Melting/Rolling
- Advanced Coating

*Potential for retrofit

NOTE: Many advanced technologies in the Blast Furnace and Basic Steel Products Industry are more energy intensive than their predecessors. Thus it is expected that these new technologies will not fully replace the old ones, but rather provide enhancement particularly for high quality steels. Other advantages include accelerated reaction rates, reduced reactor volume and residence time, lower capital investment, and higher scrap use.

Primary Aluminum Industry

State-Of-The-Art Technologies (Energy Savings by Process Step)

Alumina Refining Technologies:

- Advanced Digesters
- Heat Recovery*

Primary Aluminum Technologies

- Advanced Cells
- New Cathodes*

Semi-Fabrication Technologies

- Continuous-Strip Casting
- Electromagnetic Casting

Secondary Aluminum Technologies:	- Induction Melting - Advanced Melting

* Potential for retrofit

Advanced Technologies

Alumina Refining Technologies:	- Retrofit of S-O-A technologies*
Primary Aluminum Technologies:	Technology Introduction: 2003-2023 - Carbothermic Reduction - Inert Anodes (potential for retrofit)* - Bipolar Cell Technology - Wettable Cathodes*
Semi-Fabrication Technologies:	Technology Introduction: 1995-2010 - New Melting Technology* - Preheaters*
Secondary Aluminum Technologies:	Technology Introduction: 1995-2010 - New Melting Technology (submerged radiant burners) - Preheaters* - Heat Recovery Technology

* Potential for retrofit

Table E-13. Coefficients for Technology Possibility Curves

SIC	Industry	Process Unit	REI Old Plant lnREIo	Old Plant REIo	Old Plant a = (slope)	REI New Plant lnREIo	New Plant REIo	New Plant a = (slope)
			... GENERIC END USES OF ENERGY ------					
20	Food*	Direct Fuel	0	1	-0.00401	-0.10432	0.90094	-0.00436
		Steam	0	1	-0.00301	-0.10432	0.90094	-0.00436
		Electric	0	1	-0.00201	-0.10432	0.90094	-0.00436
281	Inorganic Chemicals*	Direct Fuel	0	1	-0.00401	-0.10432	0.90094	-0.00436
		Steam	0	1	-0.00301	-0.10432	0.90094	-0.00436
		Electric	0	1	-0.00201	-0.10432	0.90094	-0.00436
		Electrolytic	0	1	-0.00075	-0.0503	0.95094	-0.00412
282	Plastics*	Direct Fuel	0	1	-0.00401	-0.10432	0.90094	-0.00436
		Steam	0	1	-0.00301	-0.10432	0.90094	-0.00436
		Electric	0	1	-0.00201	-0.10432	0.90094	-0.00436
286	Organic Chemicals*	Direct Fuel	0	1	-0.00401	-0.10432	0.90094	-0.00436
		Steam	0	1	-0.00301	-0.10432	0.90094	-0.00436
		Electric	0	1	-0.00201	-0.10432	0.90094	-0.00436
287	Agricultural Chemicals*	Direct Fuel	0	1	-0.00401	-0.10432	0.90094	-0.00436
		Steam	0	1	-0.00301	-0.10432	0.90094	-0.00436
		Electric	0	1	-0.00201	-0.10432	0.90094	-0.00436

Table E-13. Coefficients for Technology Possibility Curves, cont.

SIC	Industry	Process Unit	REI Old Plant lnREIo	Old Plant REIo	Old Plant a = (slope)	REI New Plant lnREIo	New Plant REIo	New Plant a = (slope)
26	Pulp/Paper	Wood Preparation	0	1	-0.00305	-0.17271	0.84138	-0.0052
		Waste Pulping	0	1	-0.00131	-0.07243	0.93013	-0.00204
		Mechanical Pulping	0	1	-0.00305	-0.16882	0.84466	-0.00076
		Semi Chemical Pulping	0	1	-0.0059	-0.32906	0.7196	-0.00378
		Kraft Sulfite	0	1	-0.00611	-0.32597	0.72183	-0.00616
		Bleaching	0	1	-0.00486	-0.26365	0.76824	-0.00329
		Paper Making	0	1	-0.00654	-0.36191	0.69635	0.00527
32	Glass	Batch Preparation	0	1	-0.00102	-0.12556	0.882	0
		Melting/Refining	0	1	-0.00528	-0.16481	0.84805	-0.02535
		Forming	0	1	-0.00255	-0.20649	0.81343	-0.00404
		Post-Forming	0	1	-0.00259	-0.24747	0.78077	-0.00112
32	Cement	Dry Process	0	1	-0.00528	-0.4716	0.624	-0.00834
		Wet Process	0	1	-0.00244	NA	NA	NA
		Finish Grinding	0	1	-0.00528	-0.1764	0.83828	-0.01097
33	Iron/Steel	Coke Oven	0	1	0	-0.17429	0.84005	-0.00116
		BF/OH	0	1	0	NA	NA	NA
		BF/BOF(1)	0	1	0	0	1.0	0
		EAF	0	1	0	0	1.0	0
		Ingot Cast/Primary Roll	0	1	0	0	1	0
		Cont Casting	0	1	0	0	1	0
		Hot Rolling	0	1	-0.01774	-0.61941	0.53826	-0.03863
		Cold Rolling	0	1	-0.00675	-0.164	0.84	-0.00837
33	Aluminum	Alumina Refinery	0	1	-0.00472	-0.10514	0.9002	-0.00163
		Primary Aluminum	0	1	-0.00688	-0.05417	0.89996	-0.0094
		Semi-Fabrication	0	1	-0.01259	-0.46282	0.62951	-0.00794
		Secondary Aluminum	0	1	-0.01442	-0.42486	0.65386	-0.01589

Table E-14. Changes in Fractional Energy Shares

	Old Plant		New Plant	
	1988	2015	1988	2015
CEMENT				
- wet process: electric	0.11	0.11	NA	NA
- wet process: direct fuels (1)	0.89	0.89	NA	NA
- dry process: electric	0.09	0.09	0.17	0.21
- dry process: direct fuels (1)	0.91	0.91	0.83	0.79
IRON AND STEEL				
- EAF: electric	1.0	0.72	0.96	0.44
- EAF: direct fuels (2)	0	0.28	0.04	0.56
- Cold Rolling: electric	0.17	0.17	0.20	0.21
- Cold Rolling: steam	0.35	0.35	0.41	0.47
- Cold Rolling: direct	0.48	0.48	0.39	0.32
- Iron and Steel Making (BF/BOF): electric	0.01	0.01	0.02	0.02
- Iron and Steel Making (BF/BOF): steam	0.08	0.08	(3)	(3)
- Iron and Steel Making (BF/BOF): natural gas	0.06	0.26	0.09	0.09
- Iron and Steel Making (BF/BOF): steam coal	0.06	0.06	0.07	0.36
- Iron and Steel Making (BF/BOF): coke	0.77	0.57	0	0.53
- Iron and Steel Making (BF/BOF): fuel oil	0.02	0.02	0.82	0
OTHER SECTORS	(4)		(5)	(5)

(1) Predominantly coal
(2) Predominantly natural gas
(3) Blast Furnace/Basic Oxygen Furnace (BF/BOF)
and future new iron/steelmaking technologies; see Table M-2
(4) See UEC's in Section 5 to develop fractional energy shares
(5) Fractional energy shares, as a first approximation, remain unchanged (b=0)
Source: [31].

Table E-15. Non-energy-Intensive Industry UEC Regressions

(Data is located in Table E-22)

Agriculture - Crops (Natural Gas)

$$\begin{array}{lrrl} UECNATGS = & 1.113 & - 0.727 \; x \; RPGAS58 & \\ Std.Err. & (0.043) & (0.059) & \\ T\text{-}Statistic & 25.764 & -12.230 & \\ & & Adj.\ R^2 = 0.846 & \end{array} \qquad \text{(E-1)}$$

Agriculture - Other (Natural Gas)

$$\begin{array}{lrrr} UECNATGS = & -3.247 & - 2.774 \; x \; RPOIL58 & + 0.948 \; x \; RPGAS58 \\ Std.Err. & (0.075) & (0.427) & (0.110) \\ T\text{-}Statistic & -43.464 & -6.499 & 8.606 \\ & & Adj.\ R^2 = 0.739 & \end{array} \qquad \text{(E-2)}$$

Coal Mining (Natural Gas)

$$\begin{array}{lrrr} UECNATGS = & -2.600 & - 0.657 \; x \; RPGAS58 & + 0.832 \; x \; CURTAIL \\ Std.Err. & (0.058) & (0.107) & (0.301) \\ T\text{-}Statistic & -45.075 & -6.167 & 2.765 \\ & & Adj.\ R^2 = 0.587 & \end{array} \qquad \text{(E-3)}$$

Tobacco (Oil)

$$\begin{array}{lrrr} UECOIL = & -2.498 & - 1.229 \; x \; RPELEC58 & + 2.276 \; x \; CURTAIL \\ Std.Err. & (0.066) & (0.239) & (0.306) \\ T\text{-}Statistic & -37.993 & -5.155 & 7.428 \\ & & Adj.\ R^2 = 0.720 & \end{array} \qquad \text{(E-4)}$$

Textiles (Oil)

$$UECOIL = 0.630 - 0.741 \times RPOIL58 + 1.881 \times CURTAIL \quad \text{(E-5)}$$

Std.Err.	(0.065)	(0.104)	(0.380)
T-Statistic	9.714	-7.138	4.946

Adj. $R^2 = 0.658$

Textiles (Natural Gas)

$$UECNATGS = 0.286 + 0.757 \times RPOIL58 - 1.024 \times RPGAS58 + 0.233 \times RCUMOUT - 0.840 \times CURTAIL \quad \text{(E-6)}$$

Std.Err.	(0.057)	(0.133)	(0.131)	(0.026)	(0.162)
T-Statistic	4.993	5.711	-7.800	9.063	-5.174

Adj. $R^2 = 0.823$

Textiles (Electricity)

$$UECELEC = 0.261 + 0.157 \times RPOIL58 - 0.504 \times RPELEC58 + 0.073 \times RCUMOUT + 0.225 \times CURTAIL \quad \text{(E-7)}$$

Std.Err.	(0.036)	(0.051)	(0.091)	(0.018)	(0.079)
T-Statistic	7.340	3.076	-5.545	4.108	2.832

Adj. $R^2 = 0.843$

Apparel (Oil)

$$UECOIL = -1.578 - 0.593 \times RPOIL58 - 0.518 \times RPELEC58 \quad \text{(E-8)}$$

Std.Err.	(0.082)	(0.101)	(0.213)
T-Statistic	-19.141	-5.868	-2.439

Adj. $R^2 = 0.642$

Apparel (Electricity)

$$UECELEC = -1.668 + 0.154 \times RPOIL58 - 0.790 \times RPELEC58 + 0.075 \times RCUMOUT \quad \text{(E-9)}$$

Std.Err.	(0.033)	(0.038)	(0.055)	(0.018)
T-Statistic	-50.599	4.090	-14.262	4.212

Adj. R^2 = 0.951

Apparel (Coal)

$$UECCOAL = -1.438 - 1.721 \times RPGAS58 + 2.238 \times RPELEC58 - 0.611 \times RPCOAL58 \quad \text{(E-10)}$$

Std.Err.	(0.119)	(0.288)	(0.316)	(0.299)
T-Statistic	-12.094	-5.973	7.081	-2.043

Adj. R^2 = 0.918

Lumber (Electricity)

$$UECELEC = -0.731 + 0.628 \times RPGAS58 - 1.508 \times RPELEC58 \quad \text{(E-11)}$$

Std.Err.	(0.029)	(*Hx038*)	(0.088)
T-Statistic	-25.543	16.663	-17.149

Adj. R^2 = 0.935

Furniture (Oil)

$$UECOIL = -1.031 + 0.776 \times RPOIL58 - 1.509 \times RPGAS58 \quad \text{(E-12)}$$

Std.Err.	(0.044)	(0.199)	(0.241)
T-Statistic	-23.190	3.888	-6.253

Adj. R^2 = 0.688

Furniture (Electricity)

$$UECELEC = -1.128 - 0.352 \times RPELEC58 + 0.254 \times RPCOAL58 + 0.077 \times RCUMOUT \quad \text{(E-13)}$$

Std.Err.	(0.048)	(0.067)	(0.053)	(0.019)
T-Statistic	-23.577	-5.233	4.817	4.038

Adj. R^2 = 0.874

Printing (Oil)

$$UECOIL = -1.397 - 0.766 \times RPOIL58 \quad \text{(E-14)}$$

Std.Err.	(0.062)	(0.105)
T-Statistic	-22.502	-7.273

$Adj.\ R^2 = 0.650$

Printing (Electricity)

$$UECELEC = -1.130 + 0.491 \times RPGAS58 - 1.320 \times RPELEC58 + 0.347 \times RPCOAL58 \quad \text{(E-15)}$$

Std.Err.	(0.024)	(0.050)	(0.066)	(0.068)
T-Statistic	-46.622	9.911	-20.002	5.108

$Adj.\ R^2 = 0.965$

Rubber (Electricity)

$$UECELEC = -0.034 + 0.387 \times RPGAS58 - 0.525 \times RPELEC58 \quad \text{(E-16)}$$

Std.Err.	(0.025)	(0.034)	(0.092)
T-Statistic	-1.371	11.400	-5.700

$Adj.\ R^2\ Hx0.826$

Leather (Oil)

$$UECOIL = -0.515 - 0.215 \times RPOIL58 - 0.441 \times RPELEC58 \quad \text{(E-17)}$$

Std.Err.	(0.031)	(0.032)	(0.087)
T-Statistic	-16.472	-6.777	-5.086

$Adj.\ R^2 = 0.760$

Leather (Coal)

$$\begin{array}{lllll} UECCOAL = & 0.283 & -\ 2.357\ x\ RPGAS58 & +\ 2.733\ x\ RPELEC58 & -\ 0.568\ x\ RPCOAL58 \\ Std.Err. & (0.104) & (0.228) & (0.260) & (0.408) \\ T\text{-}Statistic & 2.717 & -10.338 & 10.495 & -1.392 \\ & & Adj.\ R^2 = 0.945 & & \end{array} \qquad \textbf{(E-18)}$$

Other Stone, Clay, and Glass (Natural Gas)

$$\begin{array}{llll} UECNATGS = & 2.235 & -\ 0.384\ x\ RPGAS58 & +\ 0.337\ x\ RPELEC58 \\ Std.Err. & (0.043) & (0.061) & (0.159) \\ T\text{-}Statistic & 51.833 & -6.326 & 2.116 \\ & & Adj.\ R^2 = 0.600 & \end{array} \qquad \textbf{(E-19)}$$

Other Stone, Clay, and Glass (Electricity)

$$\begin{array}{llll} UECELEC = & -0.202 & +\ 0.355\ x\ RPOIL58 & -\ 0.539\ x\ RPELEC58 \\ Std.Err. & (0.036) & (0.054) & (0.154) \\ T\text{-}Statistic & -5.666 & 6.521 & -3.511 \\ & & Adj.\ R^2 = 0.592 & \end{array} \qquad \textbf{(E-20)}$$

Fabricated Metals (Coal)

0

$$\begin{array}{llll} UECCOAL = & -0.725 & -\ 1.299\ x\ RPCOAL58 & -\ 0.330\ x\ RCUMOUT \\ Std.Err. & (0.087) & (0.100) & (0.035) \\ T\text{-}Statistic & -8.319 & -12.996 & -9.520 \\ & & Adj.\ R^2 = 0.970 & \end{array} \qquad \textbf{(E-21)}$$

Industrial Machinery (Oil)

$$\begin{array}{lrr} UECOIL = & -1.010 & -\ 0.944 \times RPOIL58 \\ Std.Err. & (0.084) & (0.139) \\ T\text{-}Statistic & -12.022 & -6.811 \\ & \multicolumn{2}{l}{Adj.\ R^2 = 0.619} \end{array} \tag{E-22}$$

Electronics (Oil)

$$\begin{array}{lrrr} UECOIL = & -0.924 & -\ 1.274 \times RPOIL58 & +\ 1.624 \times CURTAIL \\ Std.Err. & (0.080) & (0.137) & (0.479) \\ T\text{-}Statistic & -11.578 & -9.306 & 3.387 \\ & \multicolumn{3}{l}{Adj.\ R^2 = 0.752} \end{array} \tag{E-23}$$

Electronics (Coal)

$$\begin{array}{lrrr} UECCOAL = & 0.717 & -\ 0.800 & OUT \\ Std.Err. & (0.188) & (0.060, & \\ T\text{-}Statistic & 3.804 & -13.314 & \\ & \multicolumn{3}{l}{Adj.\ R^2 = 0.867} \end{array} \tag{E-24}$$

Transportation Equipment (Coal)

$$\begin{array}{lrr} UECCOAL = & -0.987 & -\ 1.338 \times RPCOAL58 \\ Std.Err. & (0.066) & (0.163) \\ T\text{-}Statistic & -15.009 & -8.215 \\ & \multicolumn{2}{l}{Adj.\ R^2 = 0.704} \end{array} \tag{E-25}$$

Instruments (Oil)

$$
\begin{array}{lllllll}
UECOIL = & -0.412 & - \; 0.586 \; x \; RPOIL58 & - \; 0.213 \; x \; RCUMOUT & + \; 1.667 \; x \; CURTAIL \\
Std.Err. & (0.176) & (0.149) & (0.065) & (0.363) \\
T\text{-}Statistic & -2.334 & -3.945 & -3.286 & 4.590 \\
 & & Adj.\ R^2 = 0.746 & &
\end{array}
\qquad \text{(E-26)}
$$

Instruments (Natural Gas)

$$
\begin{array}{lllll}
UECNATGS = & -0.566 & - \; 0.374 \; x \; RPGAS58 & + \; 0.049 \; x \; RCUMOUT \\
Std.Err. & (0.062) & (0.067) & (0.023) \\
T\text{-}Statistic & -9.191 & -5.580 & 2.141 \\
 & & Adj.\ R^2 = 0.550 &
\end{array}
\qquad \text{(E-27)}
$$

Miscellaneous Manufacturing (Oil)

$$
\begin{array}{lll}
UECOIL = & -0.526 & - \; 0.948 \; x \; RPOIL58 \\
Std.Err. & (0.079) & (0.131) \\
T\text{-}Statistic & -6.620 & -7.219 \\
Adj.\ R^2 = & 0.646; & D\text{-}W = 0.282
\end{array}
\qquad \text{(E-28)}
$$

Table E-16. Cogeneration Regressions

Generation

$$LNGENK = -2.799 + 0.960 \times LNSTEAM$$
$$\begin{array}{lcc} Std.Err. & (0.325) & (0.081) \\ T\text{-}Statistic & -8.605 & 11.795 \end{array}$$
$$System Weighted\ R^2 = 0.691 \qquad \text{(E-29)}$$

Generation for own use

$$LNOWNK = -1.153 + 1.307 \times LNGENK$$
$$\begin{array}{lcc} Std.Err. & (0.137) & (0.081) \\ T\text{-}Statistic & -8.392 & 16.220 \end{array}$$
$$System\ Weighted\ R^2 = 0.691 \qquad \text{(E-30)}$$

Table E-17. Regional Technology Shares

		Census Region				
Industry	Technology	NE	MW	SO	WE	US
Paper and Allied Products						
	Kraft (incl. Sulfite)	6.0%	5.0%	72.0%	17.0%	100%
	Semi-Chemical	11.0%	30.0%	48.0%	11.0%	100%
	Mechanical	19.0%	14.0%	47.0%	20.0%	100%
	Waste Fiber	18.0%	31.0%	34.0%	17.0%	100%
Hydraulic Cement						
	Wet Process	17.3%	26.6%	43.0%	13.1%	100%
	Dry Process	9.2%	28.9%	35.0%	26.8%	100%
Blast Furnace and Basic Steel Products						
	Electric Arc Furnace	23.6%	36.1%	31.6%	8.7%	100%
	Basic Oxygen Furnace	10.5%	69.5%	20.0%	0.0%	100%
	Open Hearth	34.5%	0.0%	36.2%	29.3%	100%
	Coke Oven	23.9%	50.4%	23.5%	2.1%	100%
Primary Aluminum						
	Smelters	7.0%	15.7%	43.3%	34.1%	100%

Source: [31].

Table E-18. Retirements

Industry	Retirement Rate (%)	Industry	Retirement Rate (%)
Food and Kindred Products	1.7	Blast Furnace and Basic Steel Products (Blast Furnace/Open Hearth)	50.0
Tobacco Products	4.3	Blast Furnace and Basic Steel Products (Blast Furnace/Basic Oxygen Furnace)	0.0
Textile Mill Products	4.6	Blast Furnace and Basic Steel Products (Electric Arc Furnace)	1.5
Apparel and Other Textile Products	1.9	Primary Aluminum	2.1
Lumber and Wood Products	0.7	Other Primary Metals	1.2
Furniture and Fixtures	1.0	Fabricated Metals	2.1
Paper and Allied Products	2.3	Industrial Machinery	2.7
Printing and Publishing	5.4	Electronic Equipment	4.5
Bulk Chemicals	1.9	Transportation Equipment	1.6
Other Chemicals	3.6	Instruments	1.5
Asphalt and Miscellaneous Coal Products	2.2	Miscellaneous Manufacturing	2.3

Source: [94].

Table E-19. Recycling

Sector	Estimate for 1988	Projected for 2015
Paper and Allied Products (waste pulping)	24%	37%
Blast Furnace and Basic Steel Products (scrap melting in electric arc furnace)	37%	50%

Source: [31].

Table E-20. Emission Factors

Fuel Type	Million Metric Tons Carbon per Quadrillion Btu	Proportion of Nonfuel Use (If Any) Sequestered
Petroleum		
Motor Gasoline	19.23	-
LPG	17.09	0.80
Jet Fuel	19.27	-
Distillate Fuel	19.77	-
Residual Fuel	21.44	-
Asphalt and Road	20.83	1.00
Oil	21.00	0.50
Lubricants	19.25	0.80
Petrochemical Feed	19.23	-
Aviation Gas	19.27	-
Kerosene	27.04	1.00
Petroleum Coke	19.23	0.00
Special Naphtha		
Other: Waxes and Miscellaneous	20.83	1.00
Coal		
Anthracite Coal	27.85	0.75
Bituminous Coal	25.12	0.75
Subbituminous Coal	25.98	0.75
Lignite	26.35	0.75
Natural Gas		
Natural Gas	14.39	0.33

Source: [41].

Table E-21. Data Quality References for MECS and EIA-867

A discussion of the data quality of the MECS data can be found in:
Manufacturing Energy Consumption Survey, Consumption of Energy: 1988, Energy Information Administration, Office of Energy Markets and End Use, U.S. Department of Energy, Washington, DC. pp. 151-155.

The data quality assessment on the EIA-867 data can be found in:
Quality Assessment (EIA-867 Annual Non-Utility Power Producer Report), Office of Statistical Standards, Energy Information Administration, U.S. Department of Energy. October, 1991.

Table E-22A. Non-Manufacturing Consumption and Output, 1958-1985

Sources: Consumption: [97]
Output: U.S. Department of Commerce and DRI, Inc.

Notes: All dollar values are expressed in constant 1987 dollars. The deflator is given in Table E-22D. Prices are per million Btu and quantities are trillion Btus. Output is billion dollars.
The mnemonics are as follows: NATGAS and NATGS--Natural Gas; COAL--Coal; MGAS--Motor Gasoline; LPG--Liquid Petroleum Gas; DIST--Distillate; ASPHAL and ASPH--Asphalt and Road Oil; RESID--Residual Fuel Oil; OIL--Other Oil Products; ELEC--Electricity; OUTPUT--Value of Output.

SIC=AGRI PRODUCTION

YEAR	QOIL	QNATGAS	QCOAL	QELEC	QMGAS	QLPG	QDIST	QASPHAL	QRESID	OUTPUT
58	7.3762	102.940	0	28.9716	323.195	7.0795	38.913	0	0	33.1422
59	7.0220	107.138	0	34.3114	316.264	10.9055	43.118	0	0	35.1345
60	7.1948	111.475	0	37.9725	317.889	17.1517	60.842	0	0	37.4119
61	6.9123	115.471	0	39.2486	294.175	23.8586	78.967	0	0	37.2503
62	6.9172	119.730	0	40.5588	288.592	31.2055	94.843	0	0	38.4282
63	6.6358	124.471	0	41.8007	272.451	39.1035	114.190	0	0	40.4324
64	6.3112	129.475	0	42.0976	259.165	46.9446	135.439	0	0	41.3848
65	6.1286	132.285	0	45.7348	256.769	51.3184	157.582	0	0	41.8353
66	5.4019	135.556	0	45.6017	226.408	54.1796	180.230	0	0	43.7362
67	4.9466	133.936	0	47.6933	207.215	57.5245	202.494	0	0	45.5314
68	4.6810	142.425	0	49.9145	201.274	60.7409	215.775	0	0	47.4888
69	4.2532	145.847	0	56.1346	184.952	63.5953	243.403	0	0	50.1269
70	3.7715	149.381	0	59.6285	169.632	64.7653	248.013	0	0	51.9809
71	3.5259	153.050	0	61.9214	158.168	65.5387	279.500	0	0	51.8856
72	3.1484	145.075	0	61.5577	134.524	74.8885	280.852	0	0	56.0432
73	3.7433	152.622	0	65.1086	155.756	81.0004	362.750	0	0	62.0630
74	2.7274	105.025	0	61.7525	104.507	55.3975	300.935	0	0	57.8237
75	3.1313	126.266	0	61.0749	134.889	58.4749	309.046	0	0	56.6367
76	3.1510	152.630	0	63.6322	117.027	69.6237	357.312	0	0	63.5892
77	3.1236	104.264	0	63.0804	119.113	63.2834	367.558	0	0	65.0305
78	3.5215	145.261	0	64.1388	108.567	67.2208	474.159	0	0	66.4719
79	3.4022	108.395	0	76.2524	109.567	69.8584	425.598	0	0	71.3046
80	3.0374	82.560	0	72.1000	92.010	59.4222	392.832	0	0	75.7135
81	2.9803	75.085	0	85.3624	91.562	59.7400	375.700	0	0	71.1351
82	2.7669	88.651	0	72.8230	74.519	62.1087	365.097	0	0	69.9481
83	2.7290	64.866	0	64.3551	68.297	45.1660	379.003	0	0	53.3301
84	2.7307	68.669	0	68.1875	65.776	53.4892	378.325	0	0	66.3871
85	2.6658	49.405	0	65.8861	59.946	50.0875	373.645	0	0	70.5416

Table E-22A. Non-Manufacturing Consumption and Output, 1958-1985

SIC=OTHER AGRICULTURE

YEAR	QOIL	QNATGAS	QCOAL	QELEC	QMGAS	QLPG	QDIST	QASPHAL	QRESID	OUTPUT
58	2.5390	2.4051	0.5593	17.9510	134.011	2.8475	5.7521	0	0.0011	61.522
59	2.5774	2.4991	0.5308	21.1159	139.976	4.5668	6.5582	0	0.0011	65.485
60	2.3905	2.6280	0.5199	22.8723	131.612	6.5775	8.4960	0	0.0011	66.463
61	2.3431	3.0815	0.5952	24.3574	129.767	9.5429	11.1103	0	0.0011	69.785
62	2.3114	3.1558	0.5711	25.1302	129.713	12.5553	13.6226	0	0.0011	71.060
63	2.1268	3.1223	0.5932	25.9175	121.645	15.4466	16.0172	0	0.0011	74.467
64	2.0695	3.2961	0.6027	26.8659	121.862	19.3468	19.3739	0	0.0010	76.547
65	1.8413	3.3628	0.6447	24.8460	111.322	19.4513	20.8024	0	0.0011	75.644
66	1.6836	3.7871	0.7063	28.1647	104.996	21.7993	24.3946	0	0.0012	76.732
67	1.4758	4.0688	0.7061	28.6060	94.830	22.6968	26.6664	0	0.0011	79.113
68	1.3388	3.7757	0.6780	30.5985	90.168	23.3708	28.5081	0	0.0011	79.785
69	1.1801	4.0313	0.7323	30.5875	83.272	24.4278	31.2381	0	0.0010	79.561
70	1.1148	4.3966	0.7729	32.3660	83.130	26.9107	34.1616	0	0.0011	81.885
71	0.9214	4.4839	0.8176	35.3076	71.221	24.8912	35.1845	0	0.0010	84.303
72	0.7864	4.1332	0.8423	30.6845	61.326	28.2334	35.3115	0	0.0011	86.588
73	0.8422	4.0157	0.8283	30.2093	65.908	28.3825	42.2191	0	0.0013	83.230
74	0.6484	3.0504	0.8598	31.5670	50.267	21.9930	39.7646	0	0.0012	83.089
75	0.7068	6.8090	0.8500	33.2835	55.420	22.2972	41.4848	0	0.0012	84.120
76	0.7261	14.2123	0.9037	43.7797	51.214	30.7960	56.8109	0	0.0014	87.922
77	0.7115	13.2863	0.9769	48.8151	48.966	29.7696	63.7933	0	0.0011	90.486
78	0.7949	25.8696	0.9217	59.4818	45.5072	36.0598	96.7911	0	0.0011	91.980
79	0.7107	15.1733	0.9394	60.7632	41.7407	34.5535	70.3390	0	0.0009	91.064
80	0.7007	9.6057	0.9434	61.9278	39.2793	33.6837	72.2651	0	0.0008	91.374
81	0.5566	6.9818	1.0741	56.8581	31.4403	27.3362	53.8553	0	0.0005	94.403
82	0.5066	8.1395	1.0324	48.9354	26.5730	28.0260	52.1715	0	0.0003	95.964
83	0.6432	8.1385	1.0651	58.0019	31.8740	27.9289	71.6385	0	0.0003	97.332
84	0.5236	6.7633	1.0373	49.3414	25.7073	26.2377	57.3603	0	0.0003	98.699
85	0.4866	4.5963	1.1461	45.6705	23.1177	23.3538	53.3602	0	0.0002	100.448

Table E-22A. Non-Manufacturing Consumption and Output, 1958-1985

SIC=COAL MINING

YEAR	QOIL	QNATGAS	QCOAL	QELEC	QMGAS	QLPG	QDIST	QASPHAL	QRESID	OUTPUT
58	0	0.7228	5.6050	16.7736	4.6501	2.4690	14.4013	0	1.7783	13.2922
59	0	0.7765	4.9245	16.7486	4.4388	2.3326	14.1527	0	1.7489	13.2831
60	0	0.8376	4.4300	16.8461	4.2576	2.2080	14.0049	0	1.7309	13.3109
61	0	0.8603	3.6493	16.2630	3.9090	1.9982	13.2967	0	1.6444	12.8115
62	0	0.9560	3.1551	17.0262	3.8804	1.9554	13.6853	0	1.6935	13.3638
63	0	1.0957	2.6669	18.3908	3.9610	1.9628	14.5260	0	1.7991	14.5492
64	0	1.1443	2.6591	16.6692	3.3483	1.5649	13.7212	0	1.6944	13.5340
65	0	1.5066	3.4286	19.3653	3.5924	1.5543	16.6231	0	2.0472	15.9564
66	0	1.7262	3.6785	19.6788	3.3302	1.2982	17.6275	0	2.1661	16.4888
67	0	1.9446	3.9867	19.7877	3.0064	1.0035	18.5103	0	2.2691	17.0395
68	0	1.6654	3.7169	20.7763	3.1375	1.0891	19.9894	0	2.7055	16.7740
69	0	1.4515	3.6375	22.6512	3.4023	1.2231	22.3271	0	3.2661	17.1379
70	0	1.2838	3.6490	25.7678	3.8519	1.4245	25.9377	0	4.0390	18.4311
71	0	0.9224	3.2241	24.8862	3.7042	1.4047	25.5177	0	4.1881	16.8432
72	0	0.7223	3.2544	28.2362	4.1864	1.6244	29.4314	0	5.0465	18.0040
73	0	0.8825	3.4938	28.4981	4.7691	1.4714	32.8729	0	5.4948	17.9126
74	0	1.0802	3.9201	29.4992	5.4833	1.3557	37.2223	0	6.0986	18.2782
75	0	1.3486	4.5482	32.1406	6.5529	1.2956	43.9451	0	7.0734	19.5577
76	0	1.6134	5.0299	34.1822	7.5675	1.1925	50.2325	0	7.9313	20.4716
77	0	1.8415	5.6516	35.2646	8.4071	1.0419	55.3238	0	8.6293	20.8371
78	0	1.5530	4.7076	35.1441	7.8163	0.8045	53.7639	0	8.2834	20.0146
79	0	1.5657	5.2336	42.3468	8.7755	0.6960	63.2308	0	9.6116	23.3047
80	0	1.4005	5.1552	46.4745	8.9605	0.4962	67.7577	0	10.1686	24.7670
81	0	1.1107	4.7372	47.3010	8.4707	0.2459	67.3825	0	9.9983	24.4928
82	0	0.8612	4.4431	50.2083	8.3349	0.0000	69.9295	0	10.2342	25.2239
83	0	0.8071	3.8585	47.9439	7.3925	0.0000	65.3214	0	9.4616	23.6703
84	0	0.9079	3.9309	55.2181	7.8909	0.0000	73.6338	0	10.5529	26.3206
85	0	0.9002	3.4851	55.8938	7.3847	0.0000	72.9918	0	10.3495	25.4981

Table E-22A. Non-Manufacturing Consumption and Output, 1958-1985

SIC=OIL & GAS

YEAR	QOIL	QNATGAS	QCOAL	QELEC	QMGAS	QLPG	QDIST	QASPHAL	QRESID	OUTPUT
58	0	176.749	0	15.783	24.6278	35.0137	27.160	0	9.0001	64.664
59	0	178.693	0	17.720	25.3936	37.1225	27.931	0	9.3667	68.443
60	0	171.060	0	18.885	24.2894	36.4408	26.531	0	9.0797	69.500
61	0	167.420	0	20.457	24.5437	37.7073	26.888	0	9.2749	70.604
62	0	165.791	0	22.223	25.3503	39.9332	27.930	0	9.6443	72.453
63	0	159.962	0	23.846	24.4432	39.4158	26.926	0	9.5115	75.086
64	0	160.693	0	25.579	23.2685	35.6347	30.691	0	9.3922	77.852
65	0	158.294	0	26.392	20.9358	29.9405	32.657	0	8.7667	80.370
66	0	157.812	0	27.836	18.2785	23.8438	33.847	0	8.2180	83.597
67	0	157.522	0	33.563	15.7579	17.9741	36.405	0	8.6965	87.769
68	0	163.235	0	37.113	16.4336	19.9420	37.937	0	11.8834	92.779
69	0	170.076	0	40.408	17.4963	22.4058	40.490	0	15.1793	96.085
70	0	173.760	0	44.188	17.3516	23.7998	39.907	0	18.5581	99.953
71	0	171.957	0	45.863	16.7217	24.4977	38.289	0	21.0957	98.685
72	0	174.390	0	48.536	18.0118	27.1778	41.549	0	24.5337	99.456
73	0	190.731	0	53.010	19.7770	25.8987	46.811	0	24.7026	100.577
74	0	204.774	0	56.326	22.7723	25.1856	54.972	0	25.0407	96.554
75	0	212.578	0	59.067	25.8792	24.0345	62.930	0	25.4303	92.782
76	0	225.757	0	62.983	27.8173	22.1525	67.812	0	25.7818	91.826
77	0	242.769	0	68.830	31.5591	20.8567	76.627	0	27.4290	94.304
78	0	248.550	0	81.329	34.7107	22.2914	82.497	0	29.9395	97.598
79	0	251.788	0	89.605	36.2072	22.1009	84.413	0	30.6634	99.589
80	0	256.093	0	100.531	43.4867	23.8364	97.765	0	33.5505	105.918
81	0	260.366	0	111.894	54.2788	25.8315	116.842	0	37.1027	108.380
82	0	248.977	0	118.924	51.7244	24.7546	109.731	0	36.6423	103.920
83	0	238.047	0	125.780	48.0817	23.9392	101.981	0	36.5229	96.726
84	0	239.778	0	134.152	55.8872	24.5590	114.198	0	38.5572	103.763
85	0	231.217	0	138.124	51.9046	21.4368	105.895	0	37.6967	98.932

Table E-22A. Non-Manufacturing Consumption and Output, 1958-1985

SIC=METAL & OTH MINING

YEAR	QOIL	QNATGAS	QCOAL	QELEC	QMGAS	QLPG	QDIST	QASPHAL	QRESID	OUTPUT
58	0	116.615	44.1008	24.5736	13.6299	5.3927	32.3714	0	22.3927	13.2265
59	0	123.612	42.1888	25.8609	13.9017	5.2641	34.7114	0	24.0297	13.5397
60	0	130.043	51.1256	30.3684	13.4580	5.2421	37.5995	0	28.6198	15.3178
61	0	129.516	47.4838	31.6281	12.8165	4.7526	38.0217	0	28.5487	15.1465
62	0	128.758	45.8050	33.3639	12.3632	4.2331	39.2359	0	29.3424	15.4884
63	0	131.831	46.9318	35.5875	11.9904	3.7447	41.3676	0	32.0138	15.9089
64	0	151.920	50.1496	39.9900	12.3563	4.0795	45.7591	0	33.7168	16.9923
65	0	171.822	51.5614	44.6258	12.6721	4.4227	49.9076	0	34.4205	17.9401
66	0	194.597	51.6190	49.5983	12.8266	4.8140	54.0692	0	35.4724	18.8082
67	0	196.497	45.5382	46.7833	11.8706	4.4322	51.9272	0	32.4241	17.4248
68	0	205.231	44.1706	51.4192	11.9458	4.8628	55.9081	0	31.2269	18.4283
69	0	219.898	44.9488	57.8916	11.9111	5.4214	60.4715	0	30.7852	19.3651
70	0	231.627	42.0535	62.6507	11.7805	5.8867	64.0843	0	29.6651	19.8172
71	0	230.746	37.8001	61.2098	11.2031	5.6725	63.4545	0	27.3176	18.9698
72	0	248.240	36.2828	66.0090	11.1613	6.0614	67.3644	0	26.9581	19.3781
73	0	258.561	44.6366	74.6308	11.9706	5.7314	77.2435	0	30.2068	20.9710
74	0	247.408	47.4042	75.0009	11.1528	4.9567	77.3256	0	30.8862	20.4982
75	0	220.942	46.9977	70.7088	9.5254	3.9498	71.5036	0	29.3430	17.9076
76	0	224.864	51.9082	77.8028	9.8472	3.6633	79.1594	0	31.9266	18.9827
77	0	215.323	56.5266	76.6002	9.7966	3.1559	81.1090	0	33.1354	18.6467
78	0	225.728	67.8656	90.8074	10.2884	4.0424	86.3990	0	31.6042	20.7743
79	0	229.783	84.8346	99.0999	10.1262	4.7646	84.2820	0	29.4039	21.1424
80	0	204.909	88.7913	93.0849	8.6730	4.7809	70.6230	0	23.7418	18.9586
81	0	184.551	93.2357	96.9294	7.8864	5.0783	64.8400	0	19.6534	18.7025
82	0	133.157	72.9771	74.1086	6.2486	4.5292	49.6368	0	12.6722	14.4695
83	0	134.688	85.5905	80.6292	6.3887	4.8530	50.2846	0	12.7035	15.0877
84	0	131.494	99.8405	92.0866	5.9886	4.8186	47.8683	0	12.5297	17.6217
85	0	117.077	99.3416	94.2924	5.8327	4.5407	46.5370	0	11.4843	17.6511

Table E-22A. Non-Manufacturing Consumption and Output, 1958-1985

SIC=CONSTRUCTION

YEAR	QOIL	QNATGAS	QCOAL	QELEC	QMGAS	QLPG	QDIST	QASPHAL	QRESID	OUTPUT
58	33.1053	85.110	0	19.5442	64.1250	1.4583	158.131	461.041	21.8651	330.073
59	38.9082	97.489	0	21.2501	66.0021	1.7777	163.004	495.486	23.8596	364.278
60	36.4030	93.781	0	22.5808	71.2180	1.8391	169.987	449.523	23.3175	367.596
61	37.2572	95.660	0	23.5361	71.5402	1.8813	172.894	513.262	23.3990	377.236
62	39.7399	99.269	0	25.0750	67.7357	2.0933	177.277	548.533	24.5944	386.585
63	40.2742	101.819	0	26.7810	65.6320	2.1905	184.375	491.607	23.5992	409.802
64	41.2624	103.811	0	28.1117	66.2086	2.2325	183.160	495.990	23.2518	420.257
65	43.9960	108.363	0	29.6095	65.6320	2.3258	182.785	560.173	25.0926	438.988
66	45.0162	107.986	0	30.5649	66.2036	2.4430	195.054	594.119	25.1770	440.324
67	44.5625	105.524	0	30.9402	61.5769	2.6242	184.360	567.276	24.7495	438.049
68	47.3925	111.726	0	31.3156	53.7122	2.8688	175.000	614.896	25.6370	456.037
69	47.8176	112.344	0	31.7284	53.3886	3.3449	181.065	619.674	26.3037	456.928
70	45.7534	107.120	0	31.8956	56.0488	3.4065	172.207	694.620	27.8352	436.325
71	50.3184	115.121	0	33.0591	50.9349	3.6066	175.825	762.989	29.0410	468.140
72	53.5564	122.129	0	34.3489	44.3179	3.7432	186.181	745.087	29.3186	501.098
73	55.0741	122.777	0	36.6383	44.3392	3.7470	204.797	815.481	31.2601	497.099
74	46.9714	107.078	0	39.2997	41.2787	3.4614	180.811	814.658	28.5215	443.606
75	41.5825	99.148	0	40.0469	34.2575	3.1846	178.041	632.709	25.0262	422.744
76	45.5256	106.043	0	40.6304	29.1298	3.3799	199.917	573.384	29.7130	449.733
77	48.3658	114.063	0	41.5999	28.3353	3.4046	239.132	640.348	31.4448	478.554
78	51.1925	111.469	0	46.4243	27.8330	3.5496	249.432	706.003	31.1111	503.451
79	50.0009	100.002	0	47.8330	24.9286	2.5179	221.189	670.702	26.5769	513.900
80	45.0635	82.085	0	44.8307	60.5244	2.5462	194.986	550.297	27.0899	498.193
81	42.3773	70.239	0	44.5105	51.7583	2.7175	158.171	421.421	21.5890	489.151
82	38.8209	56.444	0	42.5206	41.5796	2.9219	160.656	376.569	19.9122	448.010
83	43.0419	63.542	0	49.0038	35.3024	2.9761	166.126	454.631	16.4563	471.470
84	49.0803	71.004	0	57.1652	32.6838	3.1656	196.666	491.276	22.5858	526.581
85	51.5245	75.234	0	62.2028	31.3848	3.2089	198.880	560.868	19.9723	552.301

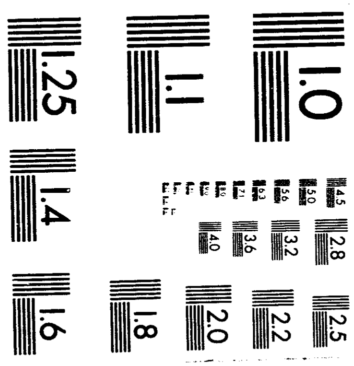
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Table E-22B. Non-Manufacturing Prices, 1958-1985

Sources: Prices: [97]

Notes: All dollar values are expressed in constant 1987 dollars. The deflator is given in Table E-22D. Prices are per million Btu.
The mnemonics are as follows: NATGAS and NATGS--Natural Gas; COAL--Coal; MGAS--Motor Gasoline; LPG--Liquid Petroleum Gas; DIST--Distillate; ASPHAL and ASPH--Asphalt and Road Oil; ELEC--Electricity

SIC=AGRI PRODUCTION

YEAR	POIL87	PNATGS87	PCOAL87	PELEC87	PMGAS87	PDIST87	PASPH87	PLPG87	PRESID87
58	16.3644	1.16530	.	27.2473	8.6781	4.5807	.	4.14053	.
59	16.1358	1.18098	.	25.7590	8.7138	4.6612	.	4.28733	.
60	15.9585	1.23606	.	24.7991	8.7950	4.4773	.	4.42141	.
61	16.1871	1.34208	.	24.8506	8.6947	4.5437	.	4.50267	.
62	16.8007	1.20576	.	24.6231	8.4413	4.3912	.	4.55108	.
63	15.9916	1.39968	.	24.4594	8.3482	4.3176	.	4.99890	.
64	16.0147	1.34901	.	24.4410	8.1398	4.2644	.	4.78496	.
65	16.3695	1.33992	.	23.4258	7.9673	4.1896	.	4.53002	.
66	16.9355	1.27066	.	21.9312	7.8323	4.0938	.	4.63524	.
67	16.5959	1.28803	.	20.9896	7.7579	3.9949	.	5.09095	.
68	15.8132	1.25008	.	19.8152	7.4423	3.9417	.	4.81486	.
69	14.8406	1.11692	.	18.1225	7.2621	3.8153	.	4.43049	.
70	14.4428	1.15219	.	17.6515	7.1323	3.4444	.	4.38128	.
71	14.9832	1.19577	.	18.1511	7.2686	3.8933	.	4.63490	.
72	14.3891	1.17895	.	16.8446	6.6138	3.5320	.	3.98035	.
73	12.8959	1.08677	.	16.3927	6.7666	3.9465	.	3.66509	.
74	16.0869	1.38060	.	17.3629	8.5602	5.8631	.	7.05352	.
75	15.2195	1.70564	.	18.2878	8.3189	5.7293	.	6.49014	.
76	13.4838	2.11894	.	18.7729	8.3864	5.7338	.	6.64328	.
77	12.4777	2.55474	.	19.2941	8.2856	5.7915	.	7.31991	.
78	12.6228	2.82137	.	19.3766	8.1080	5.5323	.	7.09733	.
79	15.5547	3.61092	.	18.9432	9.9972	7.5069	.	7.23558	.
80	20.0308	4.09268	.	19.2936	13.0761	9.9360	.	9.30083	.
81	22.8176	4.50546	.	19.8361	13.3016	10.6006	.	9.53211	.
82	20.5802	4.40538	.	21.6490	12.1172	9.5505	.	9.23836	.
83	19.4970	5.36652	.	21.8046	11.0614	8.2783	.	9.64924	.
84	19.3761	4.83685	.	21.9973	10.3677	7.9237	.	9.10984	.
85	18.6511	4.60188	.	22.2607	9.9520	7.3860	.	9.17779	.

Table E-22B. Non-Manufacturing Prices, 1958-1985

SIC=OTHER AGRICULTURE

YEAR	POIL87	PNATGS87	PCOAL87	PELEC87	PMGAS87	PDIST87	PASPH87	PLPG87	PRESID87
58	16.3639	1.16663	2.89145	26.5914	8.6781	4.5805	.	4.14042	1.42045
59	16.1348	1.18230	2.96575	25.3469	8.7138	4.6609	.	4.28731	1.42045
60	15.9576	1.23727	2.85558	24.4610	8.7950	4.4771	.	4.42137	1.39860
61	16.1855	1.34311	2.86832	24.5278	8.6947	4.5436	.	4.50266	1.38265
62	16.7997	1.20684	2.81137	24.2822	8.4413	4.3912	.	4.55102	1.35181
63	15.9911	1.40062	2.85714	24.1547	8.3482	4.3175	.	4.99886	1.33690
64	16.0141	1.34981	2.73139	24.0777	8.1398	4.2644	.	4.78494	1.44404
65	16.3688	1.34068	2.62159	23.0829	7.9673	4.1895	.	4.52998	1.28041
66	16.9335	1.27141	2.66840	21.7415	7.8323	4.0938	.	4.63525	1.41723
67	16.5933	1.28873	2.61745	20.8463	7.7579	3.9949	.	5.09096	1.50015
68	15.8116	1.25080	2.51340	19.7028	7.4423	3.9416	.	4.81483	1.42939
69	14.3408	1.11766	2.52952	18.1751	7.2621	3.8153	.	4.43049	1.47929
70	14.4413	1.15288	2.83723	17.9309	7.1323	3.4443	.	4.38127	1.29132
71	14.9815	1.19664	3.02333	18.5433	7.2686	3.8933	.	4.63490	1.70455
72	14.3863	1.17985	2.89340	17.3443	6.6138	3.5320	.	3.98035	1.64011
73	12.8923	1.08792	2.93492	17.0202	6.7666	3.9465	.	3.66507	1.86254
74	16.0828	1.38205	4.05103	18.8932	8.5602	5.8630	.	7.05351	4.26875
75	15.2157	1.70634	4.28168	19.9319	8.3189	5.7292	.	6.49012	3.72629
76	13.4831	2.11927	4.32152	20.0761	8.3864	5.7337	.	6.64328	3.55094
77	12.4776	2.55504	4.37732	20.6688	8.2856	5.7915	.	7.31991	3.74045
78	12.6220	2.82150	3.78147	20.0384	8.1080	5.5323	.	7.09731	3.32226
79	15.5530	3.61100	3.30582	19.4232	9.9972	7.5069	.	7.23560	4.23442
80	20.0308	4.09289	3.38223	19.7951	13.0762	9.9360	.	9.30083	5.40446
81	22.8173	4.50561	3.79957	20.6723	13.3016	10.6005	.	9.53208	6.08365
82	20.5811	4.40568	3.64826	22.2427	12.1172	9.5505	.	9.23837	5.96659
83	19.4949	5.36672	3.13010	21.9401	11.0614	8.2783	.	9.64924	4.59242
84	19.3771	4.83713	3.21587	22.1903	10.3677	7.9237	.	9.10985	5.49451
85	18.6505	4.60217	2.99385	22.1904	9.9520	7.3860	.	9.17780	5.29661

Table E-22B. Non-Manufacturing Prices, 1958-1985

SIC=COAL MINING

YEAR	POIL87	PNATGS87	PCOAL87	PELEC87	PMGAS87	PDIST87	PASPH87	PLPG87	PRESID87
58	.	1.51862	0.69560	14.9046	7.8678	3.99411	.	2.87993	2.24385
59	.	1.58514	0.65909	14.6757	7.9498	3.83162	.	2.97783	2.26392
60	.	1.61818	0.59489	15.4195	7.9419	3.63109	.	3.20600	2.24294
61	.	1.65695	0.57149	12.6902	7.7886	3.62444	.	2.88149	2.16219
62	.	1.64914	0.53492	13.4352	7.5053	3.38224	.	2.38212	2.17275
63	.	1.60386	0.51696	12.4932	7.0653	3.42677	.	2.47658	1.92498
64	.	1.45092	0.59886	13.2969	7.0102	3.25381	.	2.35168	1.97422
65	.	1.36489	0.65008	13.8881	7.2894	3.16018	.	2.29577	1.92276
66	.	1.27290	0.74056	15.1504	7.1587	3.09224	.	2.51290	1.92405
67	.	1.18904	0.82543	11.4273	7.0916	3.11697	.	2.38078	1.83554
68	.	1.35329	0.76144	9.9430	6.8492	2.98627	.	2.00269	1.75882
69	.	1.49488	0.71779	9.3601	6.7081	2.88819	.	1.81661	1.57753
70	.	1.67272	0.80455	9.3484	6.5666	2.83309	.	1.83916	1.84824
71	.	1.98192	0.80784	9.9553	6.6160	2.92118	.	1.93365	2.33250
72	.	2.14093	0.71196	9.6697	6.0297	2.76416	.	1.90316	2.39648
73	.	2.03362	0.78458	9.5155	6.1212	2.99459	.	2.16871	2.82072
74	.	1.99893	1.36519	11.5588	8.4533	5.14121	.	5.18425	5.27705
75	.	2.11406	1.58157	11.9272	8.6982	5.40170	.	5.46863	5.36161
76	.	2.47675	1.58676	11.9897	8.2506	5.45518	.	7.26449	5.19258
77	.	2.91442	1.51897	13.5378	7.6608	5.59183	.	5.83683	4.84875
78	.	2.95046	1.82997	12.1154	7.3611	5.28999	.	4.70113	4.26761
79	.	3.56353	1.93001	11.8946	9.4603	6.90435	.	5.55986	4.93674
80	.	3.84342	1.97775	12.3991	12.6987	9.15377	.	8.07757	5.95349
81	.	4.01373	2.05787	13.0269	12.7860	9.61315	.	7.66744	7.17099
82	.	4.07199	2.17011	14.0631	10.9596	8.80770	.	.	6.24986
83	.	4.20038	2.08049	12.0087	9.2440	7.59189	.	.	6.30447
84	.	3.99570	2.09121	13.3973	7.8084	6.67288	.	.	5.36130
85	.	3.71316	2.09925	13.1412	7.1512	5.76728	.	.	4.39371

Table E-22B. Non-Manufacturing Prices, 1958-1985

SIC=OIL & GAS

YEAR	POIL87	PNATGS87	PCOAL87	PELEC87	PMGAS87	PDIST87	PASPH87	PLPG87	PRESID87
58	.	0.58131	.	14.5747	8.3061	3.76752	.	2.87992	2.14347
59	.	0.63167	.	14.7882	8.4788	3.59975	.	2.97784	2.13335
60	.	0.66999	.	16.0252	8.5819	3.38975	.	3.20600	2.07915
61	.	0.71137	.	13.6576	8.4916	3.36318	.	2.88171	1.97368
62	.	0.73133	.	15.0081	8.2400	3.11763	.	2.38213	1.95034
63	.	0.73209	.	14.5002	7.8520	3.13102	.	2.47653	1.69176
64	.	0.66832	.	15.1712	7.7760	3.00711	.	2.35193	1.78126
65	.	0.63592	.	14.4813	8.1167	2.94750	.	2.29580	1.73142
66	.	0.60300	.	14.5398	8.0069	2.91373	.	2.51288	1.69542
67	.	0.57483	.	12.3324	7.9224	2.99001	.	2.38071	1.66335
68	.	0.58299	.	10.3850	7.5426	2.91372	.	2.00293	1.46873
69	.	0.58144	.	9.4638	7.3161	2.86333	.	1.81651	1.20783
70	.	0.59656	.	9.1165	7.1325	2.85980	.	1.83913	1.25911
71	.	0.65099	.	9.3614	7.1792	3.00671	.	1.93358	1.40173
72	.	0.65625	.	8.7851	6.5491	2.89674	.	1.90308	1.28161
73	.	0.69468	.	8.8044	6.6333	3.04253	.	2.16876	1.59754
74	.	0.76992	.	10.9007	9.1232	5.08253	.	5.18445	3.21850
75	.	0.92459	.	11.4446	9.3417	5.20164	.	5.46860	3.49231
76	.	1.23199	.	11.6603	8.8083	5.10161	.	7.26457	3.52691
77	.	1.67143	.	13.3315	8.1100	5.08225	.	5.83711	3.43918
78	.	1.74727	.	12.1164	7.7272	4.93301	.	4.70088	3.16019
79	.	2.19403	.	12.0915	9.8362	6.58998	.	5.55952	3.84749
80	.	2.48137	.	12.8628	13.0603	8.94925	.	8.07743	4.95679
81	.	2.73455	.	13.8301	12.9964	9.60744	.	7.66603	6.38389
82	.	2.94013	.	15.3093	11.0017	8.98699	.	7.17828	5.81354
83	.	3.03073	.	12.9110	9.1540	7.90943	.	7.13399	6.15614
84	.	2.88237	.	14.1694	7.6099	7.09896	.	6.47279	5.55376
85	.	2.67583	.	13.7169	6.8552	6.27607	.	6.86259	4.80373

Table E-22B. Non-Manufacturing Prices, 1958-1985

SIC=METAL & OTH MINING

YEAR	POIL87	PNATGS87	PCOAL87	PELEC87	PMGAS87	PDIST87	PASPH87	PLPG87	PRESID87
58	.	0.88479	1.34008	13.3084	8.4183	3.51138	.	2.87998	1.97421
59	.	0.93406	1.33594	13.3904	8.4790	3.37763	.	2.97779	1.98881
60	.	0.97108	1.29885	14.0063	8.4369	3.22796	.	3.20592	1.98229
61	.	1.00905	1.25655	11.5451	8.2371	3.23035	.	2.88159	1.89447
62	.	1.01962	1.20776	12.3132	7.9013	3.02677	.	2.38218	1.87421
63	.	1.00790	1.18617	11.6355	7.3990	3.07168	.	2.47644	1.62712
64	.	0.96600	1.14203	11.8004	7.2451	2.93478	.	2.35199	1.61093
65	.	0.96237	1.06082	11.7656	7.4390	2.85526	.	2.29577	1.51698
66	.	0.95467	1.05115	12.3814	7.2122	2.80601	.	2.51280	1.47493
67	.	0.94767	1.00916	9.1318	7.0555	2.84292	.	2.38079	1.36244
68	.	0.93275	0.96037	8.1385	6.6716	2.70127	.	2.00282	1.30478
69	.	0.91396	0.94610	7.7951	6.4259	2.58872	.	1.81649	1.16685
70	.	0.91839	1.12984	7.9181	6.2181	2.51913	.	1.83918	1.35876
71	.	0.98350	1.20946	8.6636	6.2084	2.58259	.	1.93362	1.70181
72	.	0.97496	1.16430	8.5782	5.6316	2.42781	.	1.90308	1.73928
73	.	1.04164	1.18280	8.7994	5.7391	2.64125	.	2.16880	2.07389
74	.	1.14913	1.86459	11.0417	7.9848	4.55416	.	5.18454	3.93584
75	.	1.38019	1.91720	11.7209	8.2809	4.80136	.	5.46879	4.06431
76	.	1.86100	1.70193	12.1442	7.8946	4.87623	.	7.26455	4.00018
77	.	2.56881	1.38277	14.1267	7.3571	5.04254	.	5.83721	3.80477
78	.	2.66356	1.72005	13.0963	7.1860	4.84812	.	4.70084	3.45584
79	.	3.30460	1.78656	13.2878	9.3858	6.42342	.	5.55958	4.13029
80	.	3.66980	1.79151	14.3145	12.8073	8.66037	.	8.07756	5.16369
81	.	3.96808	1.86502	15.5942	13.1254	9.23427	.	7.66598	6.44783
82	.	4.21808	1.88244	17.3341	11.4677	8.59463	.	7.17829	5.85805
83	.	4.34961	1.80363	14.8086	9.8513	7.53126	.	7.13403	6.10398
84	.	4.12499	1.86140	16.6182	8.4652	6.74389	.	6.47277	5.34336
85	.	3.86147	1.87969	16.2361	7.9269	5.92719	.	6.86249	4.52399

Table E-22B. Non-Manufacturing Prices, 1958-1985

SIC=CONSTRUCTION

YEAR	POIL87	PNATGS87	PCOAL87	PELEC87	PMGAS87	PDIST87	PASPH87	PLPG87	PRESID87
58	15.1275	2.87427	.	27.8196	7.8080	3.7807	2.44549	3.48463	1.48049
59	15.0070	2.90421	.	27.2474	7.6073	3.5988	2.46477	3.52347	1.53060
60	14.7923	2.96067	.	27.7299	7.5854	3.2641	2.44564	3.57867	1.50760
61	15.0276	2.96519	.	26.1879	7.4193	3.2766	2.42777	3.26871	1.51753
62	15.6018	2.89760	.	25.8216	7.1901	3.2582	2.37637	2.87197	1.45695
63	14.9207	2.85685	.	24.5671	7.0478	3.2420	2.36349	3.03802	1.40874
64	14.9826	2.72499	.	23.1714	6.8587	3.0777	2.49726	3.02845	1.39346
65	15.2896	2.66555	.	21.9811	6.8975	3.0253	2.26157	3.07557	1.42930
66	15.8293	2.57453	.	20.5356	6.8571	2.9687	2.14706	3.24890	1.39431
67	15.5219	2.49731	.	19.7322	6.8733	3.0027	2.03302	3.39252	1.43256
68	14.8211	2.34800	.	18.4328	6.6629	2.9447	1.93378	2.58627	1.40881
69	13.9006	2.23900	.	17.2554	6.4883	2.8842	1.79529	2.28786	1.30977
70	13.4371	2.23261	.	16.7356	6.4179	2.8986	1.74087	3.33820	1.27070
71	13.9988	2.34216	.	17.6515	6.5610	3.0919	2.04557	3.51801	1.70294
72	13.4839	2.27297	.	16.7690	5.9265	2.8037	1.86347	3.20671	1.65659
73	12.0887	2.25421	.	16.3217	6.0246	3.2822	1.74780	3.23610	1.85477
74	15.1619	2.41333	.	18.6031	6.7819	5.1331	3.28236	5.24319	4.12217
75	14.3603	2.74014	.	19.2409	7.8630	5.0155	3.46347	4.90521	3.79912
76	12.7351	3.13640	.	19.3893	7.8341	5.0291	3.39086	5.04048	3.51976
77	11.8336	3.56720	.	20.1330	7.8631	5.3296	3.33284	5.49998	3.87335
78	12.0450	3.64311	.	19.9608	7.6282	5.1497	2.77690	5.40906	3.37649
79	15.0062	4.08191	.	20.1048	9.4635	7.1354	3.39797	5.73661	4.53067
80	19.3213	4.61704	.	21.3374	12.3756	9.4154	4.62889	6.77247	5.69951
81	22.1943	4.94833	.	22.2877	12.5059	10.2859	5.42673	7.06238	6.45583
82	20.1402	5.60753	.	23.1179	12.3720	9.2380	5.01359	7.06752	5.56361
83	19.1764	6.22763	.	22.8814	11.4845	7.5692	4.96052	7.35843	5.16675
84	19.0071	5.92251	.	22.9958	10.7704	7.1745	5.49839	6.96599	5.17548
85	18.3298	5.64773	.	22.5712	10.1543	6.6550	5.24512	7.10115	4.43873

Table E-22C. Manufacturing Consumption and Output, 1958-1990

Sources: Consumption, 1958-1985: [97]
Consumption, 1988: [99]
Output and Deflator: U.S. Department of Commerce and DRI, Inc.

Notes: All dollar values are expressed in constant 1987 dollars. Prices are per million Btu and quantities are trillion Btus. Output is billion dollars.

The mnemonics are as follows: NATGAS and NATGS--Natural Gas; COAL--Coal; ELEC--Electricity; OIL--All Oil Products; OUTPUT--Value of Output; DOL8'. -Deflator for 1987 Dollars.

SIC=FOOD

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	171.828	151.902	295.667	250.559	53.391
59	178.297	145.648	311.604	243.253	57.762
60	183.761	149.388	316.156	240.428	60.956
61	187.761	134.336	316.291	226.954	63.317
62	192.475	134.048	338.979	217.326	65.016
63	197.419	131.767	345.946	208.311	68.247
64	205.617	147.716	387.690	220.185	77.695
65	205.665	140.824	390.580	215.394	75.696
66	209.827	140.354	418.515	209.965	80.435
67	224.283	138.899	452.915	211.206	83.257
68	227.615	160.203	542.923	219.182	91.777
69	231.617	156.925	508.301	176.249	99.324
70	233.717	154.932	558.146	149.321	115.108
71	240.021	155.129	586.322	135.308	115.279
72	254.265	194.276	543.972	130.916	117.299
73	250.845	198.139	520.249	125.641	121.628
74	260.037	154.459	527.554	88.887	125.818
75	257.792	179.413	501.474	93.101	130.677
76	274.466	198.236	484.744	94.199	133.280
77	277.138	216.734	466.095	99.834	136.638
78	284.726	230.512	464.735	111.369	138.262
79	283.657	161.002	506.265	112.540	134.895
80	287.826	125.077	527.164	122.602	140.296
81	291.994	102.466	512.771	116.723	141.352
82	302.254	104.311	526.540	118.381	156.771
83	303.857	100.408	554.659	121.138	149.786
84	306.316	88.009	553.173	128.893	154.723
85	316.148	76.961	480.964	121.100	154.884
86	318.500	0.0	0.0	0.0	0.0
87	333.677	0.0	0.0	0.0	0.0
88	341.586	89.1	488.1	149.6	171.3
89	340.410	0.0	0.0	0.0	0.0
90	347.143	0.0	0.0	0.0	0.0

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=TOBACCO

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	28.5615	2.1466	1.2262	5.9576	1.1157
59	29.4756	2.2781	1.4311	6.5861	1.1908
60	32.4867	2.5203	1.5589	7.2039	1.2522
61	29.1509	2.2434	1.5418	6.9939	1.2863
62	32.3128	2.3850	1.7161	7.3750	1.3580
63	32.3548	2.7490	2.1321	8.5025	1.7435
64	33.0059	2.9286	2.3230	8.6889	1.9176
65	32.5611	3.1251	2.6851	9.6957	2.0916
66	31.9486	3.1076	2.9441	9.6608	2.3031
67	32.1733	3.0580	3.2615	9.9614	2.5147
68	31.5166	3.6445	3.6847	8.4880	2.5761
69	30.3692	4.5151	3.9434	7.0196	2.7057
70	30.8464	5.2169	4.8237	6.3329	2.9036
71	31.3664	5.0656	4.7199	5.0587	3.0981
72	32.4133	6.6132	4.1284	4.1031	3.2960
73	33.9001	7.3256	4.1582	3.7593	3.8692
74	34.3462	6.8959	5.6341	3.7573	3.5076
75	34.6435	7.8625	3.5827	3.7017	3.6543
76	35.6843	8.7214	3.1750	4.0473	3.8351
77	33.0080	9.7534	3.1714	6.2120	4.2650
78	32.8593	7.5200	2.3080	7.9621	4.3189
79	32.2646	5.0474	3.5352	7.6447	4.5083
80	33.3054	3.2772	4.2578	9.6439	4.7526
81	32.8593	3.1017	4.1601	9.4559	4.8519
82	34.7922	2.9974	3.8226	9.6429	4.9798
83	30.7777	3.1927	4.1406	11.7259	5.2033
84	30.6290	2.7580	3.8002	11.7268	4.8734
85	30.4804	2.9785	3.7022	12.7723	5.0713
86	28.9935	0.0000	0.0000	0.0000	0.0000
87	29.1422	0.0000	0.0000	0.0000	0.0000
88	30.7777	2.0000	2.1000	16.9000	2.9000
89	29.5883	0.0000	0.0000	0.0000	0.0000
90	30.4804	0.0000	0.0000	0.0000	0.0000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=TEXTILE MILLS

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	27.9009	65.852	38.866	87.5482	39.387
59	30.8180	63.372	42.594	83.2451	43.359
60	30.0388	65.173	44.122	80.0699	43.744
61	30.8008	59.417	45.954	75.5246	44.257
62	32.9319	61.878	51.301	72.4159	46.756
63	33.8331	62.988	57.619	73.1662	48.917
64	35.8797	69.447	66.000	75.8023	53.513
65	37.7765	68.656	71.797	77.1532	56.558
66	40.4285	68.916	80.744	76.1743	61.268
67	40.5411	70.459	95.327	80.3793	67.304
68	42.2793	75.696	100.432	69.3696	73.448
69	42.4589	83.759	102.523	59.7630	77.607
70	41.8188	80.170	110.809	49.3247	79.248
71	43.0861	86.989	124.639	46.1105	82.432
72	45.2852	106.284	117.586	36.3150	91.791
73	43.7786	100.055	109.555	30.0336	96.121
74	41.3051	71.131	110.551	25.8341	88.686
75	40.3376	83.206	96.044	27.2393	87.929
76	46.0386	100.766	85.721	31.9033	92.971
77	50.3404	112.692	82.453	34.6803	91.873
78	50.4469	109.494	85.307	30.3244	91.791
79	51.3069	74.997	108.668	31.4901	90.491
80	49.4791	52.972	112.598	33.4150	87.794
81	49.1566	45.414	111.245	36.7008	87.277
82	44.7460	38.423	97.461	34.5946	81.502
83	50.2316	38.471	111.972	42.0542	89.159
84	50.9840	32.513	112.304	43.9094	90.760
85	48.1868	27.987	99.353	40.1512	87.092
86	50.0153	0.000	0.000	0.0000	0.000
87	55.8235	0.000	0.000	0.0000	0.000
88	55.5005	28.400	92.900	38.7000	101.500
89	55.8228	0.000	0.000	0.0000	0.000
90	54.6400	0.000	0.000	0.0000	0.000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=APPAREL & OTHER

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	35.6720	10.7751	7.6347	13.4148	7.2965
59	38.5674	9.9445	8.3153	12.2417	7.7567
60	38.9655	9.7842	8.6877	10.9323	7.9955
61	39.3384	7.8517	8.4152	8.5015	8.1312
62	41.8996	8.4399	10.5115	7.5417	9.1090
63	44.6091	8.3152	11.3307	7.1133	9.8174
64	46.1517	9.8676	14.0002	7.8972	11.3363
65	48.8970	10.1762	15.7052	8.3547	11.3449
66	51.2732	11.3307	19.0763	9.1083	12.5243
67	53.6111	13.9490	24.5518	10.8618	14.1482
68	55.7218	17.3486	32.1074	12.1956	17.7555
69	57.9511	15.5199	28.3947	9.1708	18.6192
70	55.4421	14.6783	28.6873	7.5714	20.6730
71	58.5742	14.6903	29.9120	6.7252	22.2797
72	64.8665	16.7597	27.4109	4.9195	24.2992
73	66.7991	15.6225	24.8448	3.2882	25.0772
74	62.1602	12.4526	25.7935	1.9645	24.8392
75	61.0561	12.0509	23.2079	2.1080	26.0354
76	64.6676	13.9670	20.2812	2.0623	25.7064
77	71.3467	15.8817	21.8967	2.5091	24.9200
78	73.9034	15.4107	25.5735	2.3149	23.0091
79	68.5582	10.2104	24.5615	2.0627	20.2720
80	69.6568	8.4767	24.4435	2.7885	20.6412
81	69.7535	10.2823	24.1603	3.3585	20.6655
82	69.3229	7.3766	19.5872	2.8575	21.6088
83	72.5839	7.6706	20.3757	2.9638	21.3209
84	74.1332	6.7524	20.3444	2.5927	24.0453
85	72.1786	5.8358	17.0990	2.2309	20.9077
86	73.0181	0.0000	0.0000	0.0000	0.0000
87	84.7468	0.0000	0.0000	0.0000	0.0000
88	79.6005	5.1000	21.7000	2.9000	22.7000
89	77.2262	0.0000	0.0000	0.0000	0.0000
90	74.9542	0.0000	0.0000	0.0000	0.0000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=LUMBER & WOOD

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	30.7633	48.1945	17.777	17.9534	12.5147
59	33.2236	48.9260	22.895	18.6026	14.0989
60	32.4591	39.5498	21.976	14.6096	14.5108
61	32.5008	30.8894	23.038	11.5903	15.4888
62	33.7677	26.3917	26.965	8.7991	16.5301
63	36.4296	38.9492	46.663	11.9362	17.1470
64	38.2695	45.8226	58.770	12.6414	19.9337
65	39.2432	49.5655	69.374	13.3968	19.9938
66	39.1652	53.1392	80.065	13.3531	22.8024
67	41.2446	59.4374	96.487	14.4964	25.9018
68	41.7938	69.6936	122.006	14.7411	30.6646
69	40.7397	68.5783	121.556	12.3782	32.7557
70	42.6614	58.2375	114.959	9.3042	35.7653
71	42.0645	51.8058	109.416	7.7854	39.6885
72	49.9018	63.3435	100.709	7.6262	46.3369
73	49.5615	66.7308	97.546	7.9329	46.5930
74	47.5708	52.9662	93.003	7.4680	50.7672
75	45.1118	56.4044	88.991	3.8294	49.4449
76	49.2211	57.9518	81.382	4.1631	53.1662
77	55.3211	53.2785	67.252	4.1615	55.1220
78	56.1408	59.5536	72.101	3.6131	56.8729
79	54.5014	49.8665	79.912	3.1163	54.8158
80	54.1501	44.2338	62.625	2.7712	50.0445
81	51.8082	40.0833	49.692	2.3613	49.5689
82	49.7005	30.4752	37.068	1.7359	49.8739
83	53.6817	32.8984	38.849	2.0818	52.7045
84	56.8434	34.2220	36.256	2.1277	57.0902
85	57.0885	33.6109	29.572	1.9334	57.2043
86	61.1869	0.0	0.0	0.0	0.0
87	71.8317	0.0	0.0	0.0	0.0
88	71.1291	28.5	35.1	2.3	56.1
89	68.9043	0.0	0.0	0.0	0.0
90	67.4882	0.0	0.0	0.0	0.0

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=FURNITURE & FIXTURES

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	13.7162	4.6066	7.2165	15.3195	4.4220
59	14.9030	4.0702	6.7211	13.5100	4.9474
60	14.6784	4.3583	6.7631	12.6502	5.0122
61	14.3290	4.1060	6.6361	11.1605	4.9986
62	15.5705	5.0781	8.2242	11.5219	5.3160
63	16.3812	4.7813	7.1562	12.5314	5.5787
64	17.5395	5.3314	6.7829	14.9921	6.3805
65	19.0497	5.6072	6.7313	18.1537	6.7797
66	20.4152	6.1316	6.7467	20.9864	7.1413
67	20.4431	6.6675	6.8621	24.6387	7.8443
68	21.3465	6.2218	9.0617	18.9851	9.0316
69	22.4744	6.5854	11.8219	14.5948	10.8434
70	21.1279	7.4205	17.4280	11.6934	11.5668
71	21.9636	7.6583	23.9831	8.5590	11.4781
72	26.3340	12.1826	26.1966	7.5180	11.8261
73	27.8197	10.5125	23.7421	4.5776	12.9759
74	25.0724	9.1489	27.5332	3.4157	13.6959
75	21.7550	9.2679	20.7796	3.1158	13.2557
76	24.0431	9.3976	20.3811	2.4866	13.5423
77	27.2607	10.5042	21.6884	3.7825	14.2964
78	29.6677	10.7214	23.6545	3.3655	14.5174
79	29.2166	9.5529	23.0160	2.9297	13.7599
80	28.6575	7.5427	21.6080	2.9027	13.4828
81	28.7737	6.2924	19.9374	3.1919	14.1366
82	27.3097	5.3323	19.5669	2.6643	13.6467
83	29.0224	4.7866	21.1612	2.3780	14.56[illegible]1
84	31.7889	4.4619	22.9489	2.5822	15.5140
85	31.9132	3.7566	22.0248	2.2669	15.2690
86	32.9370	0.0000	0.0000	0.0000	0.0000
87	36.6247	0.0000	0.0000	0.0000	0.0000
88	36.7463	5.8000	22.7000	2.9000	19.3000
89	37.3218	0.0000	0.0000	0.0000	0.0000
90	36.8680	0.0000	0.0000	0.0000	0.0000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=PAPER

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	40.478	162.359	219.762	356.677	42.439
59	44.747	165.426	233.677	356.423	47.888
60	44.925	183.178	236.683	364.801	50.924
61	46.759	176.742	242.459	366.907	53.303
62	49.250	194.010	269.310	376.074	57.629
63	52.239	206.175	286.354	361.801	63.037
64	54.700	232.429	303.778	354.762	69.291
65	58.400	258.205	339.186	370.190	73.270
66	62.634	273.244	373.104	361.385	82.455
67	63.004	273.202	399.285	346.858	88.228
68	66.817	314.368	423.991	321.439	99.341
69	70.965	385.758	428.889	289.017	107.496
70	69.175	370.768	456.209	246.758	112.870
71	69.661	413.046	506.301	245.553	119.114
72	74.782	552.935	432.224	215.092	125.528
73	81.681	548.340	379.555	197.680	129.984
74	83.770	476.254	447.243	226.671	139.449
75	73.399	468.177	391.229	202.395	133.482
76	81.317	521.891	371.879	225.035	148.280
77	85.196	521.977	363.792	241.248	152.040
78	88.828	527.736	356.205	212.696	155.625
79	89.558	446.800	428.534	213.834	157.502
80	88.168	385.318	432.824	230.854	169.523
81	89.294	295.603	451.671	249.421	178.102
82	87.461	262.680	419.327	269.340	172.442
83	93.352	246.110	452.770	334.271	176.792
84	98.759	208.670	461.134	376.558	182.902
85	96.382	184.811	420.024	380.566	179.642
86	100.433	0.000	0.000	0.000	0.000
87	105.844	0.000	0.000	0.000	0.000
88	109.448	194.800	428.300	309.000	189.400
89	109.599	0.000	0.000	0.000	0.000
90	110.047	0.000	0.000	0.000	0.000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=PRINTING

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	32.2723	9.3231	15.0242	4.1582	10.2498
59	34.4821	8.1611	14.2498	3.4740	11.2597
60	35.5699	8.8202	15.2730	3.4410	11.8705
61	36.3297	8.4010	15.8913	3.1745	12.7712
62	37.7051	9.2458	18.3266	3.1288	13.6959
63	37.8533	9.4378	18.8360	2.6941	13.9859
64	39.9517	10.4953	20.4057	2.4108	15.8147
65	41.9285	11.3040	22.6277	2.2176	16.3129
66	44.2969	12.0259	24.9670	1.8414	17.2512
67	46.4596	13.1985	28.8762	1.5636	19.8478
68	47.2847	13.5653	34.4047	1.3812	23.5566
69	49.2536	14.5217	40.1501	1.1868	25.7540
70	47.1820	13.2763	46.5750	0.9474	31.0460
71	47.4329	11.0250	46.4517	0.6898	30.9505
72	50.9241	12.6705	42.9888	1.2233	31.2541
73	52.9805	11.9831	39.1984	1.8668	33.3935
74	51.6499	8.2285	33.5995	2.1282	30.6843
75	48.9888	10.5016	34.9056	1.9973	33.8985
76	51.1661	8.5941	27.9601	1.8517	34.5399
77	56.9721	10.8352	33.8625	1.7946	36.0105
78	60.6009	10.9040	34.3426	1.5142	35.2999
79	61.3267	10.7101	39.1211	1.4392	32.3741
80	62.0525	9.0515	39.9787	0.9079	32.9439
81	63.6249	8.5820	40.7663	0.5732	35.1514
82	66.7699	8.9536	42.8204	0.7105	36.2972
83	69.5520	8.0254	46.1929	0.9289	36.4644
84	73.6646	6.8667	52.0422	1.3046	42.9001
85	76.2048	4.5614	45.2660	1.2797	42.2501
86	78.1401	0.0000	0.0000	0.0000	0.0000
87	85.7606	0.0000	0.0000	0.0000	0.0000
88	86.9702	4.4000	48.5000	0.0000	58.2000
89	86.4864	0.0000	0.0000	0.0000	0.0000
90	87.9379	0.0000	0.0000	0.0000	0.0000
78	52.0214	0	0	0	0
79	53.5913	0	0	0	0
80	48.6674	0	0	0	0
81	49.2383	0	0	0	0
82	44.2431	0	0	0	0
83	47.3830	0	0	0	0
84	48.6674	0	0	0	0
85	45.5990	0	0	0	0
86	46.6694	0	0	0	0
87	55.6607	0	0	0	0
88	59.0146	0	.	0	0
89	58.7292	0	0	0	0
90	60.4418	0	0	0	0

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=BULK CHEMICALS

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	41.398	72.991	544.47	430.527	259.144
59	47.582	78.318	627.02	468.508	268.377
60	48.080	85.875	644.89	488.381	272.321
61	49.306	81.879	648.66	486.200	280.226
62	53.469	87.979	723.84	508.898	277.176
63	57.706	92.586	815.10	512.820	288.719
64	63.169	99.306	895.70	509.629	264.029
65	68.365	100.883	1006.82	534.089	287.044
66	73.107	100.812	1138.49	524.257	285.986
67	73.897	97.674	1229.36	500.565	298.208
68	78.554	113.069	1271.66	480.050	294.069
69	83.093	142.459	1293.89	464.231	302.558
70	80.604	148.631	1338.01	420.463	277.793
71	81.843	166.434	1357.02	431.807	307.884
72	98.617	231.928	1369.07	363.185	353.264
73	111.465	253.434	1432.54	330.763	378.393
74	115.046	247.335	1736.57	334.424	380.014
75	94.162	239.004	1515.07	295.949	384.129
76	107.061	291.767	1598.64	286.327	439.741
77	119.188	353.913	1444.02	312.010	451.922
78	124.531	350.729	1382.50	277.076	442.717
79	128.580	245.156	1483.67	298.699	440.068
80	118.984	160.434	1455.70	296.903	403.629
81	120.596	123.195	1399.60	329.349	399.010
82	107.331	112.071	1226.45	302.697	360.821
83	117.065	104.678	1245.26	342.118	384.733
84	122.405	91.675	1321.74	359.182	413.997
85	115.260	79.333	1101.01	317.709	388.113
86	117.058	0.000	0.00	0.000	0.000
87	135.943	0.000	0.00	0.000	0.000
88	142.411	112.600	1439.00	263.800	394.100
89	142.231	0.000	0.00	0.000	0.000
90	144.887	0.000	0.00	0.000	0.000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=OTHER CHEMICALS

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	27.576	37.8796	48.539	58.1655	9.3900
59	30.998	35.8647	50.165	52.8097	10.4989
60	31.067	37.8451	50.996	50.0066	10.8264
61	31.992	35.9967	53.362	47.0972	11.4098
62	34.295	36.7406	57.376	45.1935	12.1536
63	37.156	37.4775	59.203	43.9460	13.4400
64	39.421	41.0862	62.488	47.0354	14.2998
65	42.862	46.5062	72.244	57.0397	15.5827
66	46.141	44.9279	73.074	57.3847	16.7871
67	48.457	45.1735	78.724	63.8537	18.0905
68	51.986	46.8967	85.782	57.9596	20.4176
69	54.412	68.4887	119.444	67.8986	23.1575
70	56.361	51.5224	102.245	45.4272	25.1671
71	57.339	55.3534	115.444	44.6088	26.4944
72	63.552	69.1267	109.179	42.0245	29.9370
73	67.017	66.0635	100.029	38.5132	31.0358
74	67.570	59.4779	116.929	36.6531	30.1998
75	65.004	57.1824	103.079	36.4044	30.2953
76	71.233	60.9729	103.749	39.3619	31.9808
77	74.649	71.6689	98.314	42.4351	33.2262
78	79.036	73.8881	99.536	40.2356	35.5346
79	81.125	57.5152	124.130	31.0504	38.3110
80	78.075	43.8064	118.636	31.0846	35.3442
81	79.698	37.0713	123.241	32.3088	37.7715
82	80.731	32.9311	125.210	32.1186	37.5995
83	81.948	31.5049	141.402	34.5686	37.6092
84	85.531	26.3222	140.829	35.7468	40.2374
85	85.676	22.9310	128.080	33.5830	39.5747
86	90.574	0.0	0.0	0.0	0.0
87	97.650	0.0	0.0	0.0	0.0
88	101.210	10.8	72.9	25.6	21.6
89	101.797	0.0	0.0	0.0	0.0
90	104.697	0.0	0.0	0.0	0.0

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=SIC 29, COAL & MISC

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	5.5963	13.4733	12.8236	4.1338	1.2965
59	5.9271	16.1308	16.9382	4.7286	1.6378
60	6.5518	18.6480	19.3915	4.9759	1.9449
61	6.0346	16.4220	18.6919	4.2658	2.1018
62	6.4247	15.4767	18.5216	3.6006	1.7230
63	7.2985	17.7127	21.4366	3.8805	1.9210
64	7.6821	18.8696	21.9381	3.6664	2.1940
65	7.7659	19.2329	22.5649	3.6101	2.3270
66	7.9568	19.7473	23.9221	3.3800	2.3543
67	8.4925	23.1251	29.5122	3.8080	2.4293
68	8.8124	19.1169	27.3581	2.2852	2.8695
69	9.0783	18.7534	27.9788	1.4393	3.0878
70	9.7808	18.5169	33.0874	0.8976	3.4598
71	9.9284	18.5605	37.5944	0.4088	3.6372
72	10.9101	23.1248	39.5528	0.2294	3.7600
73	11.5258	22.9016	39.7127	0.2813	3.9887
74	11.0370	17.3200	44.1506	0.2627	4.8314
75	10.5311	20.0935	43.7087	0.4261	4.9680
76	11.8894	20.6173	36.3583	0.1852	4.8996
77	13.3446	27.3642	39.0800	0.4417	5.7015
78	14.8881	33.4646	43.1471	0.5976	5.9154
79	15.0150	25.2291	47.7901	0.5111	5.7462
80	13.3617	20.4287	47.2774	0.5056	5.8103
81	13.3788	18.1480	41.3786	0.3045	5.3989
82	13.6695	25.0616	37.6527	0.2114	6.3941
83	13.7450	30.1836	33.6203	0.1834	6.2170
84	13.8548	29.2031	27.1544	0.1001	5.8297
85	14.6771	33.6229	21.0568	0.0399	5.9335
86	14.9893	0.0000	0.0000	0.0000	0.0000
87	16.6468	0.0000	0.0000	0.0000	0.0000
88	16.2335	3.8000	4.5000	1.8000	2.1000
89	16.0397	0.0000	0.0000	0.0000	0.0000
90	15.9257	0.0000	0.0000	0.0000	0.0000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=RUBBER & MISC

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	16.9488	21.2678	20.623	65.0229	17.354
59	20.3130	21.5195	22.665	63.1111	19.643
60	20.6650	23.2547	24.100	62.4835	20.598
61	20.9052	21.9780	24.875	58.7289	21.404
62	23.2367	24.9176	29.427	60.1173	24.021
63	24.5082	24.6960	31.247	57.4166	25.259
64	26.6332	26.7227	34.401	57.0803	27.549
65	29.5901	29.2689	41.010	63.0737	31.247
66	32.1093	28.8975	44.597	60.1090	38.389
67	33.4824	29.5922	51.751	62.1640	36.475
68	38.7804	30.5804	56.935	55.3479	43.295
69	43.0644	35.4330	64.688	49.8445	47.608
70	42.1248	35.7081	76.943	41.1637	50.733
71	46.4666	39.3990	91.607	37.6084	55.056
72	48.6545	61.4843	98.788	42.3304	61.727
73	54.6428	63.3141	89.245	40.3289	68.227
74	52.9477	50.0817	91.848	35.3920	64.740
75	45.5273	55.7432	79.126	27.4032	64.122
76	49.6261	64.0211	76.506	25.6329	67.387
77	59.3543	77.2621	83.173	28.6858	76.965
78	62.4027	68.0194	86.974	22.2128	78.375
79	60.5247	49.7873	94.440	20.5321	77.925
80	54.7879	33.2143	89.903	20.5650	73.907
81	58.5519	24.1453	95.245	19.1741	78.180
82	59.4400	23.1073	93.784	14.8524	105.079
83	63.0725	22.7199	103.417	13.0115	109.320
84	71.9617	20.7347	109.363	10.6580	100.827
85	73.1435	18.1597	98.817	7.1929	102.710
86	74.5963	0.0000	0.000	0.0000	0.000
87	84.7828	0.0000	0.000	0.0000	0.000
88	87.1580	22.2000	110.400	8.3000	106.800
89	87.6952	0.0000	0.000	0.0000	0.000
90	89.2908	0.0000	0.000	0.0000	0.000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=LEATHER

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	14.4596	9.5041	4.8844	15.5870	2.6341
59	14.8872	8.7862	5.0110	13.2687	2.6989
60	14.4472	9.7302	5.6301	12.7740	2.7057
61	14.2231	8.8463	5.8678	11.1109	2.8388
62	14.4139	9.1670	6.5399	9.9326	3.0231
63	14.3713	8.5749	6.3686	8.6508	3.1766
64	14.9945	9.3603	6.8057	8.3625	3.2892
65	15.3241	10.4295	7.8781	8.9737	3.5928
66	15.4872	10.8778	8.7675	8.7275	4.0603
67	15.8542	10.6962	9.3691	8.3978	4.5005
68	16.4358	12.6646	10.8343	8.9401	4.9304
69	15.6101	11.4455	9.0649	6.2622	5.1146
70	14.6560	12.9621	11.0830	5.2109	6.1178
71	14.1438	11.2058	9.4883	3.9856	5.0601
72	14.1274	11.5544	8.0587	3.3895	5.4217
73	13.8939	9.3901	6.4919	2.5573	5.4217
74	13.6604	7.4598	6.5888	1.6028	5.1249
75	13.1934	8.7012	6.9607	1.5179	5.2102
76	13.4269	8.7165	6.4523	1.3491	5.1522
77	13.6604	8.9150	6.6498	1.4357	4.8349
78	13.5436	8.2258	6.4025	1.4324	4.7484
79	11.7923	6.4695	7.4277	1.1977	4.3373
80	12.3761	6.1921	6.8478	1.1187	4.6437
81	12.4928	5.3356	6.4375	1.0094	4.5055
82	11.4420	5.3669	6.1497	0.8518	4.0804
83	11.3253	5.8584	6.9291	0.8005	4.0920
84	10.3912	4.8981	5.8589	0.5807	4.0426
85	9.4572	4.6778	5.0014	0.4062	3.5495
86	8.2896	0.0	0.0	0.0	0.0
87	9.5739	0.0	0.0	0.0	0.0
88	9.3404	4.5	5.2	1.3	4.7
89	9.1069	0.0	0.0	0.0	0.0
90	8.6399	0.0	0.0	0.0	0.0

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=GLASS

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	7.6439	13.7537	133.399	16.0004	9.0009
59	9.0441	14.3365	151.606	16.5739	10.8059
60	9.1041	15.2502	157.696	16.4626	11.2597
61	9.0119	13.4100	154.679	14.8310	11.4132
62	9.4551	13.1343	160.967	13.3097	12.4983
63	10.1587	13.2695	167.074	11.8887	12.9623
64	10.6604	14.0718	175.379	10.9992	13.8767
65	11.5030	13.7386	182.487	10.4951	15.1665
66	12.3238	13.8387	199.405	10.0392	16.4528
67	12.3030	12.4679	198.647	9.0283	16.6166
68	12.5695	12.2575	207.941	8.2369	16.6166
69	13.2028	13.2254	218.636	7.3731	19.9842
70	12.8236	12.2516	226.355	5.6846	21.4036
71	13.4119	12.7587	240.335	4.4200	22.2600
72	14.6426	27.5614	235.776	3.7718	24.4028
73	15.8628	36.7186	224.460	2.6085	26.4057
74	14.8644	33.6322	220.138	0.7357	26.6752
75	14.4207	37.7946	201.245	0.4794	27.0608
76	15.6409	40.5573	212.415	0.2645	29.2922
77	16.0846	46.6721	203.073	0.4141	30.4762
78	16.9721	40.5628	214.440	0.2327	32.3823
79	16.3065	20.4635	223.781	0.2300	32.5095
80	15.5300	10.3781	217.979	0.3498	31.4777
81	15.5300	8.3076	212.616	0.2075	32.3553
82	14.0879	8.1903	203.013	0.2083	31.1857
83	14.3098	8.8612	223.471	0.2723	30.6070
84	14.4207	7.9003	205.523	0.2941	31.1952
85	14.5316	7.0484	177.069	0.2753	30.4251
86	14.6426	0.0000	0.000	0.0000	0.0000
87	16.1956	0.0000	0.000	0.0000	0.0000
88	16.4174	20.8000	213.800	8.4000	34.8000
89	16.4174	0.0000	0.000	0.0000	0.0000
90	16.4174	0.0000	0.000	0.0000	0.0000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=CEMENT

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	3.8479	27.2118	164.048	194.120	17.1182
59	4.2135	25.1487	183.022	201.203	18.2714
60	3.8863	24.0349	179.100	196.932	18.5034
61	3.8608	19.4952	174.522	187.174	19.0323
62	3.9532	19.1014	193.462	189.490	20.1753
63	4.1590	19.5349	203.062	203.640	22.2464
64	4.2704	20.2797	204.915	211.019	23.5737
65	4.4345	19.8706	207.704	225.735	24.8771
66	4.4496	18.8276	210.156	225.932	26.0542
67	4.3408	16.8192	205.611	223.362	25.5731
68	4.4718	23.5718	213.289	213.079	26.7946
69	4.5692	34.2076	213.892	199.252	28.3266
70	4.1489	36.3475	216.802	173.930	28.4119
71	4.3349	42.3494	223.542	175.778	29.0534
72	4.7952	63.9824	218.041	183.618	32.3426
73	4.9992	60.7655	199.547	179.498	33.4617
74	4.8972	45.3548	234.377	191.910	33.7961
75	4.1830	33.3328	165.827	192.275	30.0053
76	4.2851	36.6177	134.167	228.527	31.1859
77	4.5911	42.1052	95.347	292.103	33.5163
78	4.8972	39.4306	85.716	292.446	35.5305
79	4.9992	22.0879	76.000	311.967	35.2381
80	4.3871	14.3828	59.958	285.571	31.5197
81	3.9790	6.3644	47.821	299.145	30.4460
82	3.5709	5.2710	32.363	248.414	28.7318
83	3.6729	5.0819	26.129	257.254	28.3554
84	3.8770	5 3652	22.660	290.111	31.1519
85	3.9790	5.5093	15.973	276.160	32.0878
86	3.8770	0.0000	0.000	0.000	0.0000
87	4.0810	0.0000	0.000	0.000	0.0000
88	3.9790	13.3000	75.900	251.500	47.5000
89	3.8770	0.0000	0.000	0.000	0.0000
90	4.0810	0.0000	0.000	0.000	0.0000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=OTHER SCG

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	22.8571	55.4602	191.893	92.525	15.3507
59	25.9602	64.2639	237.123	106.946	19.0289
60	25.4566	64.7750	232.266	103.108	19.7011
61	25.4476	58.2971	224.646	94.616	19.8614
62	26.6776	55.3213	224.020	84.030	20.7349
63	28.7033	57.2605	242.494	86.063	20.7451
64	30.4245	63.0870	271.098	91.484	23.2530
65	32.5188	64.4298	296.923	98.066	24.1094
66	33.8582	63.6912	317.230	96.154	35.9389
67	32.1637	57.1137	311.017	88.467	25.0750
68	34.0224	62.8304	317.224	88.747	33.4242
69	34.3467	73.1227	321.672	88.856	32.6736
70	32.4984	71.3309	304.336	75.920	33.1308
71	33.3295	78.9162	316.528	80.352	33.8950
72	37.1902	88.6558	311.489	79.6912	36.1026
73	39.9329	81.4760	298.674	78.6886	37.8905
74	38.2873	63.6032	302.672	72.2553	38.5252
75	34.1185	69.0768	260.001	70.9446	37.7847
76	35.7641	78.0094	281.342	70.0209	39.2758
77	38.7261	88.4222	265.273	77.8851	41.5243
78	42.2367	95.3336	278.408	81.4247	43.8449
79	42.2367	61.9162	311.941	88.0889	44.8002
80	37.5194	45.1313	280.104	71.7393	41.0866
81	35.6544	45.1226	242.165	81.6561	39.9300
82	31.1564	38.6526	196.737	56.6377	35.1869
83	32.6923	43.0227	233.430	64.8605	36.3948
84	35.4350	40.1130	232.625	68.3527	40.1603
85	35.8738	38.7131	206.637	69.4566	49.9585
86	36.8611	0.0000	0.000	0.0000	0.0000
87	41.4688	0.0000	0.000	0.0000	0.0000
88	42.6755	19.3000	175.800	26.3000	32.9000
89	42.1270	0.0000	0.000	0.0000	0.0000
90	41.1397	0.0000	0.000	0.0000	0.0000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=IRON AND STEEL

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	55.6846	244.091	248.249	216.114	85.548
59	63.6661	249.319	330.022	232.258	98.257
60	64.8321	269.216	381.746	251.247	104.443
61	61.4771	226.915	414.073	234.096	109.815
62	64.6327	231.105	480.287	244.714	113.587
63	67.5621	221.836	507.601	226.376	122.172
64	76.9795	249.500	553.044	236.676	141.380
65	84.2911	255.620	611.436	244.299	151.701
66	85.8217	241.403	657.332	223.534	164.983
67	79.6297	212.649	660.879	199.415	174.520
68	82.9687	219.320	691.755	214.134	185.159
69	84.7317	240.162	811.162	224.477	202.594
70	75.5996	212.348	760.115	202.061	197.509
71	71.5569	187.878	757.229	196.067	201.245
72	75.3951	264.015	746.693	171.045	210.717
73	91.4611	300.148	779.053	151.450	244.539
74	96.6065	290.420	794.320	133.798	251.146
75	70.4597	245.774	645.108	121.970	215.423
76	75.5001	278.861	653.840	119.919	229.651
77	74.8700	291.927	618.360	124.533	245.913
78	79.2803	314.940	716.832	96.580	262.273
79	81.8005	234.556	789.914	97.472	272.462
80	68.9896	119.932	669.025	98.077	238.251
81	71.2998	106.343	719.085	100.503	247.928
82	44.1030	71.376	518.001	68.536	178.749
83	42.8429	67.379	571.878	85.636	168.245
84	47.3582	56.386	580.982	83.643	204.389
85	43.5779	45.018	495.859	76.755	195.726
86	40.6377	0.0	0.0	0.0	0.0
87	46.6231	0.0	0.0	0.0	0.0
88	54.6037	50.6	539.2	51.2	229.5
89	52.6085	0.0	0.0	0.0	0.0
90	51.4534	0.0	0.0	0.0	0.0

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=PRIMARY ALUMINUM

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	4.1170	4.0070	122.046	15.6600	79.572
59	4.7687	3.6959	122.641	17.1770	103.524
60	4.6648	3.8848	124.886	20.3740	108.591
61	4.8793	3.3944	119.181	21.5769	102.275
62	5.3279	3.4272	132.802	33.2247	113.375
63	5.8091	3.6933	143.631	24.1728	122.451
64	6.2702	4.0063	153.435	24.0325	126.248
65	6.7581	3.9316	163.798	24.1877	138.211
66	7.5638	3.9450	177.538	22.9035	141.927
67	7.7811	3.1276	174.637	19.7967	159.628
68	7.9908	3.7164	183.139	21.3958	155.165
69	8.0613	4.4849	187.970	22.7002	179.544
70	7.4538	4.2479	181.206	20.5195	170.519
71	7.0579	4.1530	168.568	19.4940	158.233
72	9.4075	8.1362	155.331	12.4621	175.767
73	11.3317	10.5614	177.444	10.2293	217.424
74	9.7282	8.1354	184.490	7.7248	255.915
75	8.5523	7.8861	103.591	6.2316	211.092
76	10.2627	7.5153	91.459	5.2641	225.016
77	11.5455	8.0731	93.301	10.6571	244.686
78	12.1870	7.3847	81.802	10.7166	250.741
79	12.2939	5.4104	125.132	11.9423	261.194
80	11.8663	4.9441	128.425	9.3180	262.099
81	10.1558	2.9471	69.498	5.6441	256.629
82	7.5901	2.8059	49.360	4.1676	177.243
83	8.6592	2.4695	36.793	2.8135	180.391
84	9.3006	3.1926	43.802	1.3956	216.388
85	6.5211	2.2776	26.836	0.0000	189.797
86	5.8797	0.0000	0.000	0.0000	0.000
87	6.8418	0.0000	0.000	0.0000	0.000
88	8.1246	1.5000	99.100	1.8000	246.200
89	8.4454	0.0000	0.000	0.0000	0.000
90	9.0868	0.0000	0.000	0.0000	0.000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=OTHER PRIMARY METALS

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	36.0478	38.4680	113.443	48.8165	27.5057
59	40.4543	38.7948	124.375	46.9365	29.5844
60	40.3419	41.6172	129.154	44.6510	29.4267
61	41.5916	38.7441	131.030	39.5663	32.0680
62	45.4424	42.0359	147.899	35.9394	35.1433
63	48.2586	42.3733	156.402	36.0934	33.3480
64	51.5051	44.9468	167.478	36.8991	38.0428
65	56.4632	43.6253	176.692	38.2676	47.1034
66	63.7898	43.8659	195.835	39.1053	58.7570
67	58.2932	39.0158	198.554	37.3885	51.5908
68	61.5637	40.4286	211.317	36.9279	57.6001
69	65.8560	45.0492	222.376	36.1844	58.3213
70	59.6293	40.5688	226.625	31.4162	70.0777
71	59.6104	39.3521	230.418	30.5936	62.8771
72	67.3548	55.7708	239.260	29.7523	65.2651
73	77.5018	58.3968	235.975	27.6299	69.9607
74	74.2613	45.4628	245.397	22.8336	71.2234
75	59.9831	44.0311	218.814	18.0733	63.4847
76	66.3257	46.4287	233.733	18.4102	72.6157
77	70.1764	49.4303	241.451	14.0536	71.1216
78	74.5799	48.8317	248.876	11.6208	73.4941
79	73.1441	38.2469	229.191	14.0649	76.9191
80	68.6065	23.2192	217.966	12.6749	75.5420
81	67.2781	23.4724	217.527	17.1082	76.4510
82	52.9927	19.3361	195.724	15.9295	64.4220
83	57.6921	18.8037	216.201	17.2978	61.8295
84	60.9514	15.2658	204.008	16.5186	69.2469
85	57.2044	11.2744	174.079	13.6880	68.5085
86	56.6669	0.0000	0.000	0.0000	0.0000
87	60.3142	0.0000	0.000	0.0000	0.0000
88	62.4986	7.0000	104.700	5.3000	33.4000
89	59.8264	0.0000	0.000	0.0000	0.0000
90	57.9490	0.0000	0.000	0.0000	0.0000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=FABRICATED METALS

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	73.080	74.3173	98.838	35.6481	26.734
59	81.212	71.3058	106.083	34.6718	30.388
60	80.514	69.5773	106.063	33.2267	31.127
61	78.914	60.5336	105.855	30.6923	31.695
62	85.972	66.9473	127.863	32.6816	34.378
63	88.690	60.3846	122.432	29.4122	35.993
64	94.587	65.5569	139.319	32.2453	39.815
65	104.392	63.9676	152.750	34.8545	43.675
66	112.504	67.7121	184.119	37.8718	50.057
67	114.608	68.8590	213.021	43.6054	62.182
68	119.501	72.9257	234.013	39.5819	71.168
69	122.401	74.6872	236.921	35.1763	76.872
70	115.024	69.1911	251.072	28.3523	81.025
71	115.113	62.0155	248.821	23.9162	78.263
72	125.904	73.9605	251.830	20.4364	82.196
73	138.886	68.8646	241.624	17.0425	87.389
74	133.766	48.9955	234.718	12.4403	85.450
75	118.531	51.8466	216.292	10.8893	83.231
76	128.185	53.9303	217.795	10.5778	87.807
77	136.471	59.7798	209.359	12.6469	89.829
78	142.876	58.4287	222.584	10.8538	89.970
79	146.384	46.8905	223.605	11.3499	89.721
80	138.691	36.0169	215.594	10.2058	86.391
81	137.229	29.7704	212.290	10.1511	87.139
82	126.713	28.7263	208.991	11.3090	87.113
83	128.509	26.9276	210.705	11.6883	84.733
84	139.003	24.5876	213.460	10.9389	103.635
85	138.486	20.4560	186.952	9.6285	95.448
86	136.800	0.0000	0.000	0.0000	0.000
87	141.264	0.0000	0.000	0.0000	0.000
88	146.185	15.8000	203.300	9.2000	105.600
89	143.491	0.0000	0.000	0.0000	0.000
90	141.867	0.0000	0.000	0.0000	0.000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=INDUSTRIAL MACHINERY

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	82.137	44.6764	53.622	62.1049	26.129
59	91.384	44.0135	59.493	60.2403	31.022
60	89.850	46.1721	62.824	58.7950	31.776
61	88.124	43.8707	65.587	55.6785	31.868
62	96.438	49.3200	77.556	56.8395	35.386
63	102.173	48.2891	81.399	53.2147	37.737
64	113.878	54.2300	94.713	56.4525	42.992
65	125.484	52.1317	102.209	54.1258	47.366
66	142.241	53.2856	117.559	53.0716	53.978
67	144.777	53.3082	139.738	54.6489	57.008
68	143.957	50.5257	147.704	48.8437	62.948
69	150.793	51.8599	153.640	43.5318	69.953
70	144.523	50.4237	177.559	38.6704	74.116
71	138.087	46.8967	184.316	36.3054	76.538
72	156.416	57.0053	183.652	33.6146	82.093
73	182.198	55.4861	180.767	30.0997	90.531
74	190.226	41.9279	184.174	23.0166	88.539
75	170.441	47.3470	159.685	22.0770	93.281
76	174.344	46.9197	156.802	17.9087	95.417
77	190.502	50.9114	149.159	21.2864	97.045
78	207.436	49.3107	160.642	22.9285	102.687
79	220.888	40.6439	165.061	24.5807	103.633
80	215.035	31.7473	158.487	24.2493	104.330
81	219.638	29.4517	152.124	21.1479	107.714
82	194.516	28.9261	149.802	19.3994	104.283
83	188.381	26.5842	139.218	18.9469	100.232
84	234.849	24.2130	138.809	19.4847	103.043
85	247.634	21.2188	118.719	16.5775	103.515
86	256.463	0.0	0.0	0.0	0.0
87	279.400	0.0	0.0	0.0	0.0
88	319.185	14.8	126.9	17.7	114.2
89	342.724	0.0	0.0	0.0	0.0
90	348.649	0.0	0.0	0.0	0.0

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=ELECTRONIC

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	45.373	31.2606	38.844	43.6486	25.510
59	52.959	30.0135	43.708	42.8218	31.954
60	55.674	32.0766	46.530	41.8868	32.853
61	58.366	29.3666	46.886	37.3255	33.266
62	65.947	32.6969	54.303	36.4030	38.974
63	68.491	32.5012	59.012	36.6301	41.575
64	71.163	33.2038	62.917	36.7393	44.599
65	81.005	34.4461	71.805	39.8401	52.286
66	92.002	35.4326	83.060	41.4935	61.277
67	94.948	35.2079	95.555	44.0821	63.731
68	99.931	36.0285	103.035	39.6025	70.420
69	104.631	40.5546	112.286	34.5931	77.030
70	100.426	37.9919	119.002	25.9548	79.555
71	98.299	37.8643	124.748	20.2349	78.786
72	109.717	44.0142	122.294	21.2288	84.118
73	123.581	40.4358	115.403	21.8140	88.765
74	119.148	27.6322	108.804	17.6040	84.452
75	104.408	30.6520	96.803	13.0225	80.988
76	114.199	33.4915	98.097	14.1259	80.901
77	132.569	37.5740	95.462	15.9305	85.467
78	145.136	38.7943	101.560	14.2270	88.896
79	157.036	29.0914	105.362	15.5974	93.216
80	161.208	22.4283	106.402	12.2299	92.750
81	165.822	19.8297	102.147	12.3097	95.628
82	165.937	20.0077	105.117	11.5092	98.537
83	171.755	18.8746	110.202	12.5194	99.570
84	199.889	16.6433	110.539	11.7205	111.953
85	199.194	14.8023	101.609	10.6108	111.991
86	199.861	0.0000	0.000	0.0000	0.000
87	215.137	0.0000	0.000	0.0000	0.000
88	228.237	12.7000	84.600	7.1000	108.700
89	229.939	0.0000	0.000	0.0000	0.000
90	231.748	0.0000	0.000	0.0000	0.000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=TRANSP EQUIP

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	144.332	49.7548	63.016	95.970	47.887
59	162.580	46.1677	66.217	96.281	54.305
60	168.045	47.7919	69.211	100.829	56.752
61	155.210	46.6138	72.775	97.638	55.547
62	178.303	45.1678	78.888	101.020	62.644
63	193.054	43.0403	82.729	96.888	66.563
64	202.912	46.7645	95.381	102.948	68.695
65	234.396	45.5764	102.941	103.709	77.078
66	249.566	44.2880	113.232	99.986	76.986
67	245.305	43.3523	124.398	96.766	85.118
68	274.419	46.4300	138.624	95.284	99.057
69	272.374	52.3925	140.240	84.253	100.866
70	228.294	47.5482	145.283	71.640	94.828
71	249.949	48.4465	157.649	71.327	99.452
72	261.760	62.2651	153.847	67.147	102.696
73	299.722	61.8385	144.324	59.041	110.534
74	265.546	46.6886	152.802	52.286	97.158
75	243.706	49.0802	139.133	48.352	94.734
76	279.192	53.7275	152.102	51.702	101.162
77	305.455	57.3700	145.555	52.694	106.030
78	321.130	57.6946	155.745	50.495	108.399
79	315.848	48.8224	151.742	50.539	109.090
80	262.826	39.4991	134.116	47.598	102.251
81	256.419	35.6240	125.969	47.735	102.669
82	238.318	32.8823	117.262	42.909	98.322
83	270.106	32.8389	135.193	48.311	103.939
84	313.099	28.1721	135.430	51.444	114.241
85	322.966	25.6651	123.357	47.935	117.839
86	329.546	0.0000	0.000	0.000	0.000
87	351.494	0.0000	0.000	0.000	0.000
88	364.778	31.2000	138.300	36.200	127.200
89	365.235	0.0000	0.000	0.000	0.000
90	348.995	0.0000	0.000	0.000	0.000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=INSTRUMENTS

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	13.0851	8.8144	7.8396	18.6023	5.0450
59	14.9082	8.6047	8.3594	17.4182	5.8920
60	15.2865	8.8540	8.5513	15.8932	6.2594
61	14.9221	8.5915	9.0808	14.7071	6.7234
62	14.7764	9.8971	10.7855	15.0976	7.1189
63	15.4882	8.4672	10.0188	13.0010	6.6366
64	16.3950	8.1997	10.1293	12.1544	7.2941
65	18.6663	8.5380	11.7062	13.7957	8.1507
66	20.6128	7.6222	11.9706	12.7129	8.9804
67	22.1688	9.0228	16.2645	22.9994	9.7674
68	23.5847	8.8115	14.8377	15.7958	10.9803
69	25.1291	12.4203	17.4574	22.1195	12.4098
70	24.1572	12.8336	20.4661	17.3282	13.4193
71	24.8107	13.9493	22.2726	20.3116	13.7790
72	27.7339	18.8197	21.3615	20.5153	14.8854
73	31.6996	17.4438	18.4818	16.3157	15.8641
74	34.0626	15.3539	19.9196	15.7911	15.4212
75	32.2282	15.7516	18.9687	13.4752	16.8727
76	34.9388	16.3182	21.6295	13.9936	17.2561
77	38.5257	19.0602	24.5401	6.4605	18.7055
78	42.8871	17.6195	22.7096	8.8434	19.3385
79	43.9584	11.6271	23.2701	20.3112	19.9305
80	44.1421	9.6837	24.3463	21.0968	20.4270
81	45.8945	8.9874	23.9188	18.7309	20.9073
82	48.3253	8.7852	24.9629	19.8178	21.6611
83	47.0845	8.6645	27.6433	22.7669	22.5714
84	49.7924	7.5629	29.1393	23.8297	24.9304
85	51.1518	6.6025	26.6744	21.0712	25.0103
86	51.8641	0.0000	0.0000	0.0000	0.0000
87	54.8743	0.0000	0.0000	0.0000	0.0000
88	59.2865	8.6000	32.0000	21.5000	48.9000
89	60.6405	0.0000	0.0000	0.0000	0.0000
90	61.5025	0.0000	0.0000	0.0000	0.0000

Table E-22C. Manufacturing Consumption and Output, 1958-1990

SIC=MISC MFG

YEAR	OUTPUT	QOIL	QNATGAS	QCOAL	QELEC
58	13.9146	14.0793	10.6963	10.0428	4.5141
59	15.1558	12.0019	9.1356	8.5161	5.2272
60	15.5411	11.8508	8.3631	7.9713	5.3978
61	16.0854	9.6144	7.1060	6.5971	5.3159
62	16.9291	11.6186	8.7877	7.4991	6.4487
63	17.8649	10.1786	8.5923	5.6601	7.8511
64	18.9604	9.9971	8.9602	4.6458	8.2742
65	20.7133	9.9806	10.0584	4.2290	8.6324
66	21.6439	12.8059	14.6301	4.6917	8.2196
67	22.0478	12.8052	16.5188	4.1106	8.3970
68	23.2608	13.8004	17.9511	3.9427	9.5571
69	24.5258	14.6388	17.9153	3.4088	11.2665
70	23.6673	15.1920	20.7458	3.0667	11.2290
71	23.9065	15.6012	22.6634	2.8104	12.7268
72	28.5771	19.5292	24.5167	2.8543	14.2588
73	28.5771	16.2684	21.4962	2.3016	14.2725
74	26.5282	11.6293	22.1265	1.6290	13.5014
75	24.4793	12.0196	19.1418	0.8788	13.0271
76	27.8222	12.6700	17.7183	1.3491	12.6996
77	31.7044	12.0417	17.2893	1.3805	14.0678
78	32.3514	12.1201	18.7511	1.2618	13.6108
79	30.7339	9.9763	19.5549	1.3623	12.6029
80	27.9301	7.7559	19.6104	1.6775	12.3545
81	28.6849	6.0984	18.6637	1.9596	12.3883
82	28.2536	4.9170	16.4249	1.6340	12.4627
83	26.8517	5.0938	17.6174	2.0981	12.3763
84	27.1752	4.3240	18.3814	1.6749	12.6548
85	26.2047	3.6127	15.6577	1.4098	11.8939
86	26.6360	0.0	0.0	0.0	0.0
87	30.7339	0.0	0.0	0.0	0.0
88	31.9201	3.3	19.6	1.8	14.3
89	32.2436	0.0	0.0	0.0	0.0
90	32.1358	0.0	0.0	0.0	0.0

Table E-22D. Manufacturing Prices, 1958-1990

Sources: Prices: [97]

Notes: All dollar values are expressed in constant 1987 dollars. Prices are per million Btu.

The mnemonics are as follows: NATGAS and NATGS--Natural Gas; COAL--Coal; ELEC--Electricity; OIL--All Oil Products; DOL87--Deflator for 1987 Dollars

SIC=FOOD

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.18053	1.39057	1.23994	16.2434
59	3.90625	2.17615	1.45144	1.23367	16.1788
60	3.84615	2.14240	1.48710	1.16515	16.8922
61	3.80228	2.16616	1.53369	1.14061	14.6831
62	3.71747	2.10078	1.55297	1.09737	15.4348
63	3.67647	2.05830	1.52812	1.07445	15.5591
64	3.61011	1.90852	1.46057	1.04509	15.2681
65	3.52113	1.83342	1.41899	0.97156	14.9603
66	3.40136	1.80959	1.36444	0.95192	15.1576
67	3.30033	1.82586	1.31762	0.92597	12.5342
68	3.14465	1.80220	1.28322	0.90906	11.2621
69	2.95858	1.73800	1.23746	0.90752	10.4675
70	2.84091	1.87293	1.22207	1.03611	10.1329
71	2.84091	2.09973	1.27207	1.11538	10.3578
72	2.57732	2.26160	1.38444	0.98720	10.1165
73	2.42131	2.71380	1.54447	0.93772	10.0526
74	2.22717	4.51188	1.67305	1.38558	11.1218
75	2.03252	4.39950	2.16233	1.74866	12.3481
76	1.91205	4.24397	2.63213	1.81665	12.9487
77	1.78891	4.31622	3.04743	1.79724	13.7679
78	1.66113	4.01271	3.17615	1.81663	14.5950
79	1.52439	4.82072	3.46803	1.69475	14.8783
80	1.39470	5.85006	3.96276	1.72964	15.8163
81	1.26743	6.41837	4.35641	1.78296	16.4534
82	1.19332	6.23400	4.48819	1.80232	16.7583
83	1.14811	5.94439	4.25820	1.69327	17.9321
84	1.09890	6.12488	4.28582	1.65542	17.1742
85	1.05932	5.73922	4.42153	1.69222	17.0351
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	3.42011	2.80347	1.48362	14.3931
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=TOBACCO

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.48049	1.88591	1.45625	15.3211
59	3.90625	2.38274	1.90522	1.43650	15.1848
60	3.84615	2.38601	1.89236	1.34489	15.8429
61	3.80228	2.34994	1.89152	1.30315	13.5768
62	3.71747	2.28613	1.86296	1.24151	14.2813
63	3.67647	2.23022	1.82608	1.24617	14.1661
64	3.61011	2.06454	1.74522	1.23815	13.6490
65	3.52113	1.87487	1.68903	1.18101	13.1360
66	3.40136	1.83826	1.61744	1.18439	13.1603
67	3.30033	1.84464	1.55530	1.17616	10.3668
68	3.14465	1.79205	1.53960	1.29928	9.4104
69	2.95858	1.65755	1.50727	1.41362	8.9248
70	2.84091	1.74793	1.50771	1.66563	8.8438
71	2.84091	1.97404	1.58420	1.86335	9.2606
72	2.57732	2.03681	1.58320	1.69095	9.6696
73	2.42131	2.40475	1.65314	1.61858	10.1478
74	2.22717	4.17853	1.69940	2.01479	11.6826
75	2.03252	4.26456	2.26869	2.58012	13.5151
76	1.91205	4.11226	2.58894	2.59787	13.3610
77	1.78891	4.29533	3.21467	2.37292	13.7572
78	1.66113	3.76045	3.49010	2.15254	13.9617
79	1.52439	4.09378	3.57946	2.53529	14.1676
80	1.39470	5.45185	4.45395	2.48648	15.8469
81	1.26743	6.25194	4.90507	2.50647	14.1060
82	1.19332	5.90603	5.05251	2.48493	14.6894
83	1.14811	5.56957	4.81461	2.22729	14.8938
84	1.09890	5.73971	4.88320	2.15600	15.2431
85	1.05932	5.11391	5.00882	2.12455	15.1233
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	2.86657	3.33333	1.96532	13.4489
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=TEXTILE MILLS

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	1.80914	1.39283	1.43040	11.2760
59	3.90625	1.83424	1.45361	1.40840	11.1181
60	3.84615	1.81840	1.48745	1.31541	11.7823
61	3.80228	1.86889	1.53376	1.27180	9.5659
62	3.71747	1.83892	1.55422	1.20903	10.3806
63	3.67647	1.79092	1.53300	1.21896	10.6770
64	3.61011	1.64767	1.47169	1.21750	10.6572
65	3.52113	1.58356	1.43473	1.16654	10.5898
66	3.40136	1.57361	1.38643	1.17540	11.0745
67	3.30033	1.57582	1.34964	1.17230	8.6952
68	3.14465	1.60377	1.36154	1.18659	8.0048
69	2.95858	1.54245	1.34543	1.20520	7.6786
70	2.84091	1.71779	1.35940	1.36281	7.7712
71	2.84091	1.97544	1.44178	1.47098	8.2659
72	2.57732	2.14205	1.54489	1.65140	8.4858
73	2.42131	2.59399	1.70100	1.87213	8.6819
74	2.22717	4.35864	1.81471	2.51159	10.0118
75	2.03252	4.24037	2.20400	2.92195	11.7162
76	1.91205	4.06497	2.67275	2.30689	11.8415
77	1.78891	4.28351	3.15053	2.29998	12.4336
78	1.66113	3.95365	3.38180	2.62841	12.8998
79	1.52439	4.54560	3.79294	2.44313	13.0369
80	1.39470	5.77032	4.22756	2.38792	13.3459
81	1.26743	6.41058	4.82043	2.31378	13.7726
82	1.19332	6.12640	4.93252	2.35561	14.8334
83	1.14811	5.82390	4.66768	2.16562	14.7275
84	1.09890	6.03597	4.69360	2.14340	15.0391
85	1.05932	5.51506	4.78677	2.16470	14.7687
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	3.12356	3.27553	1.86898	13.4200
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=APPAREL & OTHER

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.37164	1.84284	1.60926	21.0352
59	3.90625	2.39780	1.88405	1.56260	20.8084
60	3.84615	2.38579	1.89313	1.43949	21.2708
61	3.80228	2.43763	1.91637	1.37095	18.8291
62	3.71747	2.38384	1.91502	1.28120	19.2926
63	3.67647	2.35673	1.89075	1.27309	19.3848
64	3.61011	2.21701	1.82112	1.25338	19.0266
65	3.52113	2.16077	1.78023	1.18610	18.6300
66	3.40136	2.15092	1.72005	1.18215	18.7006
67	3.30033	2.29523	1.66954	1.16908	15.9698
68	3.14465	2.17733	1.59401	1.19447	14.2543
69	2.95858	2.05037	1.50103	1.21240	12.9276
70	2.84091	2.06042	1.45228	1.35322	12.1695
71	2.84091	2.15746	1.46896	1.43782	12.0096
72	2.57732	2.40119	1.61965	1.54571	11.5158
73	2.42131	2.92330	1.81003	1.72036	11.0678
74	2.22717	4.81384	1.94440	2.33862	11.7582
75	2.03252	4.52717	2.33386	3.12187	12.4861
76	1.91205	4.41007	2.84439	2.97103	13.1369
77	1.78891	4.61766	3.20942	2.71570	14.7692
78	1.66113	4.50566	3.27606	2.75307	17.9981
79	1.52439	5.47883	3.58895	2.84666	19.0398
80	1.39470	6.85334	3.83801	2.76599	19.6355
81	1.26743	7.33415	4.10230	2.67939	19.6749
82	1.19332	7.18956	4.52804	2.70022	20.9187
83	1.14811	6.78784	4.60733	2.45589	22.2557
84	1.09890	7.07441	4.90318	2.41523	19.2461
85	1.05932	6.59218	5.28748	2.42335	20.6466
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	4.43443	4.02697	2.19653	19.4220
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=LUMBER & WOOD

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.84727	1.90367	1.49691	16.4322
59	3.90625	2.87991	1.86270	1.47688	16.2930
60	3.84615	2.89339	1.78796	1.38073	16.9586
61	3.80228	2.94812	1.72713	1.33457	14.6990
62	3.71747	2.89451	1.63509	1.27163	15.3939
63	3.67647	2.78150	1.60906	1.27042	15.3546
64	3.61011	2.57387	1.54071	1.25634	14.9109
65	3.52113	2.43850	1.49826	1.19318	14.4938
66	3.40136	2.35511	1.44199	1.18989	14.5755
67	3.30033	2.31206	1.39438	1.17562	11.8249
68	3.14465	2.25926	1.35743	1.24488	10.7523
69	2.95858	2.17801	1.30946	1.31406	10.1600
70	2.84091	2.30483	1.29401	1.52002	9.9919
71	2.84091	2.49228	1.34689	1.67253	10.3782
72	2.57732	2.55086	1.43302	1.70255	9.3661
73	2.42131	2.94407	1.56684	1.80824	8.6138
74	2.22717	4.76847	1.67117	2.35860	9.0932
75	2.03252	4.52959	2.14320	3.45439	10.4677
76	1.91205	4.58466	2.65694	2.91186	10.9399
77	1.78891	4.89015	3.06831	2.30746	11.8604
78	1.66113	4.65902	3.31125	2.15693	12.6557
79	1.52439	5.75499	3.53237	2.60555	12.9452
80	1.39470	7.10914	3.94643	2.58542	14.1157
81	1.26743	7.92077	4.53233	2.46905	14.7508
82	1.19332	7.61662	4.74762	2.47971	14.9518
83	1.14811	6.94865	4.57222	2.24922	15.2487
84	1.09890	6.93875	4.67300	2.18835	15.2795
85	1.05932	6.42184	4.82796	2.17300	15.2961
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	4.78011	3.44894	1.65703	15.5106
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=FURNITURE & FIXTURES

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.84790	1.96490	1.59391	20.0560
59	3.90625	2.82455	2.03708	1.51624	19.6797
60	3.84615	2.74410	2.07517	1.36757	20.0772
61	3.80228	2.68151	2.12858	1.27350	17.5494
62	3.71747	2.52195	2.14753	1.16055	17.9426
63	3.67647	2.50347	2.14695	1.16560	18.0281
64	3.61011	2.39430	2.08850	1.16620	17.6135
65	3.52113	2.33697	2.05263	1.11509	17.2200
66	3.40136	2.34860	2.00199	1.12480	17.2757
67	3.30033	2.37723	1.96035	1.12330	14.5556
68	3.14465	2.26254	1.85625	1.19011	13.0618
69	2.95858	2.08279	1.74884	1.25338	12.0909
70	2.84091	2.09130	1.67181	1.44336	11.4930
71	2.84091	2.19396	1.69224	1.57762	11.5833
72	2.57732	2.40082	1.72172	1.79740	11.2613
73	2.42131	2.89933	1.86141	2.06977	11.2248
74	2.22717	4.79661	1.94760	2.75813	12.3284
75	2.03252	4.59550	2.34732	3.13052	13.4622
76	1.91205	4.76260	2.83301	2.68975	14.3306
77	1.78891	4.92247	3.10942	2.50565	15.3032
78	1.66113	4.75951	3.31244	2.64014	16.4655
79	1.52439	5.85885	3.58301	2.59147	17.0277
80	1.39470	7.14550	4.06754	2.51889	17.6370
81	1.26743	7.63389	4.46899	2.42216	18.1374
82	1.19332	7.41556	4.82041	2.47366	19.0715
83	1.14811	6.93617	4.78968	2.26985	19.0732
84	1.09890	7.02606	5.00982	2.27645	19.2665
85	1.05932	6.69815	5.31860	2.32028	19.3563
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	4.51399	3.75723	2.10019	17.2254
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=PAPER

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	1.73778	0.97467	1.37225	10.7010
59	3.90625	1.69868	1.03396	1.36508	10.5837
60	3.84615	1.62396	1.07406	1.28980	11.2774
61	3.80228	1.62117	1.12085	1.26197	9.1322
62	3.71747	1.53986	1.14484	1.21285	9.9591
63	3.67647	1.51745	1.13614	1.19804	10.1725
64	3.61011	1.39703	1.08678	1.17352	10.0438
65	3.52113	1.36161	1.06262	1.10120	9.8961
66	3.40136	1.36535	1.02896	1.08767	10.2997
67	3.30033	1.41119	1.00027	1.06478	7.8403
68	3.14465	1.39722	1.00146	1.05284	7.0902
69	2.95858	1.31487	0.99190	1.05188	6.8240
70	2.84091	1.51094	1.00507	1.18673	6.9257
71	2.84091	1.78865	1.07140	1.27194	7.4007
72	2.57732	1.99568	1.19680	1.34611	7.3690
73	2.42131	2.50735	1.35948	1.47712	7.4146
74	2.22717	4.35971	1.48994	2.05253	8.6452
75	2.03252	3.67305	1.98248	2.36495	9.8762
76	1.91205	3.45525	2.47463	2.08505	10.0296
77	1.78891	3.68935	2.95141	1.94796	10.8695
78	1.66113	3.30001	3.13086	2.28750	11.1734
79	1.52439	4.02967	3.41730	2.27003	11.6994
80	1.39470	5.06718	3.92447	2.18881	12.4568
81	1.26743	6.01165	4.38170	2.18808	12.9744
82	1.19332	5.60209	4.40207	2.17344	13.6139
83	1.14811	5.24780	4.10107	1.95108	13.7610
84	1.09890	5.36860	4.06140	1.89181	15.6782
85	1.05932	4.71030	4.08137	1.86930	14.0740
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	2.45308	2.38921	1.71484	11.4355
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=PRINTING

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.48786	1.93620	1.69375	19.6616
59	3.90625	2.52273	2.04471	1.68889	19.4780
60	3.84615	2.52109	2.11686	1.59837	20.0228
61	3.80228	2.55786	2.20414	1.56547	17.6618
62	3.71747	2.49630	2.25443	1.50895	18.2333
63	3.67647	2.42423	2.25378	1.49701	18.2445
64	3.61011	2.24467	2.20385	1.46453	17.8242
65	3.52113	2.12971	2.17856	1.38139	17.3746
66	3.40136	2.07506	2.12961	1.36875	17.4136
67	3.30033	2.05614	2.09029	1.34031	14.6493
68	3.14465	2.02997	1.99347	1.42753	13.2475
69	2.95858	1.95883	1.88184	1.50821	12.3072
70	2.84091	2.12492	1.81757	1.73021	11.8723
71	2.84091	2.38126	1.84411	1.89861	12.0701
72	2.57732	2.52222	1.83829	1.66231	11.8569
73	2.42131	2.97590	1.91408	1.53180	11.8632
74	2.22717	4.88703	1.95537	1.88266	12.9488
75	2.03252	4.86126	2.43974	2.59497	13.6166
76	1.91205	4.98185	2.95416	2.71571	14.4206
77	1.78891	4.94861	3.29117	2.30267	15.2956
78	1.66113	4.80858	3.46935	2.16116	16.8843
79	1.52439	5.40348	3.81223	2.07538	18.1096
80	1.39470	6.55299	4.17480	2.06094	18.8774
81	1.26743	7.02978	4.54848	2.43226	19.4055
82	1.19332	7.00013	4.87466	2.44676	20.5378
83	1.14811	6.76606	4.78963	2.22218	20.6451
84	1.09890	7.22048	4.98769	2.16621	20.3565
85	1.05932	7.62808	5.24307	2.16161	19.8174
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	4.84739	3.86320	0.00000	18.0925
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=BULK CHEMICALS

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.07619	0.81891	1.13429	5.5979
59	3.90625	2.01939	0.85831	1.11523	5.7052
60	3.84615	1.94083	0.88194	1.04020	6.7256
61	3.80228	1.91037	0.91315	1.00681	4.7474
62	3.71747	1.79203	0.92594	0.95554	5.8945
63	3.67647	1.75407	0.91426	0.94638	6.5060
64	3.61011	1.61439	0.86469	0.93335	6.8062
65	3.52113	1.53276	0.84198	0.87730	7.0328
66	3.40136	1.51727	0.81028	0.87105	7.8520
67	3.30033	1.53182	0.78544	0.86025	5.7658
68	3.14465	1.54094	0.78415	0.86712	5.2923
69	2.95858	1.47968	0.77594	0.88871	5.3237
70	2.84091	1.63885	0.78520	1.03806	5.6331
71	2.84091	1.86904	0.84202	1.13804	6.2299
72	2.57732	2.04499	0.96959	1.21811	6.0028
73	2.42131	2.50028	1.12298	1.34975	5.9306
74	2.22717	4.27595	1.26081	1.95042	7.1049
75	2.03252	4.16817	1.60689	2.04658	8.2622
76	1.91205	3.87892	2.00456	1.94223	8.4814
77	1.78891	4.02137	2.38650	1.87672	9.2857
78	1.66113	3.58489	2.44597	2.16456	10.1971
79	1.52439	4.36452	2.57246	2.04353	10.6376
80	1.39470	5.64094	2.81143	1.98048	11.6884
81	1.26743	6.44256	3.17908	2.01911	12.6631
82	1.19332	6.03350	3.34613	2.01343	14.5786
83	1.14811	5.63653	3.20356	1.80649	13.2007
84	1.09890	5.75670	3.21153	1.75087	12.7187
85	1.05932	5.21414	3.35774	1.73691	12.6192
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	2.66121	1.89783	1.57033	10.2312
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=OTHER CHEMICALS

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	1.77753	1.22066	1.24900	15.0168
59	3.90625	1.80041	1.26137	1.22566	14.9934
60	3.84615	1.78105	1.28239	1.14216	15.6899
61	3.80228	1.82973	1.31271	1.10297	13.4525
62	3.71747	1.79397	1.31467	1.04409	14.2296
63	3.67647	1.76117	1.30414	1.06632	14.4077
64	3.61011	1.62786	1.25090	1.07447	14.1710
65	3.52113	1.57968	1.22297	1.03196	13.9402
66	3.40136	1.57200	1.18587	1.04018	14.2161
67	3.30033	1.60700	1.15593	1.03780	11.6063
68	3.14465	1.59137	1.13884	1.04763	10.5800
69	2.95858	1.52543	1.11327	1.06237	10.0028
70	2.84091	1.67781	1.11378	1.20929	9.9289
71	2.84091	1.92059	1.18003	1.30268	10.3843
72	2.57732	2.12264	1.30142	1.29177	10.5076
73	2.42131	2.59864	1.45949	1.34415	10.7885
74	2.22717	4.33997	1.60967	1.85699	12.2214
75	2.03252	4.38562	2.01907	2.40205	13.4782
76	1.91205	4.07996	2.39947	2.13613	13.9123
77	1.78891	4.17519	2.88400	2.01499	14.7682
78	1.66113	3.86403	3.16826	2.23312	15.3330
79	1.52439	4.87191	3.29396	2.30017	14.9729
80	1.39470	6.29602	3.66854	2.21677	16.7865
81	1.26743	6.80017	4.15066	2.20072	17.1567
82	1.19332	6.30595	4.07633	2.17958	18.6934
83	1.14811	5.79801	3.75338	1.95047	18.3927
84	1.09890	5.77671	3.66449	1.88775	17.8474
85	1.05932	4.98726	3.67531	1.86322	17.3856
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	3.07696	1.89788	1.57033	10.2312
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=SIC 29, COAL & MISC

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.43076	1.39757	1.22466	18.4993
59	3.90625	2.37623	1.44459	1.22261	18.4341
60	3.84615	2.27950	1.46773	1.15712	19.1408
61	3.80228	2.25201	1.50306	1.13557	16.9744
62	3.71747	2.14115	1.51275	1.09544	17.7999
63	3.67647	2.10318	1.48025	1.09522	18.2005
64	3.61011	1.96305	1.40928	1.08705	18.1641
65	3.52113	1.90422	1.36476	1.03388	18.0883
66	3.40136	1.88344	1.30810	1.03550	18.4725
67	3.30033	1.90695	1.25920	1.02875	16.0282
68	3.14465	1.87881	1.23703	1.14078	14.3616
69	2.95858	1.81143	1.20114	1.24773	13.1525
70	2.84091	1.95044	1.19261	1.48122	12.4794
71	2.84091	2.17015	1.24784	1.66785	12.4956
72	2.57732	2.29310	1.35419	1.44932	12.0970
73	2.42131	2.71365	1.51146	1.32556	11.9527
74	2.22717	4.48257	1.62927	1.68712	12.9065
75	2.03252	4.44998	1.96692	1.43102	14.0321
76	1.91205	4.38317	2.54520	2.05452	14.8676
77	1.78891	4.47914	3.06229	2.02098	16.0012
78	1.66113	4.33908	3.20044	2.15230	16.9612
79	1.52439	5.37459	3.44615	1.98341	16.3682
80	1.39470	6.60037	3.89219	1.65786	18.2430
81	1.26743	6.81480	4.17487	1.66493	19.3909
82	1.19332	7.30509	4.42864	1.66805	18.3269
83	1.14811	6.65715	4.30754	1.51182	19.3906
84	1.09890	6.55680	4.47498	1.47874	19.6794
85	1.05932	5.89561	4.67065	1.47349	19.8707
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	4.19912	2.01349	1.95568	11.9557
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=RUBBER & MISC

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.45127	1.33043	1.09565	13.9067
59	3.90625	2.31772	1.41964	1.09405	13.8582
60	3.84615	2.14413	1.48356	1.03677	14.6197
61	3.80228	2.03413	1.55746	1.01983	12.4519
62	3.71747	1.84407	1.60287	0.98494	13.2683
63	3.67647	1.80481	1.61204	0.98410	13.5363
64	3.61011	1.66308	1.57673	0.97804	13.3987
65	3.52113	1.59269	1.56590	0.92726	13.2486
66	3.40136	1.57708	1.53849	0.92785	13.6137
67	3.30033	1.59740	1.51748	0.92086	11.1417
68	3.14465	1.63394	1.46919	0.90122	10.0644
69	2.95858	1.60646	1.40832	0.89723	9.4629
70	2.84091	1.78819	1.38210	1.02349	9.2843
71	2.84091	2.03498	1.42806	1.09993	9.6260
72	2.57732	2.12159	1.49370	1.09071	9.8117
73	2.42131	2.50780	1.61769	1.14452	10.1038
74	2.22717	4.22304	1.71217	1.66969	11.4792
75	2.03252	4.16562	2.13714	2.17313	12.7392
76	1.91205	3.98025	2.59915	1.79763	13.1626
77	1.78891	4.20133	3.05201	1.72737	13.9529
78	1.66113	3.96641	3.20479	2.04764	14.7007
79	1.52439	4.53436	3.52681	1.92566	15.2352
80	1.39470	5.78022	4.00381	1.74040	16.2215
81	1.26743	6.71893	4.50311	1.72524	16.9395
82	1.19332	6.43263	4.64289	1.86790	13.2745
83	1.14811	6.07610	4.42476	1.82589	13.2734
84	1.09890	6.26463	4.48465	1.90559	15.3576
85	1.05932	5.83866	4.60217	2.01785	15.2829
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	3.22645	3.03468	2.17726	15.2023
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=LEATHER

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	1.98783	1.59388	1.25731	21.7624
59	3.90625	1.97460	1.71732	1.30918	21.3296
60	3.84615	1.92161	1.78710	1.29801	21.6125
61	3.80228	1.93813	1.85325	1.32641	19.1494
62	3.71747	1.86681	1.87695	1.33203	19.5447
63	3.67647	1.79954	1.89752	1.31278	19.3337
64	3.61011	1.63734	1.87250	1.28690	18.7190
65	3.52113	1.55200	1.86602	1.21168	18.0908
66	3.40136	1.51841	1.83578	1.20037	18.0619
67	3.30033	1.52708	1.80673	1.17939	15.0860
68	3.14465	1.58281	1.73250	1.12876	13.8417
69	2.95858	1.58609	1.66453	1.08758	12.9852
70	2.84091	1.77756	1.66000	1.18087	12.5816
71	2.84091	1.99136	1.68000	1.24311	12.8821
72	2.57732	2.27394	1.71295	1.04857	12.2812
73	2.42131	2.81828	1.82048	0.94303	11.9790
74	2.22717	4.62064	1.87772	1.36037	12.7814
75	2.03252	4.33467	2.10181	1.71396	13.6919
76	1.91205	4.27452	2.75533	1.45838	14.6211
77	1.78891	4.26669	3.20076	1.49398	16.9822
78	1.66113	4.03356	3.27574	2.05252	17.2816
79	1.52439	4.85809	3.52163	2.07575	18.6274
80	1.39470	5.95058	4.13555	2.03439	19.4922
81	1.26743	6.69867	4.56766	2.13456	20.2822
82	1.19332	6.39165	4.79029	2.10561	20.9395
83	1.14811	5.98558	4.62026	1.88028	20.7905
84	1.09890	6.14201	4.74722	1.79397	19.1912
85	1.05932	5.54431	4.94315	1.75771	19.7569
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	2.9332	3.37187	1.88825	17.5723
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=GLASS

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	1.96660	1.52798	1.17697	11.3170
59	3.90625	1.96690	1.57615	1.18150	11.0881
60	3.84615	1.94310	1.59733	1.12586	11.7174
61	3.80228	1.96996	1.63076	1.11241	9.4071
62	3.71747	1.91154	1.63614	1.08007	10.1197
63	3.67647	1.88685	1.61341	1.23449	10.4466
64	3.61011	1.75054	1.54720	1.37128	10.3891
65	3.52113	1.67119	1.50688	1.44400	10.3390
66	3.40136	1.66355	1.45236	1.57918	10.8267
67	3.30033	1.68827	1.40583	1.69032	8.4609
68	3.14465	1.77609	1.37580	1.52978	7.7310
69	2.95858	1.77615	1.33267	1.38477	7.4748
70	2.84091	1.96336	1.32124	1.39931	7.5756
71	2.84091	2.17908	1.37893	1.37096	8.1168
72	2.57732	2.34595	1.46000	1.19306	8.3519
73	2.42131	2.80993	1.59599	1.10553	8.6469
74	2.22717	4.61779	1.70169	1.51061	10.0607
75	2.03252	4.45072	2.13811	1.26768	11.3264
76	1.91205	4.22741	2.64283	2.16867	11.4230
77	1.78891	4.50887	3.18275	1.72368	12.6084
78	1.66113	4.16369	3.34227	2.47064	13.0039
79	1.52439	4.76221	3.61202	1.96845	12.7871
80	1.39470	6.10737	4.11703	2.02666	13.8993
81	1.26743	7.07889	4.45175	2.07614	14.5838
82	1.19332	6.91713	4.59790	2.10478	15.6389
83	1.14811	6.52879	4.37556	1.93150	15.8597
84	1.09890	6.67536	4.42429	1.91644	15.4363
85	1.05932	6.45782	4.54064	1.93202	15.4972
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	4.21965	2.64933	1.47399	11.8497
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=CEMENT

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	1.21861	1.04107	1.23192	10.1979
59	3.90625	1.33829	1.05800	1.21842	10.2066
60	3.84615	1.42436	1.05713	1.14364	11.0834
61	3.80228	1.57878	1.06483	1.11259	9.0117
62	3.71747	1.64954	1.05218	1.06339	9.9594
63	3.67647	1.62390	1.02939	1.05013	10.3293
64	3.61011	1.49909	0.96779	1.03071	10.3147
65	3.52113	1.45847	0.93217	0.96656	10.3063
66	3.40136	1.45751	0.88965	0.95556	10.8333
67	3.30033	1.49846	0.85258	0.93780	8.5046
68	3.14465	1.38712	0.86036	0.93908	7.6646
69	2.95858	1.22438	0.85827	0.95309	7.3106
70	2.84091	1.31959	0.87609	1.09744	7.3203
71	2.84091	1.49635	0.94430	1.19186	7.7638
72	2.57732	1.56516	1.01037	1.16604	7.7452
73	2.42131	1.92974	1.11599	1.20750	7.8078
74	2.22717	3.63223	1.21346	1.71873	9.0414
75	2.03252	3.61057	1.77110	1.91861	10.6146
76	1.91205	3.29073	2.11201	1.78715	11.3793
77	1.78891	3.43008	2.56851	1.70314	12.2493
78	1.66113	3.23121	2.70924	1.97725	12.6418
79	1.52439	3.83992	3.42470	1.92075	12.8654
80	1.39470	4.86968	3.57083	2.00223	14.3852
81	1.26743	5.65965	4.31742	2.02055	14.8448
82	1.19332	5.80089	4.39758	2.00421	15.8905
83	1.14811	5.73716	4.14433	1.79668	16.2567
84	1.09890	6.07241	4.15111	1.73917	15.8811
85	1.05932	5.67780	4.21014	1.71619	14.8361
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	3.91731	1.99422	1.45472	11.8497
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=OTHER SCG

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.86546	1.47450	1.44678	15.5004
59	3.90625	2.74364	1.51252	1.40027	15.3699
60	3.84615	2.59049	1.52478	1.28495	16.0317
61	3.80228	2.49479	1.54900	1.21893	13.7701
62	3.71747	2.31300	1.54648	1.13519	14.4809
63	3.67647	2.32803	1.53207	1.11751	14.7590
64	3.61011	2.23208	1.47455	1.09214	14.6216
65	3.52113	2.20612	1.44257	1.02119	14.4646
66	3.40136	2.23181	1.39677	1.00590	14.8101
67	3.30033	2.28989	1.35825	0.98293	12.3249
68	3.14465	2.14649	1.32444	0.97602	11.0601
69	2.95858	1.97882	1.27864	0.98160	10.2754
70	2.84091	2.00507	1.26387	1.11912	9.9468
71	2.84091	2.11500	1.31613	1.20719	10.1696
72	2.57732	2.40331	1.44602	1.27667	10.2096
73	2.42131	2.96686	1.62353	1.40133	10.3882
74	2.22717	4.91556	1.76434	1.97376	11.6593
75	2.03252	4.84972	2.09505	2.40652	12.9800
76	1.91205	4.64091	2.49963	2.22001	13.5726
77	1.78891	4.72276	2.96180	2.04648	13.6868
78	1.66113	4.49492	3.16882	2.31713	14.3893
79	1.52439	5.77270	3.47429	2.15511	14.8117
80	1.39470	7.17695	3.92425	2.12774	15.9543
81	1.26743	7.87602	4.24299	2.08299	16.6514
82	1.19332	7.77752	4.37720	2.11315	17.5029
83	1.14811	7.28946	4.15413	1.93898	17.5111
84	1.09890	7.44092	4.20203	1.92192	17.2249
85	1.05932	7.05790	4.30876	1.94018	14.0689
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	3.79307	2.64933	1.47399	11.8497
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=IRON AND STEEL

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.13909	1.62190	1.11479	10.5731
59	3.90625	2.13297	1.64286	1.11032	10.5796
60	3.84615	2.08517	1.63657	1.04644	11.3167
61	3.80228	2.11008	1.64796	1.02781	9.1461
62	3.71747	2.05011	1.63647	0.99430	10.0657
63	3.67647	2.01187	1.62050	0.98730	10.2604
64	3.61011	1.86616	1.56202	0.97569	10.0576
65	3.52113	1.79450	1.52440	0.91709	9.8787
66	3.40136	1.77247	1.47402	0.91195	10.2491
67	3.30033	1.79147	1.43456	0.90258	7.7336
68	3.14465	1.74045	1.42453	0.86558	7.2887
69	2.95858	1.64103	1.39618	0.84857	7.2925
70	2.84091	1.75014	1.40229	0.95992	7.6265
71	2.84091	1.96873	1.48016	1.02606	8.3880
72	2.57732	2.24190	1.51816	1.20702	8.2295
73	2.42131	2.78971	1.61528	1.42220	8.1644
74	2.22717	4.60595	1.69196	2.08507	9.2645
75	2.03252	4.33118	2.11403	2.73328	10.9523
76	1.91205	3.76424	2.58224	2.13892	11.1426
77	1.78891	4.03185	3.09235	2.03031	12.2904
78	1.66113	3.80037	3.21294	2.01295	13.0738
79	1.52439	4.40985	3.36956	2.02542	13.1328
80	1.39470	5.44797	3.98236	2.05302	14.2912
81	1.26743	6.29050	4.15473	2.11232	14.5857
82	1.19332	5.87207	4.32153	2.16562	16.9315
83	1.14811	5.45516	4.13189	1.94739	16.8390
84	1.09890	5.53072	4.19362	1.95102	15.1731
85	1.05932	4.89388	4.32385	1.94555	14.7360
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	2.69921	2.56262	1.6763	11.0597
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=PRIMARY ALUMINUM

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.29549	0.67854	1.43229	4.2010
59	3.90625	2.27596	0.69811	1.36333	4.0951
60	3.84615	2.23227	0.70575	1.22781	4.9537
61	3.80228	2.21199	0.71884	1.14138	2.8407
62	3.71747	2.10475	0.71560	1.03855	3.8174
63	3.67647	2.06107	0.72886	1.08624	4.3421
64	3.61011	1.91152	0.70440	1.12438	4.5208
65	3.52113	1.80561	0.70451	1.11132	4.7386
66	3.40136	1.79733	0.69871	1.15361	5.5355
67	3.30033	1.83008	0.69543	1.18348	3.4424
68	3.14465	1.75747	0.67289	1.11216	2.9324
69	2.95858	1.65361	0.64622	1.05713	2.9443
70	2.84091	1.80136	0.63830	1.14207	3.2101
71	2.84091	2.01908	0.67242	1.18029	3.7362
72	2.57732	2.10809	0.80623	1.35835	3.2990
73	2.42131	2.49605	0.96225	1.57739	2.8865
74	2.22717	4.30090	1.10941	2.21973	3.8301
75	2.03252	4.35373	1.24982	3.71794	4.4234
76	1.91205	4.28424	1.42577	2.28795	4.7883
77	1.78891	4.27518	1.68533	1.91344	5.1535
78	1.66113	3.98658	2.03869	2.13318	5.7823
79	1.52439	4.50409	1.70902	2.17676	5.7626
80	1.39470	5.57516	2.26494	2.23085	6.3938
81	1.26743	6.55337	1.94222	2.31683	6.6354
82	1.19332	6.32749	2.69904	2.31250	8.3505
83	1.14811	5.98823	3.18621	2.08642	8.6437
84	1.09890	6.13837	3.79893	2.03276	8.3514
85	1.05932	5.70734	4.42576	.	7.4946
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	3.75080	2.56262	6.44509	11.0597
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=OTHER PRIMARY METALS

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.09399	1.54481	1.42256	10.6636
59	3.90625	2.06526	1.55697	1.36378	10.5472
60	3.84615	2.01902	1.54321	1.23814	11.2961
61	3.80228	2.02524	1.54233	1.16152	9.1003
62	3.71747	1.93529	1.51565	1.06781	9.9271
63	3.67647	1.90100	1.51253	1.07105	10.2222
64	3.61011	1.75659	1.46607	1.06688	10.1356
65	3.52113	1.67392	1.44469	1.01606	10.0596
66	3.40136	1.66826	1.40888	1.01933	10.5255
67	3.30033	1.68332	1.37973	1.01418	8.1385
68	3.14465	1.69454	1.34269	1.00655	7.3893
69	2.95858	1.64704	1.29375	1.01102	7.1208
70	2.84091	1.82277	1.27639	1.14868	7.2045
71	2.84091	2.08392	1.32666	1.23682	7.7146
72	2.57732	2.20130	1.39194	1.23545	7.8530
73	2.42131	2.61873	1.51171	1.29910	8.0524
74	2.22717	4.46071	1.60648	1.82457	9.3981
75	2.03252	4.38791	1.91186	3.01726	10.8408
76	1.91205	4.49896	2.27471	2.29975	10.6845
77	1.78891	4.44213	2.65388	1.96257	11.4718
78	1.66113	4.27206	2.76263	2.12671	12.0086
79	1.52439	4.86170	3.41841	2.15887	12.2040
80	1.39470	6.39257	3.81224	2.20462	12.9478
81	1.26743	6.80356	4.07682	2.24472	13.8860
82	1.19332	6.61203	4.31110	2.29743	14.6595
83	1.14811	6.18100	4.21118	2.18401	15.2599
84	1.09890	6.31821	4.36013	2.21240	14.5744
85	1.05932	6.11125	4.57287	2.23802	13.9411
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	3.27264	2.65896	1.69557	10.0096
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=FABRICATED METALS

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.36389	2.03334	1.39539	17.1609
59	3.90625	2.36808	2.07441	1.37251	17.1143
60	3.84615	2.34654	2.08211	1.27557	17.8352
61	3.80228	2.38238	2.10742	1.22604	15.6128
62	3.71747	2.30705	2.08755	1.15942	16.3613
63	3.67647	2.28410	2.07051	1.15830	16.4807
64	3.61011	2.14611	2.00480	1.14944	16.1509
65	3.52113	2.07383	1.96316	1.08835	15.7777
66	3.40136	2.06045	1.89972	1.08522	15.7382
67	3.30033	2.06880	1.85963	1.06793	12.8680
68	3.14465	1.98187	1.77945	1.07147	11.5119
69	2.95858	1.85374	1.68310	1.08038	10.8070
70	2.84091	1.94025	1.62763	1.22426	10.5455
71	2.84091	2.11954	1.66028	1.32026	10.8277
72	2.57732	2.30853	1.72174	1.44067	10.7304
73	2.42131	2.78699	1.84571	1.60488	10.8093
74	2.22717	4.74153	1.93229	2.23351	11.9951
75	2.03252	4.73163	2.38536	2.65665	13.5444
76	1.91205	4.70744	2.85509	2.41400	14.1464
77	1.78891	4.83792	3.26694	2.26991	14.7682
78	1.66113	4.58532	3.45173	2.54212	15.7970
79	1.52439	5.43307	3.66142	2.44894	16.3532
80	1.39470	6.80857	4.12596	2.32364	17.5904
81	1.26743	7.44609	4.31471	2.24741	18.3426
82	1.19332	7.29040	4.57928	2.32951	19.2559
83	1.14811	6.91197	4.49351	2.16504	19.7351
84	1.09890	7.16332	4.64566	2.16252	18.4990
85	1.05932	7.02123	4.87069	2.21102	18.5577
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	4.55635	3.46821	1.86898	16.7437
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=INDUSTRIAL MACHINERY

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.33114	1.89433	1.38406	17.3419
59	3.90625	2.33159	1.94776	1.35869	17.0330
60	3.84615	2.29041	1.97192	1.26993	17.6051
61	3.80228	2.29102	2.01669	1.23147	15.1385
62	3.71747	2.20595	2.02143	1.17281	15.5850
63	3.67647	2.13881	2.01757	1.15708	15.6727
64	3.61011	1.96143	1.95570	1.12986	15.2970
65	3.52113	1.87765	1.92560	1.06188	14.9664
66	3.40136	1.84780	1.87187	1.04986	15.1350
67	3.30033	1.85495	1.80902	1.02955	12.6049
68	3.14465	1.83918	1.71731	1.00803	11.4982
69	2.95858	1.76214	1.61684	0.99295	10.7881
70	2.84091	1.89881	1.56480	1.10954	10.5973
71	2.84091	2.10716	1.57724	1.16937	10.9691
72	2.57732	2.28323	1.64838	1.19126	10.8169
73	2.42131	2.74484	1.78517	1.25539	10.8576
74	2.22717	4.67137	1.87997	1.78945	11.9912
75	2.03252	4.69511	2.27314	2.12574	12.9665
76	1.91205	4.63494	2.78987	2.24479	13.6422
77	1.78891	4.75313	3.20330	2.04426	14.6787
78	1.66113	4.41289	3.41795	2.20826	15.5214
79	1.52439	5.23214	3.62849	2.02214	15.9392
80	1.39470	6.74631	4.02482	2.10688	16.8438
81	1.26743	7.19100	4.28741	2.01263	17.7922
82	1.19332	6.99294	4.55442	1.99359	18.9017
83	1.14811	6.59275	4.49769	1.79629	18.8254
84	1.09890	6.77670	4.66389	1.74213	19.5097
85	1.05932	6.45976	4.91037	1.71899	19.1991
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	4.31228	3.46821	1.52216	15.8478
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=ELECTRONIC

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.11687	1.99152	1.31143	14.2112
59	3.90625	2.13512	2.04837	1.28594	13.9313
60	3.84615	2.06433	2.07511	1.19691	14.5506
61	3.80228	2.12860	2.12010	1.15498	12.2409
62	3.71747	2.11421	2.13001	1.09156	12.8556
63	3.67647	2.06816	2.07369	1.09190	12.9929
64	3.61011	1.91457	1.97012	1.08315	12.7164
65	3.52113	1.82133	1.89599	1.03124	12.4761
66	3.40136	1.79064	1.80181	1.03172	12.7641
67	3.30033	1.78682	1.71728	1.02217	10.1944
68	3.14465	1.79857	1.64688	0.98693	9.3602
69	2.95858	1.74929	1.56402	0.96780	8.9725
70	2.84091	1.89600	1.52305	1.08132	8.9777
71	2.84091	2.13003	1.56071	1.14971	9.4836
72	2.57732	2.32883	1.67120	1.19100	9.6367
73	2.42131	2.80233	1.83698	1.27204	9.8743
74	2.22717	4.72145	1.96118	1.87900	11.1889
75	2.03252	4.53281	2.35260	2.29372	12.5642
76	1.91205	4.52383	2.78443	2.12444	13.1129
77	1.78891	4.65263	3.28278	2.02029	14.0804
78	1.66113	4.33255	3.40315	2.36679	14.6500
79	1.52439	4.93325	3.67230	2.16496	14.7817
80	1.39470	6.46653	4.11400	2.21363	16.1755
81	1.26743	6.85175	4.53261	2.01805	17.2961
82	1.19332	6.57985	4.78905	2.06545	18.1037
83	1.14811	6.17437	4.65818	1.87749	18.1169
84	1.09890	6.31643	4.80093	1.87458	17.9333
85	1.05932	5.79195	5.02552	1.87633	18.0639
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	3.93663	3.30443	1.61850	15.3276
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=TRANSP EQUIP

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	1.96942	1.77499	1.31515	13.1265
59	3.90625	2.00503	1.84651	1.30640	12.9556
60	3.84615	2.00868	1.87640	1.23208	13.6017
61	3.80228	2.04793	1.90628	1.19941	11.2869
62	3.71747	1.99719	1.91299	1.15307	11.9970
63	3.67647	1.96792	1.89544	1.15567	12.2323
64	3.61011	1.82467	1.83197	1.14786	12.0970
65	3.52113	1.75211	1.79040	1.09019	11.9425
66	3.40136	1.74222	1.73115	1.09020	12.2762
67	3.30033	1.75925	1.67349	1.07825	9.7526
68	3.14465	1.72735	1.62006	1.11059	9.0085
69	2.95858	1.64132	1.55303	1.14382	8.7247
70	2.84091	1.79945	1.52661	1.31571	8.8458
71	2.84091	2.02949	1.57348	1.43989	9.4580
72	2.57732	2.21021	1.66224	1.51275	9.8030
73	2.42131	2.68774	1.79980	1.63794	10.2094
74	2.22717	4.56832	1.89976	2.21133	11.6844
75	2.03252	4.36571	2.41401	2.83728	13.1859
76	1.91205	4.28019	2.83296	2.44100	13.6002
77	1.78891	4.42965	3.32335	2.19344	14.3320
78	1.66113	4.13385	3.39423	2.55971	14.8063
79	1.52439	4.85891	3.65226	2.49399	14.8162
80	1.39470	6.03655	4.08384	2.46235	16.4471
81	1.26743	6.91990	4.47633	2.34538	17.2914
82	1.19332	6.62357	4.73153	2.40104	18.2659
83	1.14811	6.21727	4.59388	2.22500	18.5019
84	1.09890	6.34763	4.70962	2.20440	17.3135
85	1.05932	5.79046	4.92190	2.22187	17.0704
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	3.51607	3.35260	1.97495	12.9480
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=INSTRUMENTS

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.65679	2.26734	1.51779	17.4773
59	3.90625	2.54744	2.26920	1.51848	16.9301
60	3.84615	2.38597	2.23389	1.43869	17.3380
61	3.80228	2.27832	2.21581	1.41004	14.8308
62	3.71747	2.07530	2.15969	1.35894	15.2017
63	3.67647	2.03389	2.17070	1.34633	15.4226
64	3.61011	1.88543	2.12929	1.32026	15.1650
65	3.52113	1.80605	2.10662	1.24069	14.8355
66	3.40136	1.77810	2.05646	1.22753	14.9649
67	3.30033	1.79311	2.01865	1.20178	12.3107
68	3.14465	1.73740	1.88471	1.17319	11.4490
69	2.95858	1.67958	1.75557	1.15831	10.9988
70	2.84091	1.82394	1.66176	1.27862	10.9857
71	2.84091	2.11944	1.66381	1.35894	11.5355
72	2.57732	2.39618	1.81971	1.36936	11.7706
73	2.42131	2.91281	2.02213	1.43298	12.1806
74	2.22717	4.70258	2.17981	1.95199	13.5394
75	2.03252	4.41324	2.52280	2.60928	13.9326
76	1.91205	4.14572	2.91170	2.63682	14.9329
77	1.78891	4.29361	3.20105	2.32845	15.3863
78	1.66113	3.96175	3.46943	3.81090	15.9168
79	1.52439	4.62564	3.77308	2.45995	16.4673
80	1.39470	6.03026	4.23859	2.42064	17.6155
81	1.26743	6.85370	4.69480	2.46977	18.7865
82	1.19332	6.43423	4.65795	2.42710	19.8491
83	1.14811	5.95283	4.65703	2.15563	20.5547
84	1.09890	6.01496	4.73243	2.06661	19.8663
85	1.05932	5.34988	4.88061	2.01889	19.4920
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	3.36952	3.60308	1.65703	17.3988
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

Table E-22D. Manufacturing Prices, 1958-1990

SIC=MISC MFG

YEAR	DOL87	POIL87	PNATGS87	PCOAL87	PELEC87
58	3.90625	2.32003	1.75039	1.36019	20.7345
59	3.90625	2.34048	1.95578	1.37011	20.2098
60	3.84615	2.32974	2.12472	1.31047	20.4079
61	3.80228	2.37215	2.30513	1.29795	17.7107
62	3.71747	2.29494	2.44470	1.26459	17.9564
63	3.67647	2.26484	2.40597	1.26661	18.0628
64	3.61011	2.12300	2.31791	1.25652	17.7364
65	3.52113	2.03525	2.25619	1.19563	17.3772
66	3.40136	2.00030	2.17169	1.19766	17.5013
67	3.30033	2.00916	2.09922	1.18666	14.8171
68	3.14465	1.91907	2.04294	1.13497	13.5051
69	2.95858	1.79201	1.96701	1.09619	12.6413
70	2.84091	1.88319	1.93632	1.19687	12.2813
71	2.84091	2.06593	1.99987	1.25043	12.5672
72	2.57732	2.29250	2.00074	1.17024	12.3996
73	2.42131	2.80355	2.08866	1.16563	12.4590
74	2.22717	4.72758	2.13381	1.63927	13.5759
75	2.03252	4.64103	2.59074	2.07924	14.8844
76	1.91205	4.60175	3.10780	2.12450	15.7634
77	1.78891	4.74389	3.39368	2.35584	16.1115
78	1.66113	4.50849	3.62061	2.15112	17.5989
79	1.52439	5.57863	3.87723	2.22029	18.4094
80	1.39470	7.00684	4.22774	2.21132	19.3155
81	1.26743	7.00385	4.72644	2.13437	20.1548
82	1.19332	6.95862	4.98103	2.38349	20.4620
83	1.14811	6.40600	4.84538	2.25068	21.6610
84	1.09890	6.71710	4.96935	2.34280	20.4414
85	1.05932	6.09130	5.17172	2.37773	20.0751
86	1.03199	.	.	.	.
87	1.00000	.	.	.	.
88	0.96339	4.44824	3.60308	1.75337	18.4875
89	0.92081	.	.	.	.
90	0.88339	.	.	.	.

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