IMPACTS OF NEW ENERGY TECHNOLOGY, USING GENERALIZED INPUT-OUTPUT ANALYSIS

by

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The Massachusetts Institute of Technology has undertaken a program of research on Energy Analysis and Planning. The overall goals of this program are to develop concepts, information, and analytical tools that relate energy supply and demand, the economy and the environment in a manner useful to managers and policy makers in government and the energy industries. The work reported here is the second formal output of this effort.

Further research at refining this model and also developing other models relating to the overall goals of the program is underway.

David C. White
Ford Professor of Engineering

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ABSTRACT

Traditional input-output analysis was modified to include air pollution emissions, employment, and other accessory variables. Engineering studies of high and low BTU coal gasification and the gas turbine topping cycle were then utilized to incorporate these new technologies into the 1980 input-output table that was projected by the Bureau of Labor Statistics. These two techniques are shown to be able to correct many previous objections to input-output analysis and to have applicability to a wide variety of practical problems.

A series of 1985 projections featuring high, medium and low growth of energy consumption (both with and without the new technologies) were also made. Economic and environmental impacts were then calculated for these alternative futures. The major conclusions are:

1. Total investment in general and capital good industries in particular (primarily turbogenerator manufacturers, boiler makers, and construction equipment manufacturers) are quite sensitive to energy use growth rates (especially electricity).

2. Introduction of high Btu coal gasification will aggravate the demand for investment funds and introduction of the second generation gas turbine topping cycle (with or without low Btu coal gasification) will decrease the demand. These technologies will have their major impacts on the industries listed above.

3. Slight changes in the overall growth rates of total personal consumption expenditures and government spending result in large fluctuations in total investment.

4. If high energy growth continues and if investment is to remain within its historical limits as a percentage of GNP, energy investment will become a larger and larger part of total investment.

5. While interest rates are assumed to be the balancing mechanism between supply of and demand for investment funds, the very act of saving more money (which is induced by higher interest rates) means that less can be spend on consumption goods. This in turn lessens the demand for investment funds because the growth rates of consumption sectors are lower. This indirect effect of interest rates on investment has been little studied but may be quite important.

The policy implications of these results are also discussed.

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I would like to dedicate this report to my mother who has patiently waited many years for her son to finish his education.

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CONVENTIONS

$\underline{A}$ - capital letters (underlined) represent vectors or matrices

$[a_{ij}]$, $[b_j]$, - Matrix A (or vector $\underline{B}$) is composed of elements a_{ij} (or b_j)

A_{ij}, b_j - elements of matrix $\underline{A}$ (or vector $\underline{B}$) are subscripted lower-case letters

a, ,c - constants are non-subscripted lower-case letters

$\underline{A}^T$ - transpose of matrix or vector $\underline{A}$

$\underline{A}^{-1}$ - inverse of matrix $\underline{A}$ (assumed to be square)

Equation Numbers and Figure Numbers } 1.1, 3.9 - Number before decimal point refers to chapter number, while number after decimal point indicates sequence number with chapter.

Footnotes - Within Text - Numbered sequentially throughout report; used for informational purposes only.

Footnotes - within Figures - Numbered beginning with 1 with each figure.

[39], [2], etc. refer to books listed under References.

Special Symbols and Letters:

- N - number of sectors in economy
- $\underline{A}$ - N X N matrix of technological coefficients
- $\underline{C}$ - N x N matrix of capital coefficients
- $\underline{Y}$ - N X 1 total final demand vector
- $\underline{Y}^I, \underline{Z}$ - N x 1 investment component of final demand (GPDI)
- $\underline{Y}^F$ - N x 1 non-investment component of final demand, includes PCE exports, and government spending
- $\underline{X}$ - N x 1 total output vector

MCF - thousands of cubic feet

MBTU - thousands of BTU

MMBTU - millions of BTU

PCE - Personal Consumption Expenditures

GPDI - Gross Private Domestic Investment

PDE - Producers Durable Equipment

Chapter 1 Summary and Organization

1.1 Introduction

> "The breakdown did not come all at once -- not like the cataclysmic nightfall that blacked out New York and most of the Northeast in 1965 -- but it was no less eerie. House lights went out; furnaces sputtered and cooled; auto traffic jammed up at darkened intersections. Dog races were canceled because the electric rabbits would no longer run. Factories shifted to a four-day week, then a three day week, laying off 1.6 million employees. Only the most essential services operated full time -- hospitals, water and sewage plants -- and nobody knew how long they could continue."
>
> *Time*, June 12, 1972.p. 49 [15] describing events during Britain's two month coal strike.

Americans use nearly twice as much electric power per capita as the British, and hence the potential for disaster is even greater than that described above. Advances in technology can help to ward off such consequences, but before embracing new technology as a cure-all for these problems, it is important to examine the impacts of such technologies.

The research described here explores only three new technologies that could have significant commercial application by 1985. These technologies are:

(1) High Btu coal gasification,
(2) Low Btu coal gasification, and
(3) Gas turbine topping cycle (combined gas and steam cycle).

The techniques developed during the research are applicable to any possible new technologies, and provide broad but detailed looks at the United States, 15 to 20 years hence. The techniques are based on a generalized[1] form of input-output (I/O) analysis and thus can focus on the myriad interactions between the many sectors of the projected future economy.

As such, the techniques should be a useful tool for policy-makers who must decide what actions to take if there is an "energy crisis". Such possible applications will be discussed at the end of this chapter. One contribution of the techniques is that engineering studies can be used to incorporate new technologies into the I/O framework. Since engineering studies can handle relative price changes and other variables, this capability alleviates the problem of simplistic I/O projections that ignore price changes and facilitates the development of dynamic economic models in which technology depends on relative prices, energy availability, etc.

The research utilized a projection of the 1980 economy prepared by the Interagency Growth Project of the Bureau of Labor Statistics [48]. These projections were incorporated into a model that contained environmental variables and new technology representations that had been derived from basic engineering studies. The research focused on the economic impacts of investing in these highly capital intensive technologies and of day-to-day operation of such plants. An attempt was made to calculate the effects of fuel-switching and conservation policies caused by the high prices of these new energy sources but the attempt failed because of the lack of industrial price elasticity data. Finally a dynamic model was used to make a series of 1985 projections. These projections involved different rates of energy use growth and were performed with and without the new technologies.

1. "Generalized" refers to the inclusion of non-economic variables such as sulfur dioxide emissions or employment within the I/O framework and to the use of engineering studies to update projections of the technological structure of the economy.

The major results document the sensitivity of total capital investment to changes in the energy use growth rate and to the adoption of new energy technology. They also illustrate that very small changes in the overall growth rate of personal consumption or government expenditures can restrain total investment to within its historical limits as a percentage of GNP. The significance of these results is that the people of the U.S. can sustain the huge investment demands created by rapid energy demand growth by reducing the growth rate of personal consumption and government spending by less than 0.1% per year through 1985. Overall GNP growth rate remains unchanged, because the sum of the growth rates in investment and non-investment goods is a constant.

The next section (1.2) of this chapter briefly describes the generalized I/O model, while the following sections (1.3 and 1.4) summarize the results. The last section (1.5) outlines the organization of the report.

1.2 Generalized Input-Output Theory

1.2.1 Static Input-Output Models

Input-output (I/O) analysis is the study of interrelations between sectors[2] of the economy. It seeks to answer such questions as "If GNP grows by 4% per year, how will the outputs of each sector grow given that consumer's preferences and technology will change?" To perform such analysis it is first necessary to characterize the flow of goods and services between sectors. This is done with the aid of the interindustry flow table that is prepared periodically as part of the governments Census of Business.

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2 Sectors can be agricultural, industrial, commercial or service groups. Households and Government are also considered sectors.

A very simple example of a flow table for a hypothetical three sector economy is presented in Figure 1.1. Each entry in the table represents dollars of sales from sectors on the left to sectors along the top. Thus each row i can be read as sales by sector i to other sectors and each column j can be read as purchases by sector j from other sectors. Let $\underline{D} = [d_{ij}]$ by the 3 x 3 flow matrix enclosed in double lines. The entries under Final Demand (the 3 x 1 vector $\underline{Y} = [y_i]$) are the sales from each sector to private and public final consumers such as Households and Government[3]. The entries under Value Added (the 1 x 3 vector $V = [v_i]$) represent purchases of labor, depreciation changes, and profit for each sector. Note that the sum of the Value Added components and the sum of the Final Demand components are both equal to the Gross National Product (GNP) of this economy. This is true by definition of the accounting identifies. The entries under Total Output (the 3 x 1 vector $\underline{X} = [x_i]$) are the total sales of each sector either to other sectors or to Final Demand. Thus $x_i = \sum_{j=1}^{3} d_{ij} + y_i$

The objective of I/O analysis is to predict how Total Output $\underline{X}$ responds to changes in Final Demand $\underline{Y}$ or to changes in technology. The first step in this analysis forms the technological coefficient matrix $\underline{A}$ that represents input purchases required per dollar of output of each sector. This is easily calculated by dividing each column of purchases in the flow matrix $\underline{D}$ by the total output of that sector. Thus

$$\underline{A} = [a_{ij}] = [\ \frac{d_{ij}}{x_j}\ ]$$

---

3 Actual I/O tables include investment purchase, net exports and inventory change in Final Demand. For introductory purposes it is better to ignore these.

Figure 1.1

Hypothetical Flow Table (in Dollars)

From	To Sector	1	2	3	Final Demand $\underline{Y}$	Total Output $\underline{X}$
1	Agriculture	4	8	-	8	20
2	Industry	4	4	2	30	40
3	Energy & Services	-	8	2	10	20
	Value Added $\underline{V}$ (Labor etc.)	12	20	16	48 GNP	
	Total Inputs	20	40	20		

$\underline{D} = [d_{ij}]$ = Flow Matrix

where d_{ij} = dollar sales of sector i to sector j

$\underline{X} = [x_i]$ = Total Output Vector

where x_i = total dollar sales by sector i

$\underline{Y} = [y_i]$ = Final Demand Vector

where y_i = dollar sales to Final Demand by sector i

$\underline{A} = [a_{ij}] = [\frac{d_{ij}}{x_j}]$ = Technological Coefficient Matrix

$\underline{X} = \underline{A}\,\underline{X} + \underline{Y}$

or

$\underline{X} = [\underline{I}-\underline{A}]^{-1}\underline{Y}$

Basic Input-Output Relationship

Technological Coefficient Matrix (in Dollars)

	Sector	1	2	3
1	Agriculture	.20	.20	-
2	Industry	.20	.10	.10
3	Energy & Services	-	.20	.10

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1 Economists often use x_{ij} to represent the flows and x_i to represent total output. The above notation was thought to be less confusing.

The technological coefficient matrix for the three sector economy is also shown in Figure 1.1. The output of each sector that is consumed by other sectors, excluding Final Demand, can be expressed as the matrix product $\underline{A}\ \underline{X}$. The resulting vector is known as total immediate output since Total Output is obviously the sum of the immediate output and Final Demand,

$$\underline{X} = \underline{A}\ \underline{X} + \underline{Y} \qquad (1.1)$$

This expression is easily solved for Total Output as a function of Final Demand.

$$\underline{X} = (\underline{I} - \underline{A})^{-1}\ \underline{Y} \qquad (1.2)$$

The objective of I/O analysis has been achieved if it can be assumed that the inverse $(I-A)^{-1}$, which can be derived from Census data for a particular year and a particular GNP and Final Demand, applies for other years and other Final Demands. Technological change can be handled by modifying the technological coefficient matrix $\underline{A}$ to correspond to the change.

The I/O framework can also be used to calculate equilibrium relative price levels for all goods. The assumptions behind this derivation are usually that companies set prices to cover the cost of material, labor, and some nominal profit and that the relative price of labor is equal to one. Value added is the economic term that describes the labor costs, depreciation, business taxes, and profits that make up the difference between the selling price of a good and the cost of materials that went into it.

Let $\underline{V} = [v_i]$ where v_i = value added per unit sold of the ith sector.

The per unit price p_i of the ith good can be expressed as $p_i = v_i + \sum_{j=1}^{N} a_{ij} p_j$

Changing to vector notation, the per unit price vector $\underline{P} = [p_i]$ is

$$\underline{P} = \underline{V} + \underline{A}^T \underline{P} \tag{1.3}$$

Solving for prices in terms of value added

$$\underline{P} = (\underline{I} - \underline{A}^T)^{-1} \underline{V} \tag{1.4}$$

This equation makes it very simple to calculate the long term price effects on other commodities of changes in the capital or labor requirements of any one sector. Note that they tell nothing about how rapidly these price changes would propagate through the economy, nor do they indicate how consumers or other industries might react to such price changes. Thus the above equation can be used to explore the price sensitivities of various industries to changes in value added, but it cannot by itself be used to predict the response of the system to these price changes.

1.2.2 Dynamic Input-Output Models

There are many possible formulations of dynamic input-output models, but the essential concepts can be presented with a simple two-period example for times t_0 and t_1. Assume that the same technological coefficient matrix $\underline{A}$ applies for both periods.

Two conceptual changes are required to modify the static theory of the previous section. First, total final demand $\underline{Y}$ must now consist of $\underline{Y}^F$ = final demand purchases by households and governments and $\underline{Y}^I$ = capital investment purchases by all sectors of the economy:

$$\underline{Y} = \underline{Y}^F + \underline{Y}^I$$

Second, the capital matrix $\underline{C}$ must be defined as $\underline{C} = [c_{ij}]$ where c_{ij} is the marginal capital purchase from sector i by sector j required to expand the capacity of sector j by one dollar of output. Thus if $\underline{X}_1$ were the total output in period t_c and $\underline{X}_1$ the total output in period t_1, the total new investment required is $\underline{C}\ (\underline{X}_1 - \underline{X}_0)$. By defining $\underline{C}$ in terms of marginal capital requirements, difficult problems of defining and measuring capital stocks are avoided.

These relationships are summarized in Figure 1.2. The objective of the model is to find for period t_1 the total output ($\underline{X}_1$) and total final demand ($\underline{Y}_1$) given the total output in period t_0 ($\underline{X}_0$) and the non-investment final demand in period t_1 ($\underline{Y}_1^F$). The model assumes that sectors always operate at 100% capacity so that output can only be increased by capital investment.[4] The basic equations for this model are:

$$\underline{X}_1 = (\underline{I} - \underline{A})^{-1}\ \underline{Y}_1 = (\underline{I}-\underline{A})^{-1}\ (Y_1^F + \underline{Y}_1^I) \qquad (1.5)$$

$$\underline{Y}_1^I = \underline{C}\ (\underline{X}_1 - \underline{X}_0) \qquad (1.6)$$

These equations can easily be solved for total output ($\underline{X}_1$) and total final demand ($\underline{Y}_1$):

$$\underline{X}_1 = (\underline{I} - \underline{A} - \underline{C})^{-1}\ (\underline{Y}_1^F - \underline{C}\ \underline{X}_0) \qquad (1.7)$$

$$\underline{Y}_1 = \underline{Y}_1^F + \underline{C}\ (\underline{X}_1 - \underline{X}_0) \qquad (1.8)$$

These equations are easily used to calculate the effect on investment $\underline{Y}^I$ and total output $\underline{X}$ of changes in the growth rates of individual components of $\underline{Y}^F$. Various methods are available to assure that total GNP

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4 Slack variables can be used to modify this assumption but such considerations are not important at this stage.

Two-Period Dynamic Input-Output Model

Given: $\underline{X}_o = [x_{io}]$ where x_{io} = total output of sector i in period t_o

Y_1^F = final demand purchases by households and government in period t_1

$\underline{C} = [c_{ij}]$ = marginal capital purchases from sector i by sector j required to increase sector j's output by one dollar.

$\underline{A}$ = technical coefficient matrix for both periods t_o and t_1

Find: $\underline{Y}_1$ = total final demand = $\underline{Y}_1^F + \underline{Y}_1^I$, where $\underline{Y}_1^I$ = investment purchases in period t_1

$\underline{X}_1$ = total output in period t_1

Solve: $\underline{X}_1 = (\underline{I}-\underline{A})^{-1}\ \underline{Y}_1 = (\underline{I}-\underline{A})^{-1}\ (\underline{Y}_1^F + \underline{Y}_1^I)$

$\underline{Y}_1^I = \underline{C}\ (\underline{X}_1 - \underline{X}_o)$

Results:

$$\underline{X}_1 = (\underline{I}-\underline{A}-\underline{C})^{-1}\ (\underline{Y}_1^F - \underline{C}\ \underline{X}_o)$$

$$\underline{Y}_1 = Y_1^F + \underline{C}\ (\underline{X}_1 - \underline{X}_o)$$

F I G U R E 1.2

where $GNP^5 = |\underline{Y}_1^F + \underline{Y}_1^I| = |\underline{Y}_1| = \sum_{i=1}^{N} \underline{Y}_{1_i}$

and N = numbers of sectors in model.

does not exceed certain limits, but these will be discussed in later chapters. It should also be noted that, whereas the technical coefficient matrix ($\underline{A}$) was derived from basic Census data, the capital matrix ($\underline{C}$) must be estimated from capital flow data or from engineering data. There are problems with both sources of data that do not arise with technical coefficient calculations. These will be discussed in later chapters.

The model that was actually used for the 1985 projections utilizes the two period analysis described above with the further constraint that the 1985 GNP equal $1.34 trillion[6] (1958 dollars). The model is pictorially described in Figure 1.3. Given an initial projection of the 1985 final demand, one iterates around the loop until a final demand vector is obtained with the proper GNP. Convergence can be guaranteed by modifying the scaling factor.

1.2.3 Generalized Input-Output Model

The generalized input-output model used in this study is illustrated in Figure 1.4. It is referred to as "generalized" because

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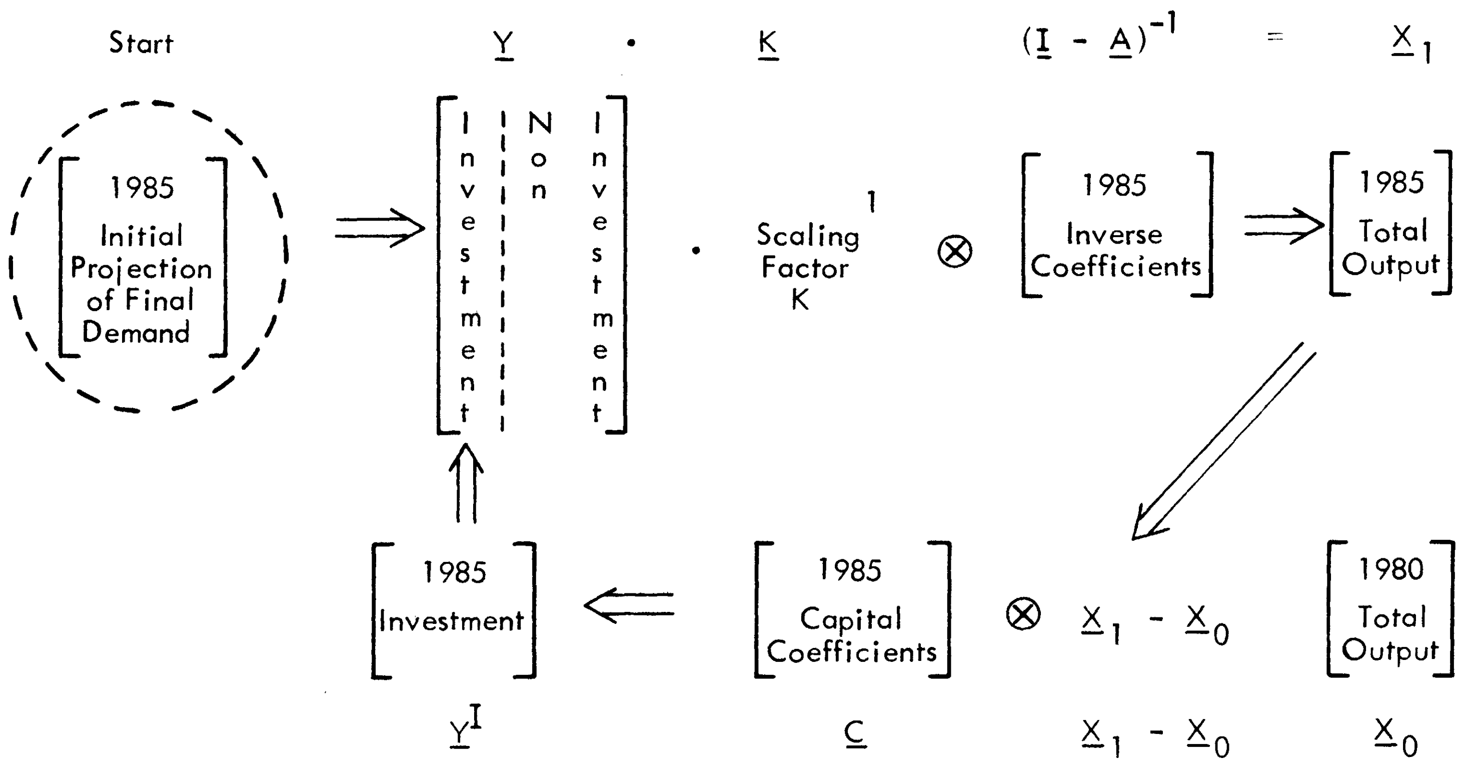
5 The magnitude signs represent the vector norm formed by arithmetic addition of the vector elements. They do not represent absolute value signs

6 This GNP represents a 4.4% per year growth rate from the BLS projection of the 1980 GNP. It was calculated by excluding any contribution from BEA sectors 84, 85, and 86 (Government Industry, Rest of the World Industry, and the Household Industry respectively). These dummy sectors were excluded because they do not interact with other sectors; they only contribute to GNP.



Symbols

- • Scalar Multiplication
- ⊗ Matrix Multiplication
- ⟹ Equals

Quasi-Dynamic Projection Model

F I G U R E 1.3

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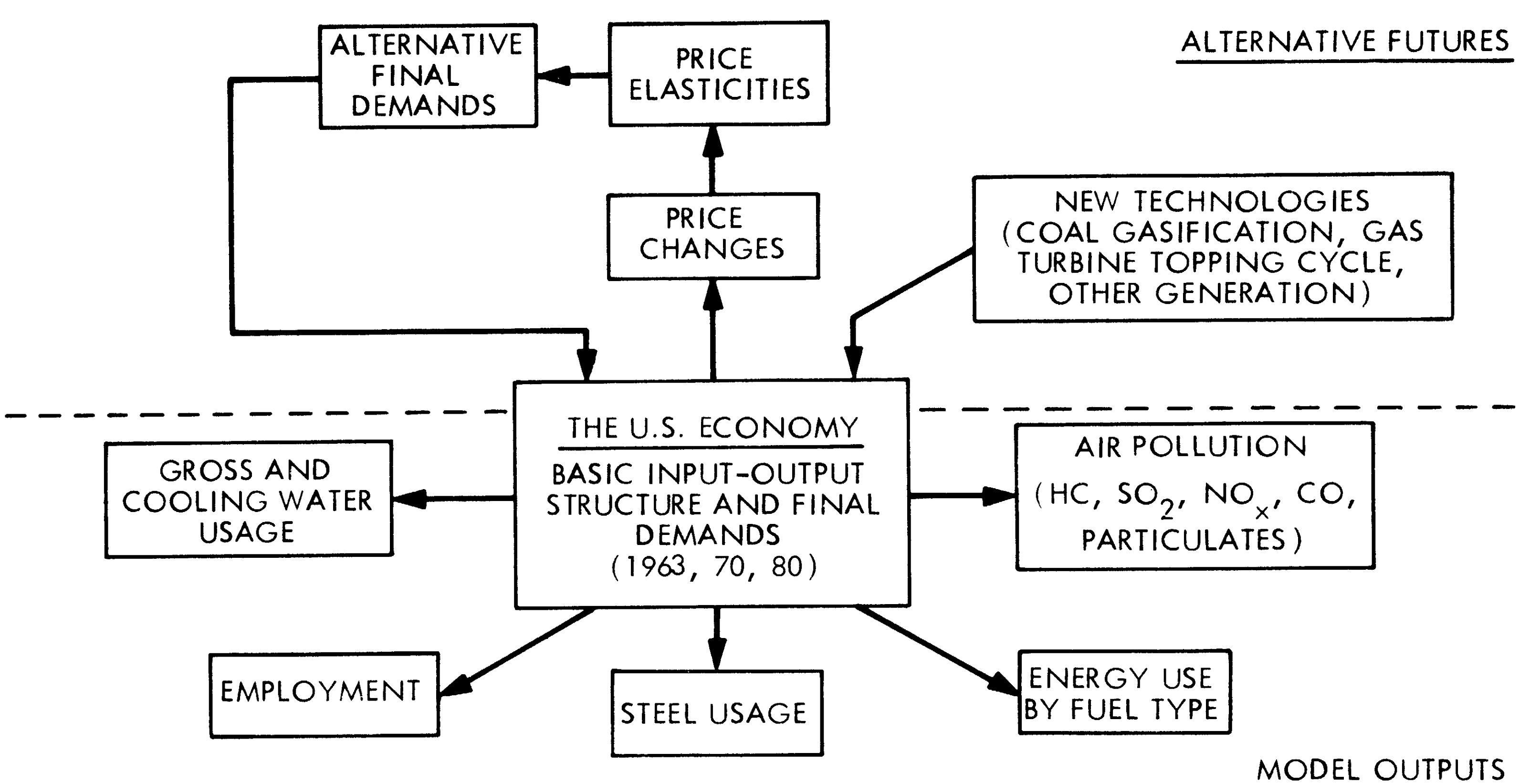
1 Scaling factor is chosen so that GNP = $|\underline{Y}| = \sum_i Y_i =$ \$ 1.34 trillion.



MODEL PROPERTIES

1. Highly Interconnected Economy
2. Quasi-Static Technology Change
3. 110 Sectors (Industries)
4. Linear
5. National

FIGURE 1.4

ENERGY-ORIENTED GENERALIZED INPUT-OUTPUT MODEL

(1) many non-economic variables such as water usage and SO_2 emissions are included in the framework and

(2) new technologies can be incorporated in it.

The non-economic quantities are referred to as accessory variables and are summarized in the bottom half of Figure 1.4. These are the outputs of the model. They are assumed to be proportional to total output of each sector. For example, let S be the total emissions of SO_2 (or any other accessary variable) by the 1980 economy and let $\underline{E} = [e_k]$ be the vector of coefficients for SO_2 emissions per dollar of total output.

In other words, e_k is the SO_2 emitted per dollar of output of the k-th industry. If $\underline{X}$ is the total output vector, then the total SO_2 emissions S is the inner product of $\underline{X}$ and $\underline{E}$ or

$$S = \underline{E}^T \underline{X} = \underline{X}^T\underline{E} \qquad (1.9)$$

Similar relationships hold for the other accessory variables.

The boxes in the upper half of Figure 1.4 represent the various means of interacting with the model. These boxes are used to specify the alternative future being investigated. This scenario can include changes in technology and in composition of GNP. Limited price changes can also be handled.

A final demand vector is constructed to represent the conditions of the scenario and the technological and capital coefficients modified to include the amount and kind of new technology that is specified. Once these changes are made, the total outputs ($\underline{X}$) are calculated in the usual way: $\underline{X} = (\underline{I} - \underline{A})^{-1} \underline{Y}$. The values of the accessory variables are then obtained by simple multiplication as indicated above.

The sectors actually used in the research are summarized at the end of this chapter in Figure 1.12 and the components of final demand in Figure 1.13. The sectors were chosen to provide at least the 83 order BEA aggregation scheme with further breakdown of major energy supplying, energy consuming, or polluting industries.

1.2.4 Derivation of New Technology Representations

The derivation of technological and capital coefficients for a new technology begins with the engineering cost study. While coefficients derived from an engineering study of an actual operating commercial plant are quite accurate, those derived from a pilot plant study are subject to some uncertainty because of potential problems associated with scaling up plant size. Coefficients based on costs projected from laboratory scale models may be quite uncertain, especially with respect to total capital cost of building such a plant. Attempting to derive coefficients for a process that has not yet been proven feasible in the laboratory (e.g. fusion) can lead to nonsense. There are many "cost" studies of processes that have never been made to work. In addition, economic impact projections based on laboratory feasibility studies are unrealistic because of the long development periods involved (especially in the energy field). For example after two decades, reactors still product only 1% of total electric power. The technologies studied here fall between the laboratory and pilot plant stage so there is some uncertainty about the actual numbers but sensitivity analysis can usually handle this problem.

Another significant characteristic of new technology engineering studies is that the costs are calculated using certain estimation schemes. These estimates detail major cost items like fuel or reactor vessels and then calculate other costs like overhead or piping as percentages of the major cost items. The result is that the larger technical and capital coefficients are more accurate than the smaller ones. While this is a disadvantage of the overall coefficients it is an advantage when calculating economic impacts because the larger impacts are caused by the larger coefficients.

The technological coefficients are derived from the engineering studies by assigning all projected operating costs (purchased material and labor) to the I/O sectors that produced the commodity. These figures were divided by the total yearly output of the proposed plant to convert the dollar flows into new technology coefficients.[7] A similar procedure was followed for deriving the capital coefficients from the construction cost estimates.

There were a few problems of classification (i.e. which sector produced a certain item like piping), but these were solved by adopting certain conventions. These conventions will be discussed later.

The new technologies were incorporated into the I/O framework using the following scheme. Suppose the old technological process for sector i (e.g. natural gas production) is represented by the technical coefficient vector $\underline{A}_i$ and capital coefficient vector $\underline{C}_i$[8]. Next let the new technological

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7 Since I/O tables are in terms of producer costs, transportation and trade markups must be removed from the engineering estimates before converting to coefficients.

8 Thus the whole technological coefficient matrix could be represented as the partitioned matrix $\underline{A} = [\underline{A}_1 : \underline{A}_2 : \ldots : \underline{A}_n]$. A similar partition holds for the capital coefficient matrix.

process (e.g. high BTU coal gasification) be $\underline{A}_N$ and $\underline{C}_N$. If the new technology is expected to take over a fraction g of the total production of sector i and a fraction h of total capital investment by sector i then the new technical coefficients are

$$\underline{A}_i' = (1-g)\ \underline{A}_i + g\underline{A}_N \qquad (1.10)$$

where g = fraction of total production supplied by new technology and the new technical coefficients are

$$\underline{C}'_i = (1-h)\ \underline{C}_i + h\ \underline{C}_N \qquad (1.11)$$

where h = fraction of total investment made up of new technology

These coefficient column vectors then replace the old ones in the technical and capital coefficient matrices.

1.3 Summary of Results

1.3.1 Impacts of Capital Spending for New Energy Technologies

The new technologies investigated are

(1) High Btu coal gasification (the Institute of Gas Technology electrothermal Hygas process)

(2) Low Btu coal gasification (the 1980 Texaco partial oxidation process with hot carbonate scrubbing) and

(3) Gas turbine topping cycle or combined gas and steam cycle electric generation plant (the 1980 United Aircraft high temperature gas turbine and waste heat boiler steam cycle). This last technology will be referred to as a COGAS plant.

The salient characteristics of these processes are summarized in Figure 1.5. In this and subsequent sections the new technology impacts will be compared to that of a nuclear steam electric generation plant. Nuclear plants were chosen for comparison because they represent a current new technology that is unlikely to change much by 1985. In addition, most readers will be familiar with its capital intensive nature and the projected high growth of nuclear power in the next fifteen years.

This section summarizes the economic impact of capital expenditures for these new technologies. The next two sections will look at impacts from actual operation of the new plants and at price changes caused by higher priced energy.

It is only meaningful to compare plants of approximately the same output capacity, so five trillion BTU/day was selected as the nominal size. This corresponds to approximately 10 high Btu gas plants or 40 low Btu gas plants. Since electricity is a secondary form of energy, 40,000 MW was chosen as the appropriate comparison size because 40,000 MW of COGAS plants requires five trillion Btu/day input energy (in the form of low Btu gas). Consequently 40,000 MW was also used as the comparison size for nuclear plants.

The economic impacts were calculated in a two step process. First the capital coefficients of each new technology and the plant comparison sizes (converted to dollars) were multiplied to obtain a vector ($\underline{N}$) representing the total investment in each new process, broken down by sectors from which the purchases will be made. Second, the investment vector ($\underline{N}$) for some particular technology was multiplied by the 1980 inverse coefficients to obtain the vector of total outputs ($\underline{X}$) caused by that new technology's investment, i.e.

$$\underline{X}_N = (\underline{I} - \underline{A})^{-1} \underline{N} \qquad (1.12)$$

New Technologies Investigated

High BTU Coal Gasification (1000 BTU/SCF)

Process:	Electrothermal Hydrogasification (Hygas)
Data Source:	Electrothermal Hygas Process - Escalated Costs [42]
Originator:	Institute of Gas Technology
Efficiency:	71.7%
Nominal Plant Size:	500 Million SCF/day (90% load factor)
Nominal Cost:	Plant - \$310-354 million[3] Gas -54.8-72.4¢/10^6Btu

Low BTU Coal Gasification (173 BTU/SCF)

Process:	1980 Texaco Partial Oxidation (Hot Carbonate Scrubbing)
Data Source:	Technological and Economic Feasibility of Advanced Power Cycles [38]
Originator:	United Aircraft
Efficiency:	87%
Nominal Plant Size:	842 million SCF/day (70% load factor)
Nominal Cost:	Plant -\$27.5 million[2] Gas - 17.6¢/10^6Btu

Gas Turbine Topping Cycle (Combined Gas and Steam Cycle or COGAS)

Process:	1980 High Inlet Temperature (2800°F) Turbine with Waste Heat Boiler Steam Cycle (Using Low Btu Gas)
Data Source:	Technological and Economic Feasibility of Advanced Power Cycles [38]
Originator:	United Aircraft
Efficiency:	54.5%[1]
Nominal Plant Size:	1000MW (70% load factor)
Nominal Cost:	Plant - \$94 million Electricity - 5.3 mills/kwhr

F I G U R E 1.5

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1 Only the efficiency of the COGAS cycle. Overall efficiency is obtained by multiplying the two efficiencies.

2 Includes working capital.

3 All dollar figures are in 1970 dollars.

These total outputs are the economic impacts of investment in each technology. Figure 1.6 compares the major impacted industries of each new technology to the projected 1980 total output of that industry and to the impact caused by projected total 1980 investment[9] i.e. if $\underline{Y}^I$ is the total 1980 investment, the outputs or impacts $\underline{X}^I$ caused by it are $\underline{X}^I = (\underline{I}-\underline{A})^{-1}\ \underline{Y}^I$. This latter impact is referred to as investment-related output in the figure.

Low BTU coal gasification has the smallest economic impact of any of the new technologies. This happens primarily because of the comparatively small investment required for processing coal into a low grade gas. Because this gas cannot be shipped long distances very economically[10], it must be consumed near its manufacturing point. One of the best utilizations of the low BTU gas is in the COGAS plant which can take advantage of its high volume, high temperature flow. Thus to calculate the probable total impact of low BTU coal gasification, the two columns in Figure 1.6 for it and the COGAS plant should be added. The resulting numbers are much closer to those for the other two technologies.

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9 The impacts of total investment are included because most sectors produce several kinds of products, only a few of which are capital investment goods, e.g. both turbogenerators and outboard motor remote controls are made by the same sector. Since these products often cannot be disaggregated and since they are usually manufactured on different machines, a better measure of the total output of capital goods (productive capacity) is the output sold directly or indirectly to the investment component of final demand. Hence both total output and investment-related output are included in Figure 1.6.

10 It is uneconomical to ship for two reasons: (1) a given diameter pipeline has only one-fifth the energy carrying capacity of natural gas (1000Btu/SCF) when used with low Btu gas (179Btu/SCF); (2) a significant percentage of the total energy content of low Btu gas is in the form of heat which would be lost in a pipeline.

FIGURE 1.6

MAJOR INDUSTRIAL OUTPUTS[1] REQUIRED TO DEVELOP

5 TRILLION BTU/DAY[2]

CAPACITY USING EACH NEW PROCESS[3]

Sector	Projected 1980 Total Output	Investment Related Outputs[4]	High Btu Coal Gasification	Low Btu Coal Gasification	COGAS	Nuclear Steam Generation
Plumbing and Structural Metals (Boiler Makers)	14752	8247	790 (5.4%,9.6%)[5]	156 (1.1%,1.9%)	305 (2.1%,3.7%)	1689 (11.4%,20.5%)
Engines and Turbines (Turbogenerators)	5457	1844	92 (1.7%,4.9%)	3 (6%, 2%)	639 (11.7%,34.7%)	1418 (26.0%,79.9%)
General Industrial Machinery (Pumps, fans)	10,9223	6041	310 (2.8%,5.1%)	89 (0.8%,1.5%)	89 (0.8%,1.5%)	320 (2.9%,5.3%)
Electrical Industry Equipment	16691	8900	142 (.8%,1.6%)	52 (.3%, .6%)	393 (2.3%,4.4%)	404 (2.4%,4.5%)
Machine Shop Products	5036	1454	18 (.4%,1.2%)	5 (.17%, .3%)	41 (.8%, 2.8%)	98 (1.9%,6.7%)
Iron and Steel Foundries	5321	2198	33 (.67%.1/5%)	20 (.4%, .9%)	37 (.7%,1.7%)	100 (2.9%,4.5%)

[1] All Outputs in millions of 1958 dollars, calculated from $X_N = (\underline{I}-A)^{-1}\ \underline{Y}_N$ where $\underline{Y}_N$ is the investment.

[2] 5 trillion Btu/day is the equivalent of 10 500 million SCF/day high Btu gas plants or 10 100,000 bbl/day oil refineries or 40 1000MW electric plants.

[3] See Figure 1.5 for definitions of processes.

[4] Output ($\underline{X}^I$) required to support projected 1980 total investment $\underline{Y}^I$, or $X^T = (I-A)^{-1}\ \underline{Y}^I$

[5] The first figure is the percentage of Total Output, the second figure is the percentage of Investment-Related Output.

The numbers presented in Figure 1.6 represent the minimum probable impact of these technologies because they do not take into account any expansion of the transportation (pipelines or transmission lines), distribution, or administration systems. Nor do they include the effects of increased manufacturing capacity required to supply the equipment for the new technologies. This investment would be over and above that indicated in Figure 1.6. In particular, the boiler-makers and turbogenerator manufacturers would have to expand significantly from their 1980 levels to meet the new technology demands. How much they would actually have to expand depends upon whether the new technology represents evolution and replacement of old technology or new markets. This will be discussed further in the section on the integrated 1985 projections.

1.3.2 Impacts of Operating the New Technologies

Operating impacts were calculated for the three new technologies, and nuclear plants were again used as the reference. The three new technologies were:

(1) high Btu coal gasification and
(2) low Btu coal gasification
(3) combined COGAS and low Btu goal gasification plant.

This last combination was chosen because it represents the most likely utilization of both processes.

Impacts are again defined as the industrial outputs required to support the direct and indirect requirements of five trillion Btu/day operation of each new technology. Figure 1.7 summarizes the major impacts and compares them to the projected 1980 total output of each sector.

As would be expected the most significant impact is on the coal mining industry. What may be surprising is that the largest other impact of the two new technologies is less than

FIGURE 1.7

MAJOR INDUSTRIAL OUTPUTS[1] REQUIRED TO SUPPORT 5 TRILLION BTU/DAY[2] OPERATION OF EACH NEW TECHNOLOGY[3]

Sector	Projected Total 1980 Outputs	High Btu Coal Gasification	Low Btu Coal Gasification	COGAS	Nuclear Steam Generation
Coal Mining	4329	321	374	386	9
Industrial Chemicals (Nuclear Fuel Reprocessing)	34030	16	13	18	985
Maintenance Repair Construction	35137	33	33	136	193
Construction & Mining Equipment (conveyors & grinders)	7798	13	13	14	2
Stone & Clay Mining	3839	25	1	2	5
Water & Sanitary Services	6928	20	9	15	6
Mineral Mining	2205	1	1	1	36

[1] All Outputs in millions of 1958 dollars, calculated from $\underline{X}_N = (\underline{I} - \underline{A})^1 \underline{Y}_N$ where $\underline{Y}_N$ is the vector of energy purchases.

[2] 5 trillion Btu/day is the equivalent of 10 500 million SCF/day high Btu gas plants or 10 100,000 bbl/day oil refineries or 40 1000 MW electric generation plants.

[3] See Figure 1.5 for definitions of processes.

1% of the total outputs of the affected industry. For industries not shown in the figure, the impacts were even less. Obviously COGAS electricity generation and coal gasification are relatively isolated sectors of the economy. Their major influence arises from their huge investment requirements as described in the last section.

For nuclear generation, the major affected industry is nuclear fuel reprocessing, which resides in the Industrial Chemicals sector (BEA 27.01). The fact that nuclear fuel reprocessing must be treated like the typical Industrial Chemical product causes a problem because it has considerably different input requirements from the typical industrial chemical. However, since it could not be broken out as a separate industry, it had to be assigned to the Industrial Chemical sector, and treated as a typical chemical. It could not be broken out because it is not a standard sub-industry and separate technical coefficients for it are not available. This assignment results in such obvious anomalies as nuclear steam generation having a large impact on mineral mining. While part of this impact represents legitimate purchases of uranium ore, most of these purchases are the result of treating nuclear fuel reprocessing like a typical industrial chemical. This illustrates the need for care in interpreting the results of an I/O simulation.

1.3.3 Price Changes

It is quite easy to calculate how some particular price change, e.g. doubling the price of oil, will affect other prices in the economy if it is assumed that such price changes are passed onto the customer. This theory was derived in section 1.2. However, in a highly competitive situation, e.g. between plastics, fiberglass, and aluminium, such price increases may be absorbed because of fear of losing market share. Also there is no data on the time it takes such price changes to propagate through the economy, so the best that can be done is to assume the changes will be complete within two or three years.

The most important criticism of possible price change calculations is that there is no data indicating how any sectors other than Households (personal consumption expenditures) respond to such price changes.[11] Without this information the price change calculation is almost useless. The information that would be required for a complete characterization of the long term effects of any price changes would be a matrix for each sector that described how the technological coefficients for that sector would be modified by a change in the price of any commodity (both elasticities and cross-elasticities would be needed for each sector for each product and between products). This is an impossible task but, if the more restrictive question of how industries would respond to fuel price changes is asked, then some answers could be derived (assuming that the data is available). It should be possible to obtain elasticities and cross-elasticities for fuels for each sector that would allow one to predict how the technological coefficient would change with different fuel prices.

Since total fuel costs make up only a few percent of the selling price of the average good sales of most products other than fuels would be only slightly affected by changes in fuel prices. Those few sectors, like basic metals and perhaps plastics, that are fuel price sensitive could be investigated

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11 A Cornell Study [8] does have time responses and an industrial price elasticity for fuel price changes but the aggregation level (i.e. all industries lumped together) is too great for their results to be useful in this study.

further. This procedure would result in an adequate representation of industrial fuel-price elastic effects. Unfortunately this data is not now available.

However, because Households consume large quantities of oil, gas, and electricity, it is useful to calculate how these purchases might change with fuel price increases. Therefore the price changes resulting from doubling the value added[12] of each of the four energy sectors was calculated. Next, using the University of Maryland's [2] long term price elasticities for Household purchases of these energy sectors, the long term declines in Household consumption were calculated. Figure 1.8 summarizes these results. Note that each row in the figure was calculated separately from all others. The long term price elasticities are still the subject of much discussion [4, 8, 12, 34]

These elasticities are important for policy purposes because they indicate how effective price uses are for curtailing growth in energy demand. When better data becomes available, this type of research may be more fruitful.

1.3.3 1985 Projections

The final exercise projected a series of five alternative 1985 futures involving various energy use growth rates, both with and without new technologies. These will be referred to as the Low, Medium, High, High plus Hygas, and High plus Hygas plus Gas Turbine futures, and are defined below.

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12 Value Added is defined as the labor, depreciation, business taxes, and profits of each sector. The seemingly strange procedure of doubling value added was chosen because pollution controls typically affect labor and capital (depreciation) charges, not material requirements. Thus it makes most sense to double these quantities and test the price sensitivity of the fuel sectors to this change.

F I G U R E 1.8

EFFECTS OF DOUBLING VALUE ADDED FOR ENERGY INDUSTRIES ON PERSONAL CONSUMPTION OF FUELS

Modified[1] Energy Sector	Relative Price Increase[2]	Long-term Price Elasticity[3]	Long-term Change in Personal Consumption of Fuel	Personal Consumption of Percentage of Total Consumption[4]
Coal	71.3%	-.222	-15.8%	2.3%
Refined Oil	28.9%	-.094	- 2.7%	40.2%
Natural Gas	60.7%	0.0	0.0%	25.4%
Electricity	78/6%	-.214	-16.8%[5]	25.9%

[1]Each row is associated with a different case that entails doubling the value added of the indicated industry only.

[2]This number multiplied by the actual dollar price of the energy source gives it new dollar price increase.

[3]Calculated using the University of Maryland's long-term personal-consumption price-elasticities for each fuel.

[4]Industry (including electric utilities and commercial establishments) and government are the other consuming sectors besides households (personal consumption).

[5]If Halvorsen's [22] residential price elasticity (-1.1) is used, this number becomes -89.4% The Cornell report [8] gives similar results.

All of the projections used the 1980 technical coefficient matrix with some modifications of the energy sectors. The investment component of final demand was recalculated for each projection using the 1975 Battelle capital matrix modified slightly for the new technologies. The initial final demand projection for each alternative differed only in the amount of oil, natural gas, and electricity purchases.

The medium energy use growth rate future assumes a continuation of the 1970-80 final demand growth patterns and no change in industrial technology from 1980.

The high energy use future reflects a 4% higher final demand (than the Medium future) for oil, natural gas, and electricity and increased industrial consumption (reflected in slight increases in the energy rows of the technical coefficient matrix). These changes assume increased air conditioning and electric heat, worse gasoline mileage and longer yearly driving distances. All of these projections assume that there will not be a supply limitation on natural gas and that the same domestic to foreign crude and natural gas ratios apply in 1985 that held in 1980.

The low energy use future involved 6% lower final demand (than the Medium future) for oil, natural gas, and electricity and better conversion efficiency for electricity conversion and transportation. Figure 1.9 summarizes these assumptions. Two alternative high energy growth futures were also investigated. The High plus Hygas future included the introduction of high BTU coal gasification (Hygas) while the High plus Hygas plus Gas Turbine future included Hygas and the gas turbine topping cycle (supported by low BTU coal gasification). These technology modifications are described in Figure 1.10.

F I G U R E 1.9

1980-1985 Modifications

	Low energy	Medium energy	High energy
Technical Coefficients	Standard 1980 (BLS) coefficients used except (1) 1980 electric utility vector of Istvan [27] substituted for 68.01 (2) Electric conversion efficiency increased by 1.4% for all fuels[1] (3) Conversion efficiency of buses, trolleys, and taxis (65.02) increased by 1% for oil[2]	Standard 1980 (BLS) coefficients used except (1) 1980 electric utility of Istvan [27] substituted for 68.01 column	Standard 1980 (BLS) coefficients used except (1) 1980 electric utility vector of Istvan [27] substituted for 68.01 column (2) Industrial electric and gas usage increased 6.75%[3] (3) Industrial usage of plastics [28] and rubber [32] increased 4.5%[4]
Initial Final Demand	Projection of 1980 final demand (104 order with 5 components) at 1970-80 growth rate of individual elements, except (1) consumption of oil, electricity, and gas reduced 6%[5] Investment recalculated (see text)	Projection of 1980 final demand at 1970-80 growth rate of invididual elements Investment recalculated (see text)	Projection of 1980 final demand at 1970-80 growth rate of individual elements except (1) consumption of oil, gas, and electricity increased 4%[6] Investment recalculated (see text)

[1]Technical coefficients reduced by 4% while engineering efficiency changed from 34% to 35.4%.

[2]Technical coefficients reduced by 4% while engineering efficiency changed from 25% to 26%.

[3]Technical coefficients of all industries increased by 6.75% for electricity which is half of the projected 1970-80 rate of change.

[4]Technical coefficients of all industries increased by 4.5% for plastics and rubber, which is half of the projected 1970-80 rate of change.

[5]Final demand for electricity, gas and oil reduced by 6% corresponding to more efficient cars, appliances, and furnaces.

[6]Final demand for electricity, gas, and oil increased by 4% corresponding to more travel, air conditioning and second homes.

FIGURE 1.10

1985 NEW TECHNOLOGY MODIFICATIONS

	Capital	Operating
Hygas (Coal Gasification)[1]	25% of new capacity (gas) additions will be in form of coal gasification.	5% of natural gas demand supplied by coal gasification
Gas Turbine Topping Cycle (combined with Low Btu coal gasification)[2]	50% of fossil generation (15% of total generation) capacity additions will be added in form of gas turbine topping cycle.	38% of fossil generation (23% of total generation) will be by gas turbine topping cycle.

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1 High + Hygas Future: High Future is modified by the above addition of High BTU coal gasification (the IGT Hygas process).

2 High + Hygas + Gas Turbine Future: High Future is modified by the addition of both new technologies indicated above. Note that low BTU coal gasification is used in conjunction with the gas turbine.

The projection procedure aimed at a GNP of $1.34 trillion (1958 dollars)[13] in 1985 for all five alternative futures. This was accomplished with a three-part balancing process using the model of Figure 1.3.

First, the investment requirements for each of the initial final demand projections were calculated and added to the final demand vectors. This resulted in significantly different values of total GNP (between $1.29 and $1.43 trillion) because the alternative investments were quite sensitive to the rate of energy growth and to the introduction of new technology.

Second, these final demands were scaled (by a constant factor applied to purchases of each sector) so that they summed to the proper GNP. The required investments were recalculated with the result that the new GNP's were now less than $1.34 trillion because the investment was not as great as in the initial projection. This occurred because the scaling procedure changed the 1980-85 growth rates for each industry and consequently the required investment changed also.

Third, some linear combination of the scaled and initial projections for each future was chosen so that when investment was recalculated and added to final demand the total had the proper GNP. The proper combination or weighting factor could be calculated analytically and eliminated any convergence problems. This resulted in a balanced projection for each future.

The major assumption in this procedure was that all sectors had the same income elasticity so that a constant scaling factor could be applied to all purchases of final demand. This is a bad assumption for such industries as food and kindred products, but since the conclusions of this study are based on a differential analysis of the various projections

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13 This GNP represents a 4.4% growth rate from the projected 1980 GNP.

and not on the absolute numbers involved, this assumption is not a major problem.

The salient points of the various balanced 1985 projections are summarized in Figure 1.11. As is indicated in Figure 1.11, total investment becomes a larger percentage of the 1985 GNP as energy use increases from low to high. The introduction of high Btu coal gasification further increases investment while the introduction of the gas turbine topping cycle (with or without low Btu coal gasification) decreases it. The output of coal mining is seen to increase dramatically with the introduction of coal gasification. The three illustrated capital producing industries (Plumbing, etc.) respond to different energy use growth rates more than total investment as a whole. Total employment is approximately constant, but there is no indication of how the required skills might change. Certainly more people will be employed in construction and in the capital goods industries for the higher energy growth rate scenarios. Air pollution and steel usage behave as expected. The large decrease in water usage caused by the introduction of the gas turbine topping cycle results from the fact that the gas turbines are air cooled and that the conversion efficiency is higher than the standard generation plant.

The most important fact concerning these balanced-projections is not found in Figure 1.11. The non-investment components of the balanced final demand projections were within 0.3% of the initial projections. In other words, only a very slight change in personal consumption and government expenditures was enough to balance the investment demands of the rapidly growing energy sectors. It seems unlikely that most sectors would notice a difference in sales of 0.3% over a five year period.

F I G U R E 1.11

BALANCED 1985 PROJECTIONS
(1958 dollars)

	Low	Medium	High	High Plus Hygas	High + Hygas + Gas Turbine
GNP (billions)	$1340.8	$1343.0	$1339.0	$1340.9	$1341.0
PCE (% of GNP)	70.2%	70.0%	69.6%	69.3%	69.4%
Investment (%)	16.6	16.8	17.5	17.7	17.5
Government (%)	13.8	13.8	13.5	13.6	13.6
Total Output (billions)					
Coal Mining	$ 5.0	$ 5.1	$ 5.2	$ 6.5	$ 6.6
Plumbing, Structural Metals	18.2	18.5	19.3	19.0	19.7
Engines & Turbines	7.5	7.6	7.9	8.0	8.0
Construction Equipment	11.1	11.5	12.5	12.9	12.6
Private Employment (millions)	99.2	99.2	99.2	99.2	99.2
Air Pollution (million tons)					
Particulates	48.6	49.0	50.0	50.2	50.1
Hydrocarbons	91.7	92.2	92.3	92.3	92.1
SO_2	75.2	76.1	78.2	78.2	78.2
CO	122.7	123.9	124.8	124.8	124.2
NO	30.4	31.8	32.6	32.6	32.5
Steel Usage (million tons)	194.0	195.0	198.1	199.6	198.6
Water Usage (trillion gallons)					
Gross	278.1	280.6	286.7	291.2	266.5
Cooling	126.0	128.3	134.3	137.8	117.8
Energy Use (10^{15} BTU)					
Coal	24.9	25.3	26.0	28.5	28.5
Oil	43.0	43.9	44.5	44.4	44.4
Gas	46.1	46.7	48.5	48.5	48.2
Electricity	33.0	33.8	34.9	34.8	34.8

If most sectors were growing at the same 4.4% per year that GNP is projected to grow at, a decrease of 0.3% in sales would decrease the growth rate to 4.35%, hardly a significant change.

1.4 Conclusions

The major conclusions of this study are the following:

1. Total investment in general and capital good industries in particular (primarily turbogenerator manufacturers, boiler makers, and construction equipment manufacturers) are quite sensitive to energy use growth rates (especially electricity).

2. Introduction of high Btu coal gasification will aggravate the demand for investment funds and introduction of the second generation gas turbine topping cycle (with or without low Btu coal gasification) will decrease the demand. These technologies will have their major impacts on the industries listed above.

3. Slight changes in the overall growth rates of total personal consumption expenditures and government spending result in large fluctuations in total investment.

4. If high energy growth continues and if investment is to remain within its historical limits as a percentage of GNP, energy investment will become a larger and larger part of total investment.

5. While interest rates are assumed to be the balancing mechanism between supply of and demand for investment funds, the very act of saving more money (which is induced by higher interest rates) means that less can be spent on consumption goods. This in turn

lessens the demand for investment funds because the growth rates of consumption sectors are lower. This indirect effect of interest rates on investment has been little studied but may be quite important.

The policy implications of these results are quite important. Different sectors of the economy respond differently to changes in the interest rate. Housing construction seems to be particularly sensitive to interest rates. Knowledge in advance of what investment demands are likely to be provides additional information for planning government spending and taxes. Certainly more work on consumer and industrial response to interest rate changes needs to be performed. There are also questions of whether enough skilled construction labor will be available to build all of the new required energy facilities. Manpower training programs can be developed if the need for such labor can be predicted long enough in advance. The generalized I/O model is, in fact, applicable to all of the above questions, either in pointing out the need for policy or in analyzing the effects of new policy. While the major government policy variable represented in the generalized input output framework is government spending (broken down by sectors), the outputs provide insights into the possible effects of other types of policy decisions like Manpower training.

The input-output models are not generally used the way standard simulation models are. While they can be used to make point predictions of future events, their major use is in comparative analysis. The basic model provides what might be called Nominal Futures against which the modified futures (changes in technology or final demand) can be compared. This comparative analysis often results in conclusions that are not as sensitive to particular assumptions as point predictions would be. Of course, sensitivity sutdies are still an important point of any research.

It is the ability to incorporate engineering studies into the generalized input-output framework that negates many previous objections to input-output analysis. Engineering studies can be used to determine how technology is likely to change if relative price changes or if some fuel becomes unavailable or how technology may improve with time. More work is needed to improve technology forecasting but the potential payoff is great.

Three areas stand out now as both important from the policy decision point of view and as areas where generalized input-output analysis can provide some unique capabilities. Obviously more techniques than just input-output would be needed to answer the whole question, but input-output will play the central integrating role in these studies. These areas are:

(1) Impacts of Capital Expenditures for Environmental Quality. There is a question of whether the 1975 air quality standards could be met (especially by the electric utilities) even if the technology were now available because of capacity constraints on the production of such equipment. What is the best that can be done environmentally at reasonable cost? This study would require knowledge of the production capacity of the many sectors of the economy, and the various options (like fuel switching or SO_2 control) available to meet the different levels of emissions standards. The study could be performed at the national level but regional studies would be more useful. This would entail obtaining all of the above information in regional form and the use of regional I/O tables which are now available [36].

(2) Impacts of Multiple Investment Programs (e.g. Energy and Pollution Controls). Both the government and industry have goals which entail large investment programs as in the industries attempts to meet energy demand and the government attempts to control pollution. Generalized input-output analysis is valuable for examining the combined impacts of these various programs on different sectors of the economy. This is another form of bottleneck analysis and requires information similar to that described above.

(3) Impacts of Alternative Methods of Meeting Oil and Gas Demand. Two extreme cases are possible: (a) the U.S. can rely on a massive oil and gas import program to meet its growing energy needs or (b) the U.S. can stimulate oil and gas development internally. The economy, in terms of employment and sizes of various industries, will be quite different in these two cases. A first approximation to answering these questions could be obtained by ignoring the effects of any price changes in oil or gas products and focusing on the different final demands and industrial structures that might result.

These are important questions and the techniques developed in this study can help to answer parts of them. More research is needed to expand the applications of generalized input-output analysis, but hopefully this report has shown that there is a value to such research.

1.5 Organization

The methodology of transforming engineering data into the I/O format and using it as described in Chapter 2. The results begin in Chapter 3 where impacts of capital expenditures for the new technologies are calculated. Operating and price impacts are then presented in Chapter 4. These results are then integrated in Chapter 5, where a series of high, medium, and low energy growth futures are projected for 1985. Final conclusions and recommendations are made in Chapter 6. The Appendices contain detailed derivations of the new technology coefficients, background information on the economy, energy use, and the environment and a summary of data sources for the model. The model itself is fully documented in Reference [28].

FIGURE 1.12

GENERALIZED INPUT-OUTPUT MODEL SECTORS

SECTOR NUMBER	BEA CLASSIFICATION (ISP)	INDUSTRY NAME
		Standard 104 Industries
1	1.0	Livestock & livestock products
2	2.0	Other agricultural products
3	3.0	Forestry & fishery products
4	4.0	Agricultural, forestry & fishery services
5	5.0	Iron & ferroalloy ores mining
6	6.0	Nonferrous metal ores mining
7	7.0	Coal mining
8	8.0	Crude petroleum & natural gas
9	9.0	Stone & clay mining & quarrying
10	10.0	Chemicals & fertilizer mineral mining
11	11.0	New construction
12	12.0	Maintenance & repair construction
13	13.0	Ordnance & accessories
14	14.01-13, 14.18-32	Food & kindred products
15	14.14-14.17	Grain milling
16	15.0	Tobacco manufactures
17	16.0	Broad & narrow fabrics, yarn & thread mills
18	17.0	Miscellaneous textile goods & floor coverings
19	18.0	Apparel
20	19.0	Miscellaneous fabricated textile products
21	20.0	Lumber & wood products, except containers
22	21.0	Wooden containers
23	22.0	Household furniture
24	23.0	Other furniture & fixtures
25	24.01	Pulp mills
26	24.02-24.07	Paper & allied products except containers & boxes
27	25	Paperboard containers & boxes
28	26	Printing & publishing
29	27.01	Industrial chemicals
30	27.02	Fertilizers
31	27.03-17.04	Agricultural and miscellaneous chemicals

SECTOR NUMBER	BEA CLASSIFICATION (ISP)	INDUSTRY NAME
32	28.0	Plastics & synthetic materials
33	29.0	Drugs, cleaning & toilet preparations
34	30.0	Paints & allied products
35	31.01	Petroleum refining & related industries
36	31.02	Paving mixtures & blocks
37	31.03	Asphalt felts & coagings
38	32.0	Rubber & miscellaneous plastic products
39	33.0	Leather tanning & industrial leather products
40	34.0	Footwear & other leather products
41	35.0	Glass & glass products
42	36.01	Cement, hydraulic
43	36.13	Lime
44	36.02-36.12,36.14-36-22	Stone & clay products
45	37.01	Primary iron & steel manufacturing
46	37.02	Iron & steel foundries
47	37.03-37.04	Iron and steel forgings
48	38.01-38.04	Primary nonferrous metals manufacturing
49	38.05-38.14	Miscellaneous non-ferrous metals
50	39.0	Metal containers
51	40.01-40.02,40.04-40.09	Heating, plumbing & fabricated structural metal products
52	40.03	Heating equipment except electric
53	41.01	Screw machine products, bolts, nuts, etc. & metal stampings
54	42.0	Other fabricated metal products
55	43.0	Engines & turbines
56	44.0	Farm machinery and equipment
57	45.0	Construction, mining, oil field machinery, equipment
58	46.0	Materials handling machinery & equipment
59	47.0	Metalworking machinery & equipment
60	48.0	Special industry machinery & equipment
61	49.0	General industrial machinery & equipment
62	50.0	Machine shop products
63	51.0	Office, computing & accounting machines
64	52.01-52.02,52.04-52.05	Service industry machines
65	52.03	Refrigeration machinery
66	53.0	Electric transmission & distribution equipment & electrical industrial apparatus

SECTOR NUMBER	BEA CLASSIFICATION (ISP)	INDUSTRY NAME
67	54.0	Household appliances
68	55.0	Electric lighting & wiring equipment
69	56.0	Radio, television & communication equipment
70	57.0	Electronic components & accessories
71	58.0	Miscellaneous electric machinery, equipment & supplies
72	59.0	Motor vehicles & equipment
73	60.0	Aircraft & parts
74	61.0	Other transportation equipment
75	62.0	Professional, scientific & controlling instruments & supplies
76	63.0	Optical, ophthalmic, & photographic equipment & supplies
77	64.0	Miscellaneous manufacturing
78	65.01	Railroad transportation
79	65.02,79.01	Local, suburban & interurban highway passenger trans.
80	65.03	Truck transportation
81	65.04	Water transportation
82	65.05	Air transportation
83	65.06-65.07	Miscellaneous transportation
84	66.0	Communications except radio & television broadcasting
85	67.0	Radio & TV broadcasting
86	68.01,78.02,79.02	Electric utilities
87	68.02	Gas utilities
88	68.03	Water & sanitary services
89	69.01	Wholesale trade
90	69.02	Retail trade
91	70.0	Finance & insurance
92	7.10	Real estate & rental
93	72.0	Hotels & lodging places: personal & repair services, except automobile repair
94	73.0	Business services
95	74.0	Research & development
96	75.0	Automobile repair & services
97	76.0	Amusements
98	77.0	Medical, education services & nonprofit organizations

SECTOR NUMBER	BEA CLASSIFICATION (ISP)	INDUSTRY NAME
99	78.0	Federal government enterprises
100	79.0	State & local government enterprises
101	80.0	Imports
102	81.0	Business travel, entertainment & gifts
103	82.0	Office supplies
104	83.0	Scrap, used & secondhand goods
	84-86 (not included)	
		Dummy Industries
105	These sectors do not have	Fossil steam generation
106	ISP classification	Nuclear steam generation
107		Hydro-generation
108		Other generation
109		Transmission
110		Distribution
111		General administrative services
112		Personal automobile use
113		Space conditioning
		New Technologies
114		Coal Gasification
115		Gas-turbine-topping cycle

F I G U R E 1.13

FINAL DEMAND SECTOR

Sector Number	BEA (ISP) Classification	Sector Name
1 (105)[1]	96.60	Personal Consumption Expenditures (PCE)
2 (106)	96.70, 96.80	Gross Private Domestic Investment (GPDI)
3 (107)	96.90	Net Exports
4 (108)	97.10, 97.20	Federal Government Purchases
5 (109)	98.60-98.90	State and Local Government Purchases
6 (110)	99.02	Total Final Demand

[1] These numbers apply if final demand components are listed sequentially after the main 104 industries.

Chapter 2 Methodology: New Technologies and Generalized Input-Output Analysis

2.1 What is Input-Output Analysis?

2.1.1 Methods of Representing Economic Activity

Ever since the first two cavemen got together to barter berries for meat, man has been interested in representing economic activity in some form or another. The type of representation that he has used depended upon the question he wanted to answer. For example, the forecast macroeconomic variables of GNP growth and interest rate provide a good barometer of average stock market behavior. Or the microeconomic theory of the firm and general equilibrium help to explain Adam Smith's Invisible Hand whereby the maximum social "good" is attained by individuals pursuing their own interests. Purpose determines the usefulness of any of these representation techniques.

2.1.2 Input-Output Analysis

The object of input-output analysis is to represent in detail the interactions between the various industries and services that make up the U.S. economy. This form of representation is quite useful for forecasting industrial demand in a manner consistent with growth of the economy as a whole. It is also very useful in policy planning studies at the federal or regional level, where decision makers much be cognizant of the detailed impacts of alternative programs.

The heart of input-output analysis is the interindustry flow table that traces the flow of goods between sectors of the economy on their way to the final consumer. Figure 2.1 contains an 8-sector flow table for the U.S. economy in 1958.

F I G U R E 2.1

Eight Sector Input-Output Table[a] for 1958 (millions of 1947 dollars)

Sector	Sector[b] 1	2	3	4	5	6	7	8	Final demand	Gross domestic output
1. Materials	8,565	8,069	8,843	3,045	1,124	276	230	3,464	3,994	37,608
2. Metalworking	1,505	6,996	6,895	3,530	3,383	365	219	2,946	19,269	45,100
3. Construction	98	39	5	429	5,694	7	376	327	39,348	46,322
4. Transportation eq. & utilities	999	1,048	120	9,143	4,460	228	210	2,226	22,625	41,059
5. Services & trans.	4,373	4,488	8,325	2,729	29,671	1,733	5,757	14,756	137,571	209,404
6. Mining	2,150	36	640	1,234	165	821	90	6,717	−653	11,199
7. Agriculture, etc.	506	7	180		2,352		18,091	26,529	8,327	55,992
8. All other	5,315	1,895	2,993	1,071	13,941	434	6,096	46,338	82,996	161,080
Value added	14,097	22,522	18,320	19,877	148,614	7,344	24,923	57,777		313,475
Total inputs	37,608	45,100	46,322	41,059	209,404	11,199	55,992	161,080	313,475	921,240

[a] Each entry tells the volume of sales by the sector named at the left to the sector numbered at the top.
[b] The sector numbers across the top correspond to the sectors numbered and named in the table.

Source: Carter [6], p. 7

Obviously with only 8 sectors in the whole economy, industries must be highly aggregated. Much more detailed tables have been prepared; the Bureau of Labor Statistics has gone as high as 450 sectors, while the standard Office of Business Economics tables are published at 365 order.

From a national income or GNP point of view, a decline of \$100 million in automobile production combined with offsetting increases of \$50 million each in bicycle production and mass transit usage produces no net charge. Obviously the affected industries do not consider the situations equivalent. This is the gap that input-output analysis fills. As the economy becomes more complex and as economic interdependencies grow, input-output analysis becomes more important. Fortunately this coincides with many recent developments that extend the usefulness and timeliness of input-output data. Traditionally the time lags involved in the preparation of the tables from census data forced economists to rely on tables that were five or more years old. The use of annual surveys (not censuses) to update the tables has brought current data one step closer. In addition, the Interagency Growth Project of the federal government has begun to project input-output tables ten to fifteen years into the future to show what the economy may look like then. [48, 49, 50, 51]. See Yan [55] for an excellent introduction to I/O analysis.

This report documents the first use of input-output analysis as a tool for new technology assessment. Using data from engineering studies, such new industries as coal gasification or such new technologies as the gas turbine topping cycle were directly incorporated into the I/O framework. The basic economic information in the flow tables was also augmented with a variety of environmental indicators, such as SO_2 emissions and water usage. To perform this task, input-output representations of both the capital and operating requirements of the new industries or processes had to be developed. The next section describes this process in detail.

2.2 Technological Coefficients

2.2.1 Historical Derivation

Referring to Figure 2.1, the question can be asked: "What would be the input requirements for each industry if each industry produced only one unit of output?" In other words, what is the fractional input requirement per unit of output for each industry[14]? This is a very simple calculation that only involves dividing each entry in a column by the total output of the industry that column represents. So far all the operations and the data have direct ties to basic census data and cannot really be disputed. The leap between input-output data and input-output analysis involves the assumption that the same fixed proportions of input requirements that held during the Census also hold at other levels of output. It is this linear, fixed-proportions assumption that allows What-if types of questions to be answered. Other assumptions involving the relationship between inputs and outputs could be made, but this linear one is simple and has some empirical validity. For some industries such as farming, where the output is determined as much by the weather as by other material inputs, this assumption may not be very good, but nevertheless, it is used.

It is important to notice that in deriving the input requirement coefficients, the process went from flows to coefficients. In attempting to project new technology's impacts on the economy, the opposite approach must be used. That is, the input requirements are first determined and then future flows are calculated. The next section discusses the actual derivation of the coefficients.

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[14] Economists refer to these input requirements per unit output for each industry as technological coefficients. This terminology will be adopted throughout the rest of the text.

2.2.2 Derivation of Technological Coefficients for New Technologies

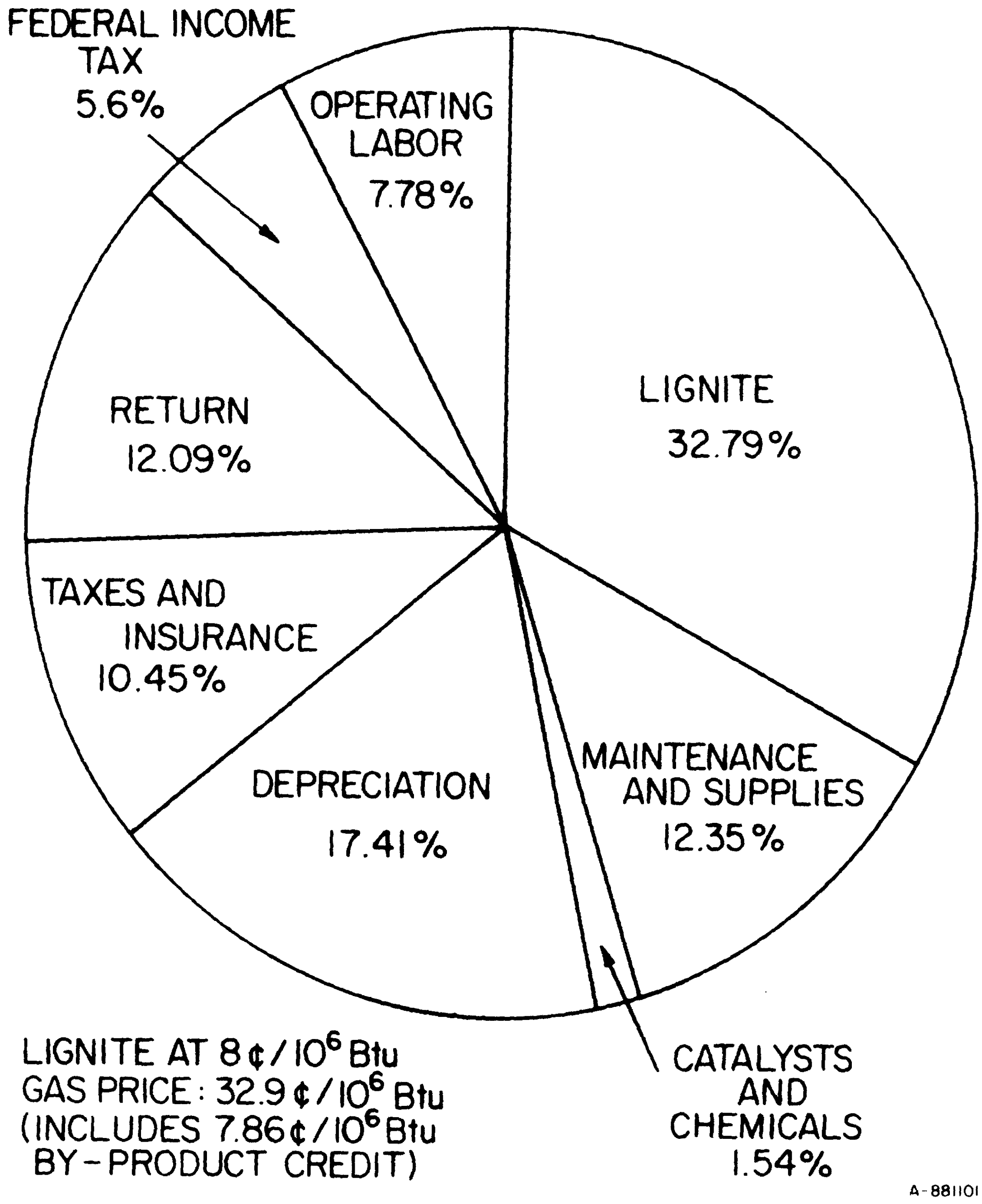
The process of deriving technological coefficients for new technologies is best explained using an example. The example we shall use is taken from a report by the Institute of Gas Technology (IGT) [42]. This report describes a 500 billion BTU/day gasification process that operates via hydrogasification and electrothermal gasification of lignite. This particular report specifies an MHD power cycle as the primary energy producer to run the plant. Other reports in the IGT series have specified other power cycles [43]. This example was used because of its ready availability. Its use does not imply that it is or is not the most likely future gasification process.

Figure 2.2 describes the components of the price of pipeline quality gas from such a process. Figure 2.3 lists 10 sectors in our hypothetical economy (not including the households or value-added sector). The construction of technical coefficients for coal gasification involves transforming the pie chart of Figure 2.2 into a chart where all purchases are from one of the eleven sectors in the model. Obviously, these eleven sectors are being used for illustrative purposes only. The model actually used in this study had 110 sectors, with manufacturing especially broken up into much more detail. (See Figure 1.11).

A first pass at this process appears in Figure 2.4. Supplies are assumed to be 15% of Maintenance and Insurance 10% of Local Taxes. In this figure, all purchased commodities or services are assigned to the sector that manufactures or supplies them. Retail trade is ignored in this round. For example, catalysts and chemicals are assumed to be purchased directly from the chemical manufacturing sector even though they may have been purchased from a local distributor.

F I G U R E 2.2

COMPONENTS OF PIPELINE GAS PRICE



Source: Tsaros [42], p. 67

F I G U R E 2.3

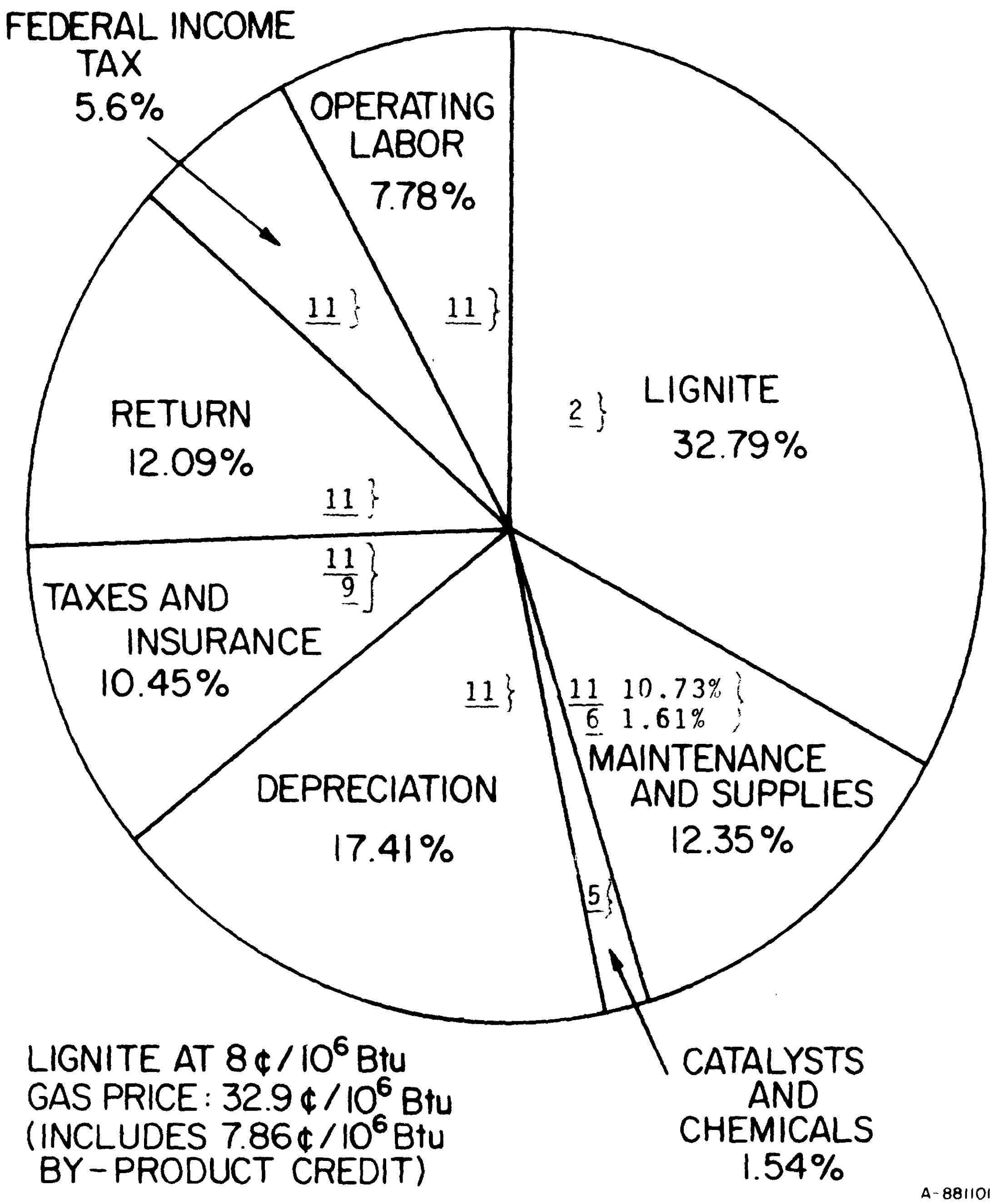
HYPOTHETICAL TEN-SECTOR ECONOMY

Number	Sector Name
1	Agriculture, Forestry, and Fishing
2	Mining
3	Construction
4	Nondurable Manufacturing (Food Processing, Textiles, etc.)
5	Chemicals, Petroleum Refining
6	Durable Manufacturing
7	Transportation, Communications, Utilities
8	Wholesale and Retail Trade
9	Finance, Insurance, Real Estate
10	Other Services
11	Value Added
	a. Labor (wages, salaries)
	b. Investors (interest and dividends)
	c. Capital Depreciation
	d. Government (state, local, Federal taxes)

FIGURE 2.4

COMPONENTS OF PIPELINE GAS PRICE

PRELIMINARY ASSIGNMENT OF SECTORS



The convention followed in input-output analysis is that wholesale and retail trade do not purchase any goods for resale. Instead, the purchaser is shown as having bought any particular good directly from the manufacturer at the producer's price (i.e., what the manufacturer receives from a wholesale buyer) <u>and</u> paying the trade margin or mark-up directly to the wholesale and retail trade sector. Thus any transaction is recorded as two separate entries, one to the manufacturing sector and one to the trade sector.

Transportation charges are handled similarly to trade margins. The purchaser is shown as paying the transportation charges directly to the transportation sector. Figure 2.5 applies these concepts to the IGT example. Here 25% of the price of lignite is assumed to be transportation charges. No trade margin for lignite purchases is included because the company is assumed to buy directly from the mine. Supplies and catalysts and chemicals are assumed to have a 30% trade margin and a 10% transportation margin.

All that remains now is to collect and sum all corresponding items. This result is displayed in Figure 2.6.

What we have referred to as technological coefficients in this paper and in the I/O literature might more properly be called operating input coefficients. Technological coefficients is clearly a misnomer since only in the crudest sense could these coefficients be said to represent the technology of the industry. There certainly is no danger of revealing trade secrets from this approach. The operating input coefficients are much more analogous to the ingredients list in a cooking recipe. By combining all of these inputs in some artful way, a car, transistor, etc., results.

FIGURE 2.5

COMPONENTS OF PIPELINE GAS PRICE

FINAL ASSIGNMENT OF SECTORS (INCLUDING TRADE AND TRANSPORTATION MARGINS)

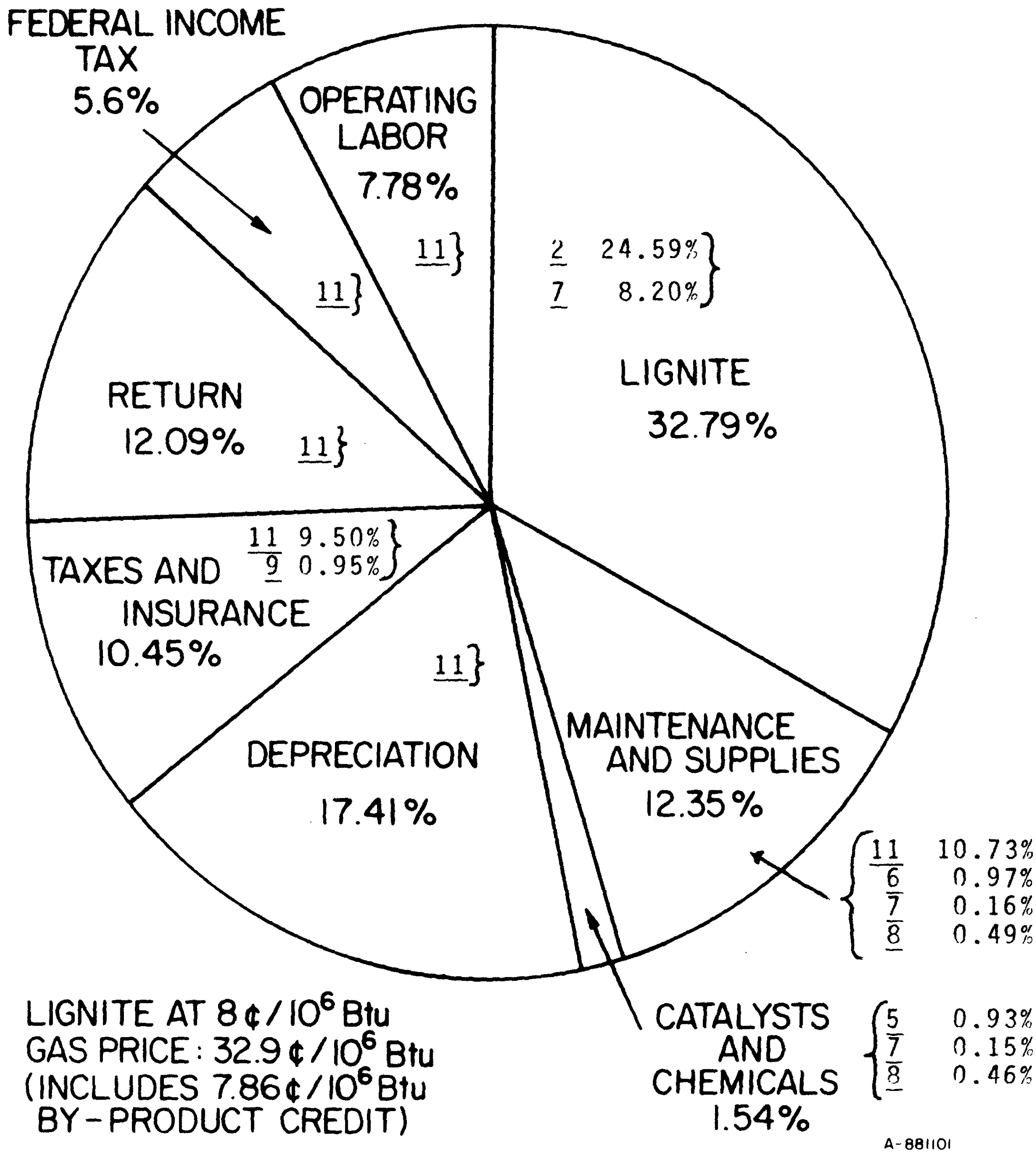


FIGURE 2.6

TECHNOLOGICAL COEFFICIENTS FOR COAL GASIFICATION

Industry Number	Sector Name	Technological Coefficient
1	Agriculture, Forestry, and Fishing	0.0
2	Mining	0.2459
3	Construction	0.0
4	Nondurable Manufacturing (Food Processing, Textiles, etc.)	0.0
5	Chemicals, Petroleum Refining	0.0092
6	Durable Manufacturing	0.0097
7	Transportation, Communications, Utilities	0.0851
8	Wholesale and Retail Trade	0.0095
9	Finance, Insurance, Real Estate	0.0095
10	Other Services	0.0
11	Value Added	0.6311

Especially when dealing with new technologies such as coal gasification, there are many competing processes that perform the same function or yield the same product. In developing the technological coefficients to represent such technology, it is important to make sure that the coefficients are representative of all the processes or if this cannot be done, to be sure that any conclusions from such a study are not sensitive to the exact process chosen.

2.3 Capital Coefficients

2.3.1 Historical Development

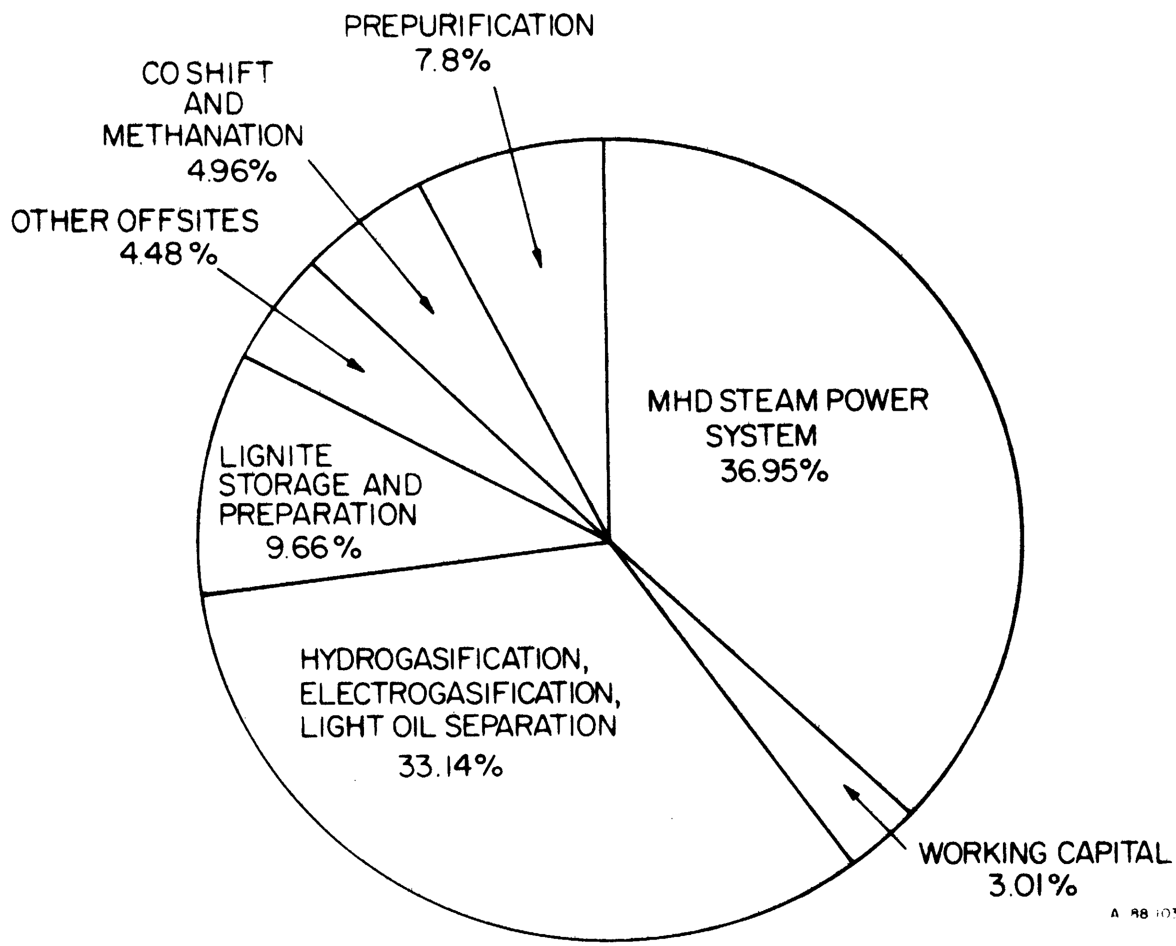
Capital coefficients describes the capital equipment purchases necessary to build a new plant for some industry. There are a number of problems associated with attempting to derive capital coefficients from historical data, not the least of which is the rapidly inflating cost of capital equipment. Does one look at replacement cost or original cost? Does human capital, such as knowledge in an engineer's head, or patent rights (such as Xerox or Polaroid hold) enter into the numbers? Does one look at the best new technology or the average technology for any given process?

Fortunately these questions do not arise when one is concerned with the economic impacts of building new technology from scratch at one point in time. The next section discusses this.

2.3.2 Capital Coefficients for New Technology

The process involved in deriving capital coefficients is quite similar to that for the technological coefficients. The basic starting point is the engineering design study. We shall continue using the IGT coal gasification example. Figure 2.7

INVESTMENT BREAKDOWN FOR PIPELINE GAS PLANT



Source: Tsaros [42] p. 65

FIGURE 2.7

illustrates the type of pie chart obtained from the engineering study. This is not very informative for our purposes, but Figure 2.8, taken from the same source, provides a breakdown of equipment and installation costs for the various parts of the process. The numbers in parentheses are the fraction of total fixed investment that each entry represents before trade and transportation margins are taken out. The engineering study contains many more detailed tables than this. For example, Figure 2.9 gives a detailed description of the equipment required for the lignite drying section of the plant. The basic strategy for the derivation of capital coefficients then is to assign each piece of equipment to its producing industry; remove the transportation and trade margins; allocate construction, insurance, engineering, interest, etc., charges; and divide the total purchases from each section by the total cost of the plant. The procedure yields a vector whose elements sum to 1.0 and which can be used to allocate each dollar spent on coal gasification plants to the respective industry of origin.

From this basic percentage capital distribution vector, the capital coefficient vector can be found by multiplying by the capital/output ratio that describes the dollars of capital investment in plant per dollar of product output from the plant. This is calculated easily by dividing the capital cost of a new plant by the value of its yearly output.

These are the procedures that were followed to derive capital and technological coefficients for all the various new energy technologies that are discussed later. Detailed derivations of the coefficients and the assumptions behind them are found in the Appendices.

FIGURE 2.8

INVESTMENT SUMMARY

500 Billion BTU/Day Pipeline Gas from Lignite

Section	Process Equipment, $	Bare Cost Installed, $	Fraction of Total
Lignite Storage and Reclaiming	1,710,000 (.007)[5]	3,420,000	(.015)
Lignite Grinding and Drying	5,864,000 (.026)	11,728,000	(.051)
Slurry Preparation	1,652,700 (.007)	4,958,000	(.022)
Hydrogasification	35,681,700[1] (.156)	68,887,000	(.302)
Prepurification I	4,767,200[2] (.021)	8,340,000	(.037)
CO Shift	1,913,500[3] (.008)	3,587,000	(.016)
Prepurification II	4,130,000[4] (.018)	7,888,000	(.035)
Methanation, Drying	4,117,500 (.018)	6,706,000	(.029)
Offsite Equipment	-- (.337)	86,144,000	(.378)
Subtotal, Bare Cost		201,658,000	(.884)
Contractor's Overhead & Profit		15,588,000	(.068)
Subtotal		217,146,000	(.952)
Interest During Construction 5% of Subtotal		10,862,000	(.048)
Total Fixed Investment		228,108,000	(1.000)
Working Capital		7,085,000	(.031)
Total Capital Investment		235,193,000	(1.031)

[1] Includes $121,500 tower packing (.0005)

[2] Includes $240,000 initial catalyst charge (.001)

[3] Includes $372,000 tower packing plus initial zinc oxide and carbon (.002)

[4] Includes $1,811,000 initial catalyst charge (.008)

[5] Numbers in parentheses are fractions of total fixed investment

FIGURE 2.9

LIGNITE GRINDING AND DRYING EQUIPMENT SUMMARY

Equipment	Description	Cost/Unit $	Total Equipment Cost $
Crusher Feed Hopper	600-ton capacity hopper, ½ hr. residence time, 35 ft x 35 ft x 20 ft x ½ in. thick; 60^{o} slope of bottom cone	39,000 (2)[1]	78,000
Grinder-Dryer Feed Hopper	600-ton capacity feed hopper, ½ hr residence time, 35 ft x 35 ft x 20 ft x ½ in. with 6-60^{o} cones	45,000 (2)	90,000
Crusher	Precrusher hammer mill to crush 5 in x 0 mined lignite to 1½ in. size; 1159 tons per hour capacity, 500 hp motor	50,000 (2)	100,000
Grinder-Dryer	Williams 100-in: roller mill dryer to grind and dry 1.5 in. lignite at 35% moisture to -10 + 100 size at 13% moisture, 189 tons per hour of feed to give 135 tons per hour of product	433,000 (12)	5,196,000
Crushed Lignite Conveyor	Tube conveyor, 30-in tube, 48-in. belt, 500 ft/min. 100 hp motor-driven, 1135 tons per hour feeds G-202	50,000 (2)	100,000
Grinder-Dryer Distribution Conveyor	48-in. belt, 300 ft c-c, 450 ft/min with 6 tripping stations, 100 hp motor-driven, includes tripper	90,000 (2)	180,000
Ground Lignite Conveyor	Tube conveyor, 16-in. tube, 24 in. belt 500 ft/min. 40 ft rise 100 c-c, 50-hp motor driven, 269 tons per hour	20,000 (6)	120,000
		Total	$ 5,864,000

1 Number of units required

2.4 Uses of the Coefficients

Given $\underline{A}_N$, the new process's technical coefficient vector and $\underline{K}_N$, the percentage capital distribution vector,[15] there are a number of useful calculations that can be made. For example, the economic impact of c dollars worth of production using the new process can be found without modifying the original technical coefficient matrix $\underline{A}$, assuming that the new process results in additional purchases from all sectors and is not a replacement for another process. If this is the case, then the additional sales by each sector $\underline{X}_A$ can be found by treating the purchases of c dollars worth of the new process as a final demand vector, c $\underline{A}_N$. Thus

$$\underline{X}_A = c\ (\underline{I}-\underline{A})^{-1}\ \underline{A}_N \qquad (2.1)$$

Similarly the economic impacts of d dollars of capital expenditures for new process equipment can be found by

$$\underline{X}_B = d\ (\underline{I}-\underline{A})^{-1}\ \underline{K}_N \qquad (2.2)$$

if the new process does not replace an old process (e.g. Polaroid prints).

Since most new technology does replace some older process, a different methodology is required to calculate economic impacts for these cases. Assume that the old process occurs in sector i in the technology coefficient matrix $\underline{A}$ and the capital matrix $\underline{C}$ and let $\underline{A}_i$ and $\underline{C}_i$ be the respective column vectors for this process.[16] A new process rarely replaces an old one completely instantaneously. If g is the fraction

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[15] This vector was defined in the previous section. The capital vector for the new technology will be designated $\underline{C}_N$.

[16] See footnote 10 for the definitions of $\underline{A}_i$ and $\underline{C}_i$.

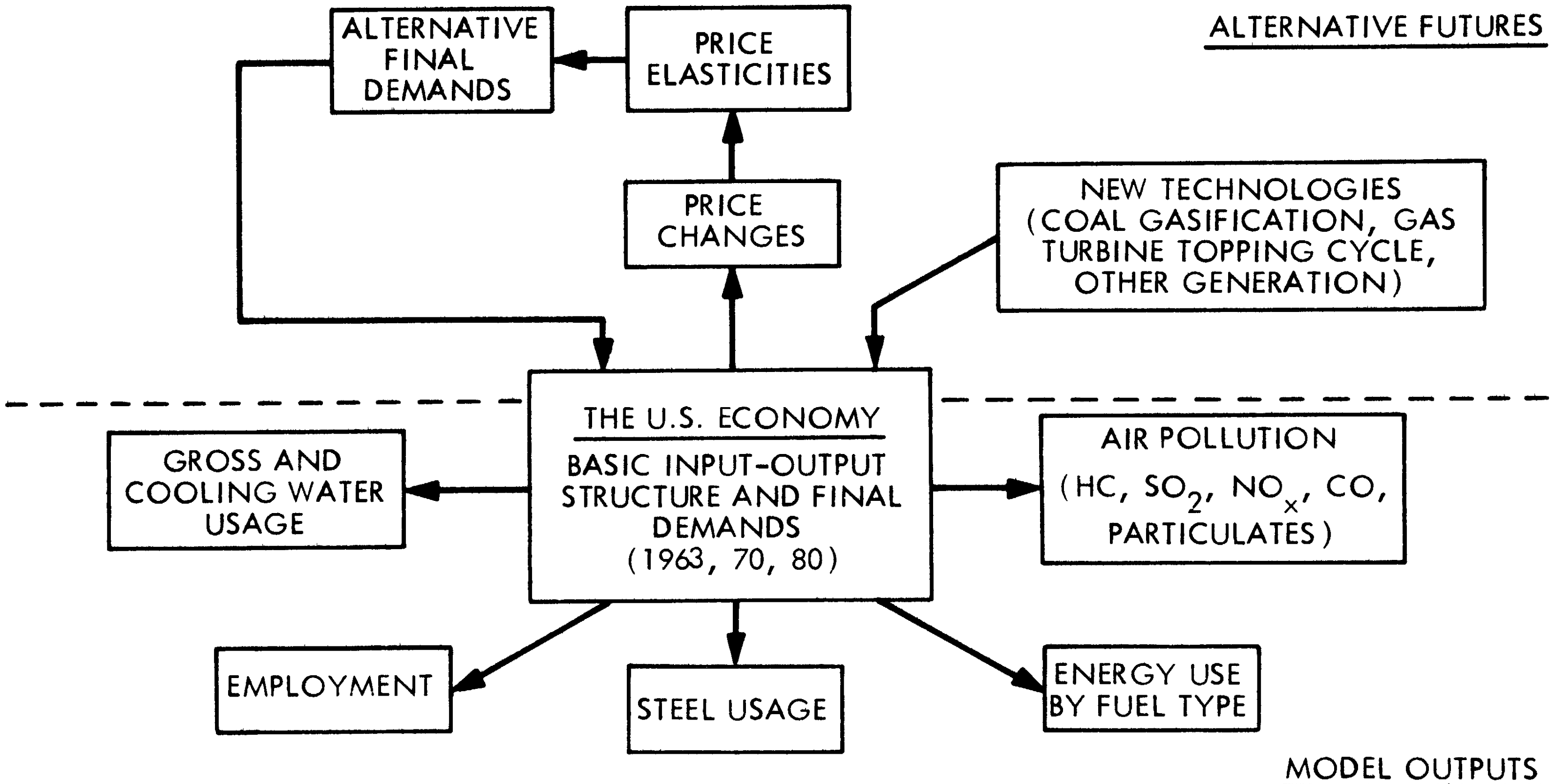
of total output for sector i produced using the new technology, then the composite new technology coefficient vector $\underline{A}'_i$ can be expressed as $\underline{A}'_i = (1 - g)\ \underline{A}_i + g\ \underline{A}_N$. Similarly if h is the fraction of additional capital investment by sector i in new technology equipment, then the composite capital vector $\underline{C}'_i$ can be expressed as

$$\underline{C}'_i = (1 - h)\ \underline{C}_i + h\ \underline{C}'_N \qquad (2.3)$$

The new composite technical and capital coefficient vectors replace the old ones in their respective matrices. These matrices can then be used as they would be normally. The above process of combining new and old technologies is representative of what Carter [6] refers to as "imbedded technology". It is also possible to introduce a new technology as a completely new industry and add it to the capital and technical coeffical matrices as sector N + 1, when N is the original number of sectors. This was not done for two reasons. First, most new processes are replacements for older processes and hence the problem of relative weights must be addressed whether it is represented as a separate sector or combined with another sector. Second, in compiling historical I/O tables, the Commerce Department relies on the Standard Industrial Classification scheme, and this scheme forces new industries into old classifications until the industry becomes large enough to justify a revision in the scheme. For these reasons, the two above methods of calculating impacts and incorporating new technologies were used rather than adding new sectors.

2.5 Overview of the Generalized Input-Output Model

The generalized input-output model is diagrammed in Figure 2.10. The core of the model is the I/O framework that contains final demands and technological coefficients for 1963



MODEL PROPERTIES

1. Highly Interconnected Economy
2. Quasi-Static Technology Change
3. 110 Sectors (Industries)
4. Linear
5. National

FIGURE 2.10

ENERGY-ORIENTED GENERALIZED INPUT-OUTPUT MODEL (actual), 1970 (projected) and 1980 (projected).[17] There are also capital coefficients for 1958 and 1975. Figure 2.11 summarizes the data sources for this I/O information and for the long-term residential price elasticities.

The boxes below the horizontal line of Figure 2.10 represent the non-economic outputs available from the model. Section 1.2.3 described how these accessory variables are assumed to be proportional to the total output vector ($\underline{X}$). Each set of accessory coefficients (used to convert the total output into values of accessory variables) can be considered a separate module of information. The mere separation of these modules adds several major advantages to the model, the most important being its ease of update: any one module can be updated without affecting the rest of the model. The second advantage is that it allows for expansion possibilities, enabling the central model to interact with any number of other models. Because of the separation each module could easily be a part of an entirely separate model, acting as the interface between the I/O model and a second model (e.g. a separate model could predict pollution coefficients which would in turn be used by the I/O model). There are many potential applications of this approach.

Another advantage of the accessory coefficient approach is that it allows the accessory variables to be treated like other variables in I/O. Thus each industry can be characterized in a particular year by its technological coefficient column ($\underline{A}_i$), its capital coefficient column ($\underline{C}_i$), and by a column vector of its accessory coefficients (which can be expanded to include any variables that are proportional to the total output $\underline{X}$). This is a very flexible scheme. Figure 2.12

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17 The 1970 coefficients are projected and not actual because there was no Census-derived I/O table for that year.

FIGURE 2.11

SOURCES OF INPUT-OUTPUT DATA[1]

Item	Source Reference	Description
FINAL DEMANDS		104 x 6 Final Demand Vectors
1963	[49][2]	Actual
1970	[52][2]	4% unemployment basic projection by Bureau of Labor Statistics (BLS)
1980	[51][2]	4% unemployment basic projection by Bureau of Labor Statistics (BLS)
TECHNOLOGICAL COEFFICIENTS (Basic)		104 x 104 Technological Coefficient Matrix
1963	[49][2]	Actual
1970	[52][2]	Projected by BLS
1980	[51][2]	Projected by BLS
CAPITAL COEFFICIENTS		104 x 104 capital coefficient matrix
1958	[21][3]	Battelle Memorial Institute projections
1975	[21][3]	
ELASTICITIES	[2]	University of Maryland Long-term Personal Consumption Expenditure Price Elasticities
NEW TECHNOLOGIES		
High BTU Coal Gasification	[42, 43]	Institute of Gas Technology Hygas Process
Low BTU Coal Gasification	[39]	1980 Texaco Process
Gas Turbine Topping Cycle	[39]	1980 United Aircraft Combined Gas & Steam Cycle

[1] All sources and modifications are documented in [28]

[2] Originally had 83 sectors but disaggregated to 104 sectors (see [28])

[3] Originally had 112 sectors but aggregated to 104 sectors (see [28])

FIGURE 2.12

OUTPUTS OF GENERALIZED INPUT-OUTPUT MODEL AND DATA SOURCES

Item	Reference	Source
Final Demand by Sector	-	See Figure 2.11
Total Output by Sector	-	Calculated
Air Pollution Emissions	[25]	International Research and Technology
SO_2		
CO		
NO_x		
Particulates		
Hydrocarbons		
Energy Usage	[38]	Battelle Memorial Institute (Reardon)
Coal		
Crude Petroleum		
Refined Petroleum		
Natural Gas		
Electricity		
Steel Usage	[44, 47]	Censuses of Manufactures and Mining
Employment	[51, 52]	Bureau of Labor Statistics
Water Usage	[46, 47, 54]	Censuses of Manufactures and Mining
Gross (including recirculation)		Water Resources Council
Cooling		

summarizes the outputs of the model and the basic data sources used to construct the accessory coefficients.

The only special convention used involved the calculation of electricity consumption on the basis of 3412 BTU/kwhr, which is the thermodynamic equivalent and does not include any thermal losses associated with the generation of electricity. All such thermal losses are attributed to the electrical utility sector. This convention is discussed more in References 28, 29 and 37. It has the advantage of assigning the thermal losses to the sector that actually causes them and which gets credit for any efficiency increases. It has the disadvantage of making the total electrical utility number (since waste heat is twice as large as the total useful electrical energy).

The only other energy related criticism of the I/O data is that the projected 1970 and 1980 I/O tables imply more natural gas will be used than any other authority in projecting. Whether this was done purposely or not is unclear. Reference 28 discusses this further.

2.6 Methodology in the Generalized Input-Output Model

This section and section 2.7 discuss problems with the generalized I/O model and with the derivation of new technology coefficients. The problems are summarized and various recommendations made to correct them. These two sections can be skipped without loss of subject continuity.

2.6.1 Problem Areas

Overall, the two major deficiencies of the model used in this study are the lacks of both dynamic behavior and regional impacts. In other words, it would have been very nice to tie final demand dynamically to the income generated via the value added coefficients as well as to be able to represent state or regional effects in the model. Of course this defect is a defect of the particular implementation used for this report and not a defect in the generalized input-output methodology itself.

There are two methods of representing pollution within the input-output framework. Leontief is responsible for both of the representations. He seems to be inclined toward representing pollution within the matrix as a separate anti-pollution industry or set of industries, such that other sectors of the economy, desiring to eliminate a certain amount of pollution from their output, purchase pollution abatement from the anti-pollution industries. There is some economy of effort in this approach since there are relatively few types of pollution abatement processes for all industries and these could be adequately represented by several anti-pollution industries. This would enable one merely to calculate the desired reduction in pollution and have each industry purchase that amount from the various anti-pollution industries.

Conceptually we prefer the actual modification of the technical coefficients for each industry to represent pollution abatement activity. After all, there is no anti-pollution industry and the individual decision unit within the input-output framework is the factory or plant and it decides whether to install pollution abatement equipment. Thus, by resorting to the anti-pollution industry artifice, one distorts the actual industry structure. Actual emissions of pollutants can easily be represented by a set of emission coefficients. This coefficient approach is easily generalized to handle outputs other than pollution.

The general coefficient approach assumes linearity of pollution or whatever with a rising level of industry sales and it assumes a homogeneity of the industry's product and processes. For example, the paper industry can produce paper by any of four different methods and the pollution impact of each of these four methods is quite different. Or, as another example, fuels used by an industry have a different pollution impact depending upon whether they are used for heat or as a processing material. The conclusion of all of this is that the finer the scale of representation of industries within the economy, the easier it is to use the general coefficient approach. Best of all would be to represent the economy or represent each industry as a weighted sum of the various technological processes used by that industry to produce its output. For example, within the input-output table the paper industry would be represented as a single set of technology coefficients which would be a weighted sum of the process coefficients for each of the methods of making paper. It would be extremely easy to carry the definition of process to an extreme; for example, the difference between plastic and paper cartons as packing material could be viewed as a different process. Thus it is important that process be defined in a reasonable manner and also that within the input-output table itself that each process not be represented. The reason for representing processes is to allow one to calculate technology coefficients for a particular industry. It is not necessary that this level of detail be carried over into the entire input-output table. This methodology can be looked upon almost as a subroutine for generating industrial coefficients. This will result in vast savings in computational time.

This general coefficient approach also assumes that the dollar flow of goods is proportional to the product flow or material flow of goods. This is definitely not true in some cases. If one compares the actual Btu flow of coal to various sectors of the economy with the corresponding dollar flows, one immediately discovers that there are significant differences in the implicit prices paid for coal. Part of this variation is due to the economies of large-scale purchasing. Part of it is also due to differential transportation or production costs. This is especially true for coal shipment, where the value of the coal FOB the mine is about $4.54, while the average rail charge to transport the coal to its final destination is about $3.01 or two-thirds of the actual value of the coal itself. Since the input-output table is constructed in purchaser prices, theoretically the different transportation charges should not enter into this problem, but in fact because of the way the input-output tables are constructed by the Commerce Department such differences do remain. This type of problem can be handled with some extra work if it is true that within each block (that is for each sale from one industry to another industry) all changes in dollar flows in that particular cell are proportional to changes in the actual material flow. Of course there are many cases in which this is not true. For example, the steel industry's sales to the boiler manufacturers can change dramatically merely because of a change in the grade of steel being purchased rather than because of any change in the quantity of steel being purchased. However, for energy flows this is typically not the case. (Unless the electric utility industry switches from burning #6 distillate to burning gasoline or from bituminous to lignite).

All in all, the input-output table can be made quite suitable for tracing energy flows in the economy if the problem of secondary products and transfers are handled judiciously. A transfer or secondary product does not represent an actual transfer of goods. Instead it is an accounting convention to move all secondary production of a particular good to the proper primary sector for distribution. Since the Commerce Department does publish both primary and secondary matrices, this problem can be dealt with.

The consumption side of the input-output table is not particularly well represented in a static scheme such as the one used for this report. Dynamic models have been developed that tie final demand to the income produced via the other added coefficients of the model. But even this tying of aggregate consumption to aggregate income is not really an adequate representation of the consumption function. What are needed are better behavioral models of why people buy certain commodities: what function is fulfilled by the service rendered by these goods. This is particularly important for purposes of projection of energy consumption because the production of an air-conditioner or the production of an automobile does not require nearly as much energy as the use by the consumer of either of these goods. Much more sophisticated relationships will be needed than simple multiple regressions of automobile usage or air-conditioner usage versus past data. At the very least one must look at market saturation mechanisms and the income elasticities of such demands.

It is also extremely important in such endeavors to tie the concept of transportation or comfort to an overall quality of life index. This is important because even though air-conditioners, for example, are heavy energy users, it may be that people have come to regard them almost as necessities rather than luxuries. In making policy statements about how energy demands can be reduced one must be especially concerned about performing such reductions at minimum damage to the quality of life in the nation. This is not to say that the efficiency of air-conditioners cannot be increased significantly: one must be very careful of the capital costs associated with such increases in efficiency. It will also be important to learn whether people respond more to changes in the price of energy or to changes in the capital cost of energy-using equipment.

The methodology discussed in this report is quite capable of adaptation to regional modeling efforts. If and when such research can be done, and there are extremely large computational and data gathering problems involved in such models, the payoffs could be quite significant. It is not completely necessary that one have a multiple region input-output model that can be used for predicting trade flows, for example,between regions. Merely having state input-output tables will enable one to answer many significant questions. For example, the impact of the 1975 air quality standards on electrical utilities will vary quite a bit from region to region because of the availability or lack of low sulfur fuels and the particular fuel mix within the region.

To assess the overall usefulness of the generalized input-output methodology,one must be able to relate the usefulness of the outputs to the accuracy thereof and the effort involved in getting that accuracy. The data gathering aspects of input-output analysis are very difficult. The advantage of going to such lengths to gather the data is that one immediately has the ability to perform integrated forecasts. For example, one will not have to predict electric energy usage, steel usage, the number of colored television sets separately. The United States is one economy. Information about one segment of it has a bearing on all segments of it. Therefore, by studying the interrelationships between industries,one can automatically achieve simultaneously better relationships and forecasts for all industries involved. In-depth industry analysis should enable one to predict technical coefficients five, ten and perhaps fifteen years into the future. This, of course, ignores sudden changes in taste or consumer preferences, as that which led to the decline of the returnable bottle for soda manufacturers and to the spectacular rise of the throwaway bottle and can.

This is not really a technology change within the industry, but must be represented as such in the input-output table. Carter [6] refers to all such changes as structural changes. Such changes in fact reflect not only changes in technology but changes in product mix and in such preference items as throwaway bottles. Barring such small perversities, however, the prospect is quite good of doing relatively detailed forecasts of the future. This should be of immense help to both policy planners and industrial leaders combined. Thus the conclusion is that such models and data gathering efforts are indeed worthwhile.

2.6.2 Recommendations

If the following recommendations were implemented, the interpretation attached to any particular entry in the input-output table would be much more accurate and the use of the input-output framework for forecasting purposes would be much simpler. We therefore recommend that:

1. The treatment of services within the input-output table should be detailed much more than it currently is. The current method of distributing purchases of services is to allocate them to sectors on the basis of number of employees within a particular industrial sector. This process could be significantly improved with more work. Perhaps the institution of a census of services would be worthwhile. Certainly this sector of the economy is not dealt with very well at all and, since services now make up 50% of private GNP, further documentation of service industries is definitely in order.

2. The Commerce Department, which publishes both the censuses and the national input-output tables every five years, should begin to make changes in their procedures such that the published input-output tables are designed with forecasting in mind. The original efforts of publishing the input-output tables were more designed for representing "the actual formation of Gross National Product within the economy." There are many instances where values are imputed to services such as owner-occupied dwellings or consumer credit agencies and no such transactions actually occur there. To the extent that such imputations are well-documented, then they are quite usable, but the current lack of documentation leaves many people in the dark as to the exact interpretation of numbers within the table. More attention should be focused on actual material or dollar flows between sectors, than on such artificial transactions as imputations of values or transfers of secondary products.

3. It would be extremely useful if for certain rows of the matrix, in particular energy rows and major material rows such as steel, separate material flow rows corresponding to the dollar flows in the input-output table were published by the Department of Commerce. The census generates much data along these lines, both in terms of dollar flows and material flows, and it would be very good if these flows were integrated with one another.

4. More in-depth industry analyses should be made in the sense of defining technology coefficient vectors for each of the various processes used by the industry and then forming the actual set of technology coefficients used in the input-output

table by some weighted combinations of these process vectors. The Interagency Growth Project does sponsor many such in-depth industry analyses, but these studies are rarely if ever published and are typically for internal consumption only. Such publications would be invaluable in the updating of forecasts using the input-output table.

5. Many more studies of consumption behavior must be made using new and different approaches to the problem. For example, opinion polls to determine the uses to which people put energy and how they would rank various possible uses of energy, e.g. air-conditioning versus toasters.

6. More documentation must be put out by the Commerce Department on the entire process of deriving the national input-output tables.

7. The Commerce Department could improve its representation of activities or functions within the consumer sector by the use of more dummy industries similar to the real estate sector in the present table. Such dummy industries could for example provide a better representation of personal automobile transportation and space conditioning.

2.7 New Technology Coefficients

2.7.1 Problem Areas

The problems faced in deriving capital and operating coefficients for new technologies are distinctly different from those of constructing an input-output table from census data. With census data, one has to allocate the usage of goods and services between various sectors until the total approximates that of a control total. The interlocking arrangements of rows and columns for each industry make this task somewhat easier, although practitioners may say more difficult. When dealing with a new technology, however, there are no control totals. The cost of a new plant can be estimated and that cost used as a control total but in no sense is this cost a hard number. The situation is no better for operating costs. Estimated engineering efficiencies, such as pounds of coal per Kwhr, can be remarkably illusory. Probably the most notable example of this in the current study occurred in the IGT use of cost estimates for an MHD power cycle. This technology still does not exist and could not be bought at the moment for any amount of money. Another example was a cost study for the Kellogg molten carbonate high BTU gasification system. Costs were generated for a process that cannot be made to work at the present time because no material exists that can withstand the corrosion of the pressurized hot carbonate.

How can such mistakes happen? Ignorance, pure ignorance! When an engineer is forced to come up with a cost estimate for a new plant, he immediately looks around for a recently constructed "similar" plant. If the plant happens to involve new technology, there will be no similar plants in existence. Then he must resort to some of the standard estimation schemes that work fairly well for old technology plants. There are a number of these procedures. The more accurate ones (used for competitive bidding on plant construction) are very expensive to use and require much information. The very detailed actual construction type of estimate is never used in the first stages of contemplating a new technology. Instead the desired volume of product is used to determine the physical scale of the project. Appropriate sizes of equipment are fitted to the basic process steps and the costs are estimated from the size of these individual equipment pieces. From this basic equipment cost, total installed costs are estimated by allowing certain percentages of equipment costs for piping, structures, contingencies, etc. This is an extremely crude estimating method but it is adequate for routine process plants. Since the engineer doing the costing does not know of any problems that can arise with the new technology, he usually assumes there will be none or, at most, increases his contingency factor somewhat.

The engineer is not being diabolical in this procedure, but does the best he can with the very limited knowledge that he has. There may be an element of duplicity involved if the costs of the resulting product determine whether additional funding will be forthcoming from the government or private sources. No construction company in the world would contract to build this new plant at the above price, of course. Suppose, for example, there there were an unforeseen corrosion problem and, hence, all vessels must be constructed out of a special alloy that was twice as expensive at the standard grade (not an unheard-of occurance). Factors like this are the cause of the price rises that occur over the research and development life of a product. Changes in interest rates and inflation (of construction wages in particular) exacerbate the situation.

The fact that there is a working model of a process does help the estimation schemes. They provide information about types of problems that do occur and a small amount of information about problems that do not occur. However, estimations are usually made for full size plants on the basis of laboratory models, pilot plants, or demonstration plants. Whenever a plant is scaled up there is the possibility of an emergent problem. For example, fluidized beds which work fine on a small scale tend to develop bubbles when scaled up. These bubbles substantially reduce the yields from such a process. Of course, once a full-scale plant is developed, the new technology is no longer so new and cost estimates can be made much more accurately.

What are the implications of all this for attempts to incorporate new technology into future-oriented input-output tables? The practical situation is really not as grim as indicated in the previous paragraphs. The major reason for this is that before a new technology can have any economic influence and hence enter the input-output flow matrix, the technology must be proven commercially. Businessmen like uncertainty even less than input-output economists, because they have money riding on the betting wheel of technology. Hence by the time there might be a significant impact the technology will be proven enough that good capital and operating coefficients can be derived. This assumes, of course, that one has access to the required information. There is a great deal of sensitivity about costs of new technologies, especially if a private organization is involved. For example, the IGT Hygas demonstration plant preliminary engineering design report is completed and contains detailed cost data, but it is confidential material. We were fortunately allowed to examine a copy of the report, from which all cost information had been expunged, but were not allowed to reference or quote from the report. The IGT process is 10 years away from commercial reality but enough information exists now and more will become available in the next few years to predict fairly accurately (± 25%) what the capital and operating coefficients will be, in terms of current dollars.

What may happen, of course, is that another coal gasification process may prove to be cheaper. Already the Hygas oxygen process seems to be cheaper than the electrothermal process. To do accurate predictions of the future then may require that the mix between the various processes be foreseen properly. This is a more difficult job than assessing the capital and operating coefficients of each process. On this problem there is little to say except that, by the time commercial feasibility is proven, the economics will have sorted themselves out enough to allow better prediction of this process mix. Such information does not exist now although some processes are dropping by the wayside. To predict which, if any, of the survivors will be the big winner is too much to ask at this point. Fortunately the technical and capital coefficients for the various processes may not differ by that much, even though the technologies are quite different. This depends on particular circumstances.

2.7.2 Recommendations

The following recommendations would enable engineering data to be incorporated to I/O tables more easily:

1. More documentation should be provided by the Department of Commerce on the actual construction of their official national input-output table. In particular, the prorating of inputs of services on the basis of number of employees and the construction of control totals for each industry should be documented.
2. A standard methodology should be developed to handle confusing classification items like piping or instrumentation or confusing situations like the construction component of installing a boiler. Is this component assigned to construction or value added? Some research needs to be done on what the process industry terminology and costing procedures mean by certain words or concepts, e.g. "bare cost," "contingency cost," "engineering, design, and construction cost."

3. A more satisfactory method of handling secondary products should be developed than that of transferring the product to its primary industry. These transfers distort the input structure of various industries unless the I/O table is first purified or only the primary matrix is used. For certain purposes it would be better not to transfer any products at all, rather than distort actual industrial behavior.
4. The treatment of special items like computer and photocopying leasing or the imputation of values to consumer credit should be explicitly explained. A major revision of the Standard Industrial Classification Manual would be a great boon to such research. BEA Industry 37 (Iron and Steel Production) is particularly bad.
5. Certain standard "modules" for construction of piping systems or insulation for the operation of typical consumer billing departments should be published. What is needed is detailed percentage breakdowns (by input-output sector) of many trivial construction or operating items. This is much more useful than total construction vectors for typical electrical utilities.

The following recommendations should make new technology studies much more meaningful and useful:

1. Research on dynamic input-output models should be initiated and these models should concentrate on state-space types of dynamic models, as well as the simpler Leontief dynamic inverse approach. The focus here should be on developing actual simulation models of flows of goods and

services through the economy and on detailed representations of industries within the economy.

2. Regional input-output models should be developed with energy as their primary focus and the flow of materials in general as a major component of the focus. A complete multi-regional input-output model is not completely necessary in this context, since the purpose of the work is not so much to predict inter-regional flows of goods and services but more to predict impacts within a region of new technology, pollution, etc.

3. Water pollution coefficients should be developed to go into the input-output framework along the same lines as the air pollution coefficients do. This could be implemented as a two-stage process with a crude set of coefficients such as that developed by the Harvard Economic Research Project or by International Research and Technology for the report to the Population Commission and a second stage in which individual industries were studied in detail to determine the pollution per dollar impacts of that industry. Theoretical engineering work also needs to be done to define the limits of applicability of the linearity assumptions of pollution and total output of a particular industry. More complicated models can be included within the input-output framework if more complicated models are justified by increased accuracy.

4. Research is needed on the projection of input-output tables in constant dollars. It is known, for example, that the so-called double deflation scheme that involves simultaneous deflation of the inputs and outputs of an industry can lead to nonsense in certain cases. It is important to

know what impact this has, if any, on projections in constant dollars.

5. Much more engineering data should be integrated into the input-output tables. This is very analogous to the in-depth industry studies recommended previously.

6. An explicit study of the use of input-output analysis for forecasting of energy demand should be made using the most recent energy flow data that is available. Oak Ridge National Laboratory is in the process of preparing a 365-order energy flow table for 1963. When this study is published it should enable one to do much better energy use forecasting.

7. The time structure of investments for the energy industries, e.g. the investment profile over time of a typical nuclear generation plant, should be studied. This corresponds to the economic concept of a lag structure. Such a study is quite important if dynamic models are going to be used.

Chapter 3 Impacts of Capital Expenditures for New Energy Technologies

3.1 Summary of the Impacts

3.1.1 GNP and Investment Perspective

The energy-producing industries are extremely capital intensive. Attempts have been made to estimate the total capital value associated with these and other industries, but this is an extremely difficult task and people have generally had more success in calculating the incremental investments necessary to produce some change in the capacity of an industry. To the extent that such numbers are meaningful electric utilities, for example, have a capital to output ratio of 5.3 (the highest of any sector) while the industrial average is .8. When, for example, a major investor such as the electric utility industry switches from a less capital intensive technology to a more capital intensive technology as in the switch from fossil to nuclear steam generation plants, the economy receives an extra added amount of investment over and above what would normally be predicted for a particular increase in demand.

In order to put the remarks of this chapter in perspective, it is necessary to look at how investment fits into the GNP figures and how investment by the various energy-producing industries fits into the national investment figures. A breakdown of Gross National Product by major compenents is given in Figure 3.1. As can be seen from this figure, personal consumption figures make up approximately 63% of GNP while government expenditures eat up another 22% of GNP. Thus, investment makes up slightly less than 14% of GNP in 1970. The importance of this investment component of GNP is easily misjudged by the size of it: 14 percent of GNP is still over $135 billion. Not only are entire industries completely

FIGURE 3.1

1970 GROSS NATIONAL PRODUCT OR EXPENDITURES[1]

	Dollars	% of Subaccount	% of Account	% of Total
Personal Consumption Expenditures				
Services				
Transportation	17.9	6.8	2.9	1.8
Housing	91.2	34.7	14.8	9.3
Household operation	36.1	13.7	5.8	3.7
TOTAL	263.5	100.0	42.6	26.9
Non-durable goods				
Gasoline and oil	22.9	8.6	3.7	2.3
Food and beverages	131.8	49.7	21.4	13.5
Clothing and shoes	52.6	19.8	8.5	5.3
TOTAL	264.7	100.0	42.9	27.1
Durable goods				
Furniture and household equipment	37.4	42.2	6.0	3.8
Automobiles and parts	37.1	41.8	6.0	3.8
TOTAL	88.6	100.0	14.3	9.0
TOTAL goods and services	615.8	--	100.0	63.2
Government purchases of goods and services				
State and local	122.2	--	55.6	12.5
Federal	97.2	--	44.3	9.9
TOTAL	219.4	--	100.0	22.5
Net exports	3.6	--	--	0.3
Gross private domestic investment				
Change in business inventories	2.8	--	2.0	0.2
Fixed investment				
Residential structures				
Nonfarm	29.7	22.4	21.9	3.0
TOTAL	30.4	22.9	22.4	3.1
Nonresidential				
Producers' durable equipment	65.4	49.3	48.3	6.7
Structures	36.8	27.7	27.1	3.7
TOTAL nonresidential	102.1	77.0	75.4	10.4
TOTAL fixed investment	132.5	100.0	97.9	13.6
TOTAL gross private domestic investment	135.3	--	100.0	13.8
TOTAL	974.1			100.0

[1]Subaccounts do not add to totals because "miscellaneous" categories are missing.

Source: Economic Report of the President 1971, [10] dependent on the investment component of GNP, but also it is investment that enables the economy to grow in the future. It is primarily because of the growth properties of business investment that this component of GNP is so important. Excluding home insurance from the investment figure the remaining non-residential investment amounts to 10.5 percent of GNP. Two-thirds of this amount comprises business purchases of durable equipment, the remaining one-third is made up of purchases of structures.

Figure 3.2 provides us with a more detailed picture of purchases of new plants and equipment. In 1970, total purchases of new plant and equipment were almost $80 billion. Separating out the sectors that produce energy such as petroleum, electricity, gas utilities, and the mining industries (of which coal is a significant part), it is apparent that over 25 percent of the new plant and equipment purchases are made by energy-producing sectors of the economy.

Capital investment can be shown in even more detail. Figure 3.3 provides a breakdown of capital expenditures by type and by year for the electric utility industry. This exponential increase in construction expenditures coincides with the acceleration in the rate of growth of electricity. The electric utility industry is comprised of more than just massive power stations and tie lines. In 1971, generation accounted for only 56% of all investment, while transmission accounted for 15%, distribution for 23% and administrative building approximately 5% of all electric utility investment expenditures. Figure 3.4 provides a similar breakdown for the gas utility industry.

To further illustrate that we are not experiencing a transient problem that will go away shortly, Figure 3.5 reproduces the latest capital expenditure survey of McGraw-Hill for the period 1972 through 1975. It is obvious from

FIGURE 3.2

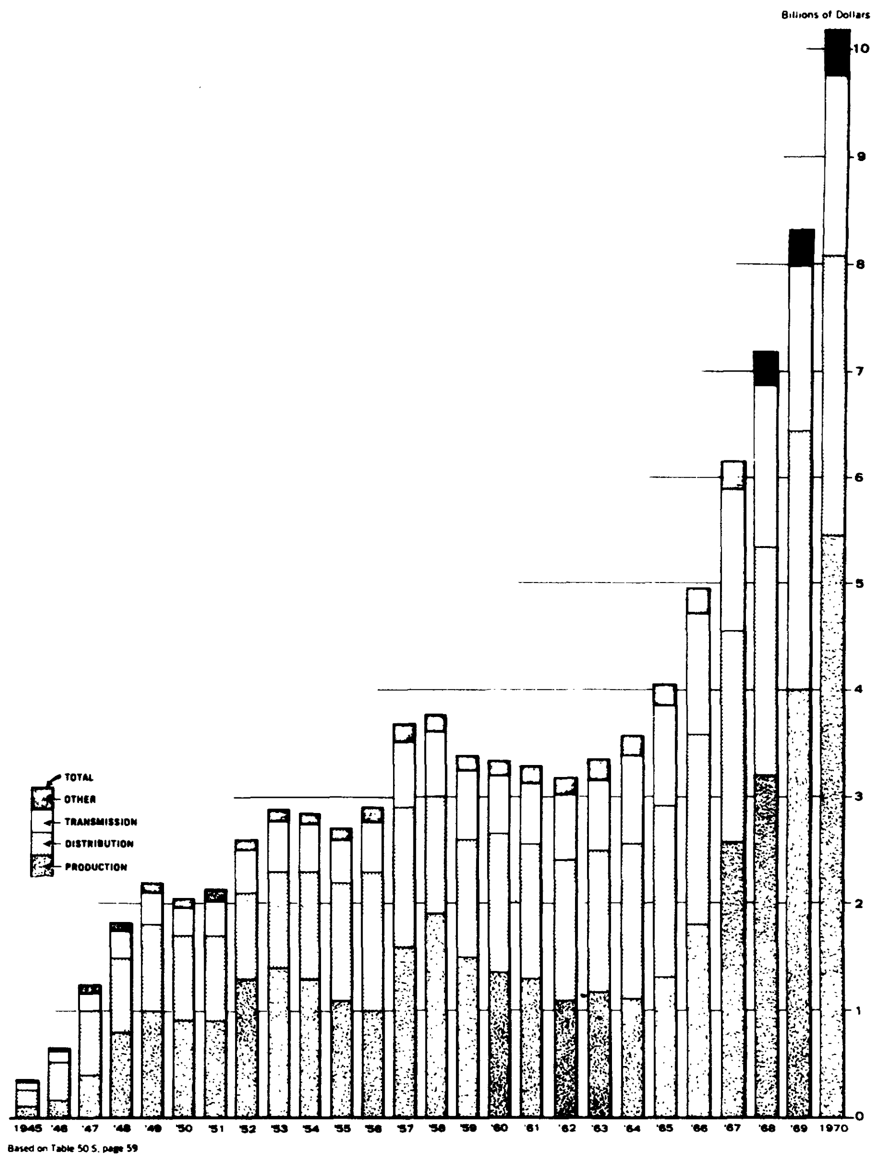
1970 NEW PLANT AND EQUIPMENT EXPENDITURES
(current dollars)

	Dollars	% of Subaccount	% of Account	% of Total
Manufacturing Industries				
Durable goods industries				
Primary Metals	3.24	20.5	10.1	4.0
Electrical machinery & equipment	2.27	14.3	7.1	2.8
Machinery except electrical	3.47	21.9	10.8	4.3
Transportation equipment	2.43	15.3	7.6	3.0
Stone, clay & glass	.99	6.2	3.0	1.2
Other durables	3.41	21.5	10.6	4.2
TOTAL	15.80	100.0	49.4	40.0
Nondurable goods industries				
Food, including beverage	2.84	17.5	8.8	3.5
Textile	.56	3.4	1.7	0.7
Paper	1.65	10.2	5.1	2.0
Chemical	3.44	21.3	19.7	4.3
Petroleum	5.62	34.7	17.5	7.0
Rubber	.94	5.8	2.9	1.1
Other nondurables	1.11	6.8	3.4	1.3
TOTAL	31.95	--	100.0	40.0
Public Utilities				
Electric	10.65	81.0	22.2	13.3
Gas and other	2.49	18.9	5.2	3.1
TOTAL	13.14	100.0	77.5	16.4
Other				
Mining	1.89	5.4	3.9	2.3
Railroad	1.78	5.1	3.7	2.2
Air Transportation	3.03	8.7	6.3	3.8
Other Transportation	1.23	3.5	2.5	1.5
Communication	10.10	29.1	21.1	12.6
Commercial and other	16.59	47.9	34.7	20.8
TOTAL	34.62	100.0	72.4	43.4
TOTAL	47.76	--	100.0	59.9
TOTAL All industries	79.71			100.0

Source: Economic Report of the President, 1971 [10].

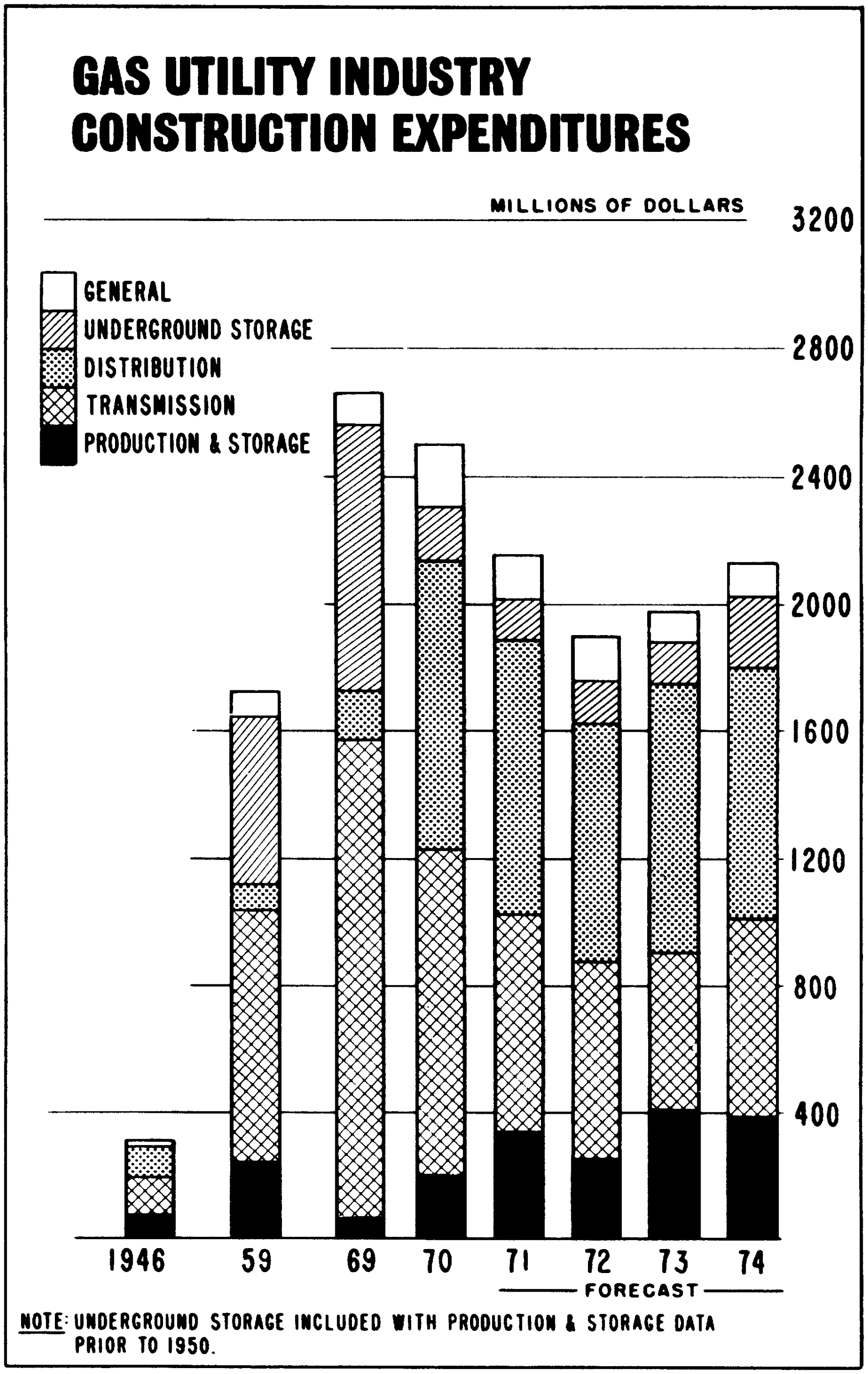
F I G U R E 3.3

ELECTRIC CONSTRUCTION EXPENDITURES
INVESTOR-OWNED ELECTRIC UTILITIES
(including Hawaii since 1960)
By Type of Utility Plant - 1945-1970



Source: Edison Electric Institute Statistical Year Book 1970, [14]

FIGURE 3.4



Source: Gas Facts 1971, [1], p. 179

FIGURE 3.5

PLANS FOR CAPITAL SPENDING
(Billions of Dollars)

INDUSTRY	Actual	Planned	% Change	-----Prelimianry---- 1973	1974	1975
Iron & Steel	$ 1.70	$ 1.58	- 7%	$1.98	$2.46	$2.66
Nonferrous Metals	1.08	1.24	15	1.35	1.51	1.39
Electrical Machinery	2.14	2.20	3	2.38	2.50	2.55
Machinery	2.80	3.37	20	3.68	3.76	3.72
Autos, Trucks & Parts	1.51	1.69	12	1.71	1.97	1.85
Aerospace	.38	.32	-16	.39	.37	.36
Other Transportation Equipment	.24	.33	37	.42	.37	.36
Fabricated Metals	1.25	1.61	29	1.40	1.48	1.52
Instruments	.67	.78	17	.78	.84	.88
Stone, Clay & Glass	.85	1.23	45	1.21	1.23	1.25
Other Durables	1.53	1.89	24	1.76	1.74	1.80
TOTAL DURABLES	14.15	16.24	15	17.06	18.23	18.34
Chemicals	3.44	3.65	6	3.80	3.99	3.91
Paper & Pulp	1.25	1.66	33	1.48	1.60	1.55
Rubber	.84	1.06	26	1.10	1.20	1.25
Petroleum	5.85	6.61	13	7.34	7.78	7.70
Food & Beverages	2.69	3.05	13	3.32	3.36	3.33
Textiles	.61	.71	16	.62	.64	.64
Other Nondurables	1.15	1.52	32	1.35	1.40	1.43
TOTAL NONDURABLES	15.83	18.26	15	19.01	19.97	19.81
ALL MANUFACTURING	29.98	34.50	15	36.07	38.20	38.15
Mining	2.16	2.84	31	2.94	2.96	2.91
Railroads	1.67	1.79	7	1.95	2.09	2.07
Airlines	1.88	2.76	47	2.01	2.03	1.75
Other Transportation	1.38	1.94	41	1.78	1.94	2.06
Communications	10.77	11.63	8	12.79	13.94	15.19
Electric Utilities	12.86	14.27	11	15.70	16.01	16.97
Gas Utilities	2.44	2.81	15	2.67	2.83	2.55
Commercial[1]	18.05	20.40	13	20.60	21.01	21.01
ALL BUSINESS	81.19	92.94	14	96.51	101.01	102.66

[1] Figures based on large chain, mail order and department stores, insurance companies, banks and other commercial businesses.

Source: [33].

looking at this table that the trends, especially in the energy-producing sectors of the economy, are continuing. Also notice that all capital expenditures in all sectors of the economy, with the possible exception of iron and steel are increasing more rapidly than GNP is expected to increase.

3.1.2 Comparison of the Energy Technology Investment

The word "impacts" as used in this and following chapters will mean the total sales (both direct and indirect) of each sector required to support some level of specified activity. E.g. the impacts of capital purchases $\underline{M}$ are the total sales ($\underline{X}_m$) required to meet these purchases or $\underline{X}_m = (\underline{I}-\underline{A})^{-1}\,\underline{M}$.

The comparisons that are made in this chapter use gross private domestic investment (GPDI) as the reference. GPDI is composed of both residential and non-residential building construction and equipment purchases and comprises about 16% of GNP in total value. On a sector by sector purchase basis, the variation is much greater. For example, GPDI represents 70% of new construction and 0% of mineral mining purchases by final demand.

Appendix I contains comparisons of GPDI and total output for each sector and also comparisons of GPDI impacts and total output for each sector.[18]

The costs and plant sizes used in this chapter are summarized in Figure 3.6. Three very detailed comparison tables based on these costs are presented in this section. Figure 3.7 summarizes what each of these comparisons will illustrate. The first table (Figure 3.8a) compares $10 billion worth of investment in each of the new technologies to the total projected

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[18] GPDI impacts are the total sales by each sector ($\underline{X}^I$) required to meet the GPDI component of final demand ($\underline{Y}^I$) or $\underline{X}^I = (\underline{I}-\underline{A})^{-1}\,\underline{Y}^I$.

FIGURE 3.6

NEW TECHNOLOGY PLANT SIZES AND COSTS
(millions of current dollars)

Technology	Nominal Plant Size	Nominal Plant Cost
High BTU Coal Gasification (IGT Hygas Process)	500 Billion BTU/day	Base Cost $304.8 Pollution Equipment 50.0 Total Cost 354.8 (274.2 in 1958 dollars)
Low BTU Coal Gasification (1980 Texaco process)	842 million SCF/day (147 Billion BTU/day)	Total Cost $27.5 ($21.3 in 1958 dollars)
Gas Turbine Topping Cycle (1980 Combined Cycle)	1000 MW	Total Cost $94.0 ($72.6 in 1958 dollars)
Nuclear (Pressurized Water Reactor)	1000 MW	Total Cost $240 ($205.8 in 1958 dollars)

FIGURE 3.7

SUMMARY OF DETAILED COMPARISONS

Exhibit 1 (Figure 3.8a): Iso-Dollar Comparison

1980 Gross Private Domestic Investment (GPDI)

vs.

$10 Billion Investment in Each New Technology

Exhibit 2 (Figure 3.9b): Iso-Dollar Impact[1] Comparison

Impact[1] of 1980 GPDI

vs.

Impact[1] of $10 Billion Investment in Each New Technology

Exhibit 3 (Figure 3.10): Iso-BTU Impact[1] Comparison

Impact[1] of 1980 GPDI

vs.

Impact[1] of Five Trillion BTU/Day Capacity Addition[2] of Each new Technology

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1 Impacts refer to total sales (direct plus indirect) by each sector required to support purchase of given investment.

2 5 Trillion BTU/day equals 10 Hygas plants, or 43 Low BTU gas plants, or 41,000 MW of electric generation.

1980 GPDI. The second table compares the impacts of these $10 billion purchases with that of the total GPDI (impacts include direct plus indirect purchases of goods and services). The third table compares the impacts of equal energy capacity investments (instead of equal dollar investments) in each of the new technologies to that of total 1980 GPDI. Investment is calculated to provide 500 trillion BTU/day capacity of high or low BTU gas and to provide 41,000 MW of electrical output.[19] The 41,000 MW of electrical generation can be fueled by 500 trillion BTU/day of low BTU gas (assuming the gas turbine topping cycle is used). Nuclear investment impact is also calculated at 41,000 MW capacity.

Figure 3.8a describes the actual investments made for the new technologies at $10 billion each and compares it to the 1980 projected GPDI. Here the differences between Value Added components and variations in the details of equipment provided in the engineering estimates are obvious. These purchases were derived by multiplying the capital coefficients by $10 billion so that it should be obvious that the Value Added coefficients varies from .35182 to .09911.[20] All of the equipment lists for

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19 Equal capacities are calculated on the basis of equal total yearly outputs, which take into account the load factors associated with each technology. Hygas plants (at 90% load factor and 500 billion BTU/day/plant) processes about 160 trillion BTU/year. The low BTU gas plants (at 70% load factor and 100 million BTU/minute/plant) process about 37 trillion BTU/year. Thus approximately 4.3 low BTU gas plants or the equivalent in terms of yearly energy output to a Hygas plant. Since this given size low BTU gas plant can power a 945 MW second generation COGAS plant [39, p. 101], 4100 MW of COGAS plants are the equivalent of one Hygas plant.

20 The percentage capital coefficients were actually used. See section 2.3.2 for a description of the difference.

F I G U R E 3.8a

COMPARISON OF 1980 TOTAL INVESTMENT (GPDI) WITH $10 BILLION INVESTMENTS IN NEW ENERGY TECHNOLOGY[1]

	1 GROSS INVESTMENT	2 HYGAS	3 LOW BTU GAS	4 COMBINED CYCLE	5 NUCLEAR
1 LIVESTOCK & PRODUCTS	258.000	0.0	0.0	0.0	0.0
2 OTHER FARM PRODUCTS	729.000	0.0	1.450	0.0	0.0
3 FORESTRY & FISHERY PROD	73.000	0.0	0.0	0.0	0.0
4 FARM, FOREST, FISH SERV	13.000	0.0	0.0	0.0	0.0
5 FERROUS METAL MINING	53.000	0.0	0.0	0.0	0.0
6 NONFERROUS METAL MINING	32.000	0.0	0.0	0.0	0.0
7 COAL MINING	9.000	53.100	0.0	0.0	0.0
8 CRUDE OIL AND NATURAL GAS	53.000	0.0	0.0	0.0	0.0
9 STONE & CLAY MINING	60.000	0.0	22.360	0.0	0.0
10 MINERAL MINING	0.0	0.0	0.0	0.0	0.0
11 NEW CONSTRUCTION	74246.000	3427.770	0.0	2036.990	2178.000
12 MAINT & REPAIR CONST	0.0	0.0	0.890	0.0	0.0
13 ORDNANCE, ACCESSORIES	100.000	0.0	0.0	0.0	0.0
14 FOOD & KINDRED PRODUCTS	0.0	0.0	0.0	0.0	0.0
15 GRAIN MILLING	0.0	0.0	0.0	0.0	0.0
16 TOBACCO MANUFACTURES	12.000	0.0	0.0	0.0	0.0
17 FABRIC, YARN, THRD MILLS	171.000	0.0	0.050	0.0	0.0
18 MISC. TEXTILE GOODS	336.000	0.0	0.730	0.0	0.0
19 APPAREL	729.000	0.0	1.870	0.0	0.0
20 MISC FAB TEXTILE PRODUCT	45.000	0.0	0.050	0.0	0.0
21 LUMBER & WOOD PRODS	129.000	0.0	186.390	0.0	0.0
22 WOODEN CONTAINERS	18.000	0.0	0.0	0.0	0.0
23 HOUSEHOLD FURNITURE	351.000	0.0	0.0	0.0	0.0
24 OTHER FURN & FIXTURES	2565.000	0.0	4.360	1.880	18.170
25 PULP MILLS	0.0	0.0	0.0	0.0	0.0
26 PAPER & ALLIED PRODS	0.0	0.0	4.620	0.0	0.0
27 PAPER CONTAINERS, BOXES	97.000	0.0	0.0	0.0	0.0
28 PRINTING & PUBLISHING	126.000	0.0	0.100	0.0	0.0
29 INDUSTRIAL CHEMICALS	0.0	71.100	3.630	0.0	0.0
30 FERTILIZERS	0.0	0.0	0.360	0.0	0.0
31 AGR & MISC CHEMICALS	0.0	0.0	5.600	0.0	0.0
32 PLASTICS & SYNTH MTRL	277.000	0.0	0.0	0.0	1.360
33 DRUGS, CLNG, TOILET PREP	405.000	0.0	0.0	0.0	0.0
34 PAINTS & PRODUCTS	15.000	0.0	3.740	0.0	0.0
35 PETROLEUM REFINING	0.0	0.0	54.160	0.0	0.0
36 PAVING MIXTURES	0.0	0.0	22.310	0.0	0.0
37 ASPHALT FELTS, COATINGS	0.0	0.0	2.390	0.0	0.0
38 RUBBER & PLASTIC PRODS	262.000	0.0	16.700	0.0	0.0
39 LEATHER TANNING PROD	12.000	0.0	0.0	0.0	0.0
40 FOOTWEAR & LEATHER PROD	115.000	0.0	0.050	0.0	0.0
41 GLASS & GLASS PRODS	66.000	0.0	0.670	0.0	0.0
42 CEMENT, HYDRAULIC	0.0	0.0	8.350	0.0	0.0
43 LIME	0.0	0.0	1.250	0.0	0.0
44 STONE & CLAY PRODS	0.0	10.870	449.640	28.210	0.0
45 PRIMARY STEEL	0.0	0.0	278.590	0.0	0.0
46 IRON & STEEL FOUNDRIES	0.0	0.0	148.470	0.0	0.0
47 IRON & STEEL FORGINGS	0.0	0.0	5.650	0.0	0.0
48 PRIMARY NON-FER METAL	0.0	0.0	0.0	0.0	0.0
49 MISC NON-FER METALS	479.000	0.0	357.270	0.0	0.0
50 METAL CONTAINERS	175.000	0.0	0.0	0.0	0.0
51 PLUMBING&STRUCTURAL META	1490.000	2530.079	1665.699	840.379	1825.060
52 HEATING EQUIP EXC ELEC	0.0	0.0	5.030	0.0	0.0
53 SCREWS & METAL STAMPINGS	70.000	0.0	14.470	0.0	0.0

1 See Figure 3.7 for details of comparison.

F I G U R E 3.8a (continued)

	1 GROSS INVESTMENT	2 HYGAS	3 LOW BTU GAS	4 COMBINED CYCLE	5 NUCLEAR
54 OTHER FAB METAL PRODS	549.000	249.980	90.520	274.970	141.800
55 ENGINES & TURBINES	948.000	268.140	0.0	1980.160	1562.610
56 FARM MACHINERY & EQUIP	3427.000	0.0	0.260	0.0	0.0
57 CONSTRUCTIONEMINING EQUI	3294.000	151.460	86.220	0.0	0.0
58 MATERIAL HNDLG MACH	1126.000	72.700	156.420	1.990	19.570
59 METALWORKING MACH	3169.000	5.800	0.050	4.390	3.870
60 SPECIAL INDUSTRY MACH	3659.000	3.790	0.0	0.0	219.690
61 GENERAL INDUSTRY MACH	2737.000	909.030	822.740	151.910	220.810
62 MACHINE SHOP PRODUCTS	58.000	0.0	0.730	0.0	0.0
63 OFFICE COMP MACH	12099.000	0.0	0.0	19.890	0.0
64 SERVICE INDUSTRY MACH	1411.891	165.200	77.990	0.0	25.290
65 REFRIG MACHINERY	1598.108	0.0	0.0	0.0	0.0
66 ELECTRICAL INDUSTRY	4266.000	271.650	397.110	1118.729	301.970
67 HOUSEHOLD APPLIANCES	414.000	0.0	0.0	0.0	0.0
68 ELEC LIGHTING EQUIP	258.000	15.870	68.320	0.0	87.160
69 RADIO,TV & COMM EQUIP	7504.000	0.0	37.770	3.550	0.0
70 ELEC COMP & ACCESS	748.000	0.0	0.210	0.0	0.0
71 ELEC MACH EQP & SUPPLIES	363.000	0.0	3.270	0.0	0.0
72 MOTOR VEHICLES & EQUIP	15423.000	0.0	5.500	0.0	0.0
73 AIRCRAFT & PARTS	3207.000	0.0	0.0	0.0	0.0
74 OTHER TRANSPORT EQUIP	4391.000	0.0	0.160	0.0	0.0
75 SCIENTIFIC & CONTROL INS	2110.000	55.950	1.870	0.640	62.980
76 OPTICAL & PHOTO EQUIP	3659.000	0.0	0.670	0.0	0.0
77 MISC MANUFACTURING	843.000	0.0	1.920	1.030	0.0
78 RAILROAD TRANSPORTATION	1147.414	1.190	50.410	0.790	0.770
79 LOCAL PASSENGER TRANSPOR	0.0	0.0	0.0	0.0	0.0
80 TRUCK TRANSPORTATION	1592.730	43.510	104.540	28.900	28.080
81 WATER TRANSPORTATION	66.474	60.450	39.730	40.150	39.020
82 AIR TRANSPORTATION	82.383	2.500	2.000	1.660	1.610
83 MISC TRANSPORTATION	0.0	0.0	0.930	0.0	0.0
84 COMMUNICATIONS EXC RADET	1449.000	0.0	9.080	0.0	0.0
85 RADIO & TV BROADCASTING	0.0	0.0	0.0	0.0	0.0
86 ELECTRIC UTILITIES	0.0	0.0	6.800	0.0	0.0
87 GAS UTILITIES	0.0	0.0	1.350	0.0	0.0
88 WATER & SANITARY SERV	0.0	0.0	2.230	0.0	0.0
89 WHOLESALE TRADE	7265.648	271.050	323.670	244.170	227.530
90 RETAIL TRADE	6959.336	90.350	126.320	81.390	75.840
91 FINANCE AND INSURANCE	0.0	100.000	102.530	71.060	116.100
92 REAL ESTATE & RENTAL	4063.000	1.540	14.840	0.0	2.100
93 HOTEL, PERS & REPAIR SER	0.0	0.0	0.0	0.0	1.400
94 BUSINESS SERVICES	0.0	175.950	636.989	344.870	447.700
95 RESEARCH AND DEVELOPMENT	0.0	0.0	0.0	0.0	0.0
96 AUTO REPAIR & SERVICE	0.0	0.0	11.830	0.0	0.0
97 AMUSEMENTS	83.000	0.0	0.0	0.0	0.0
98 MEDICAL & EDUCATION SERV	0.0	0.0	2.850	0.0	0.0
99 FED GOVT ENTERPRISES	0.0	0.0	0.930	0.0	0.0
100 STATE&LOCAL GOVT ENTERPR	0.0	0.0	3.680	0.0	0.0
101 IMPORTS	50.000	0.0	0.0	0.0	0.0
102 BUSINESS TRAVEL, GIFTS	0.0	0.0	18.000	0.0	0.0
103 OFFICE SUPPLIES	0.0	0.0	0.0	0.0	0.0
104 SCRAP, SECONDHAND GOODS	-990.000	0.0	0.0	0.0	0.0
105 SUM	183041.625	9008.996	6481.952	7277.664	7608.453

the new technologies were very good on major items, like boilers and turbines, and very poor on small items, like lunch room equipment and adding machines. The conclusion of this is that one must be very careful about drawing inferences from small differences in coefficients or dollar flows. The standard engineering estimation schemes that were used in costing these plants cover the cost of many small items, like telephones, by increasing the cost estimates of the big items like turbines or by some simple percentage add-on figure for miscellaneous equipment. Since, by definition, major impacts are not made by minor items, there is no great loss if these items "fall through the cracks."

Figure 3.8b compares the effects of equal capital expenditures ($10 billion) for each of the three new technologies that we have discussed and, in addition, for nuclear steam electric generation (a conventional pressurized water reactor is used). All comparisons are in millions of 1958 dollars and represent direct plus indirect effects of capital expenditures. There are several things to notice about these figures. First the zero under New Construction (section 11) for Low BTU Gas occurs because of the way the capital coefficients were derived for this technology. In essence, all expenditures that normally would have gone to New Construction were disaggregated into concrete, steel, etc. and assigned directly to the sector that supplies such commodities to New Construction. The zero is of little significance. Second, the total output resulting from each of these technologies varies from $14.1 billion to $20.3 billion for an initial expenditure of $10 billion. Part of this variation is true and part is spurious. Low BTU Gas Plants represent the low of $14.1 billion. Because construction items were assigned directly to the supplying industry, rather than going through sector 11, the value-added component of New Construction (about 36% of total construction) is missing from the total. This would add perhaps $1 billion to the total. For High BTU Gas Plants the total of $20.3 billion is probably too high because of the convention followed of assigning labor costs to New Construction rather than to Value-Added. This

F I G U R E 3.8b

OUTPUTS REQUIRED TO SUPPORT EQUAL CAPITAL INVESTMENTS IN NEW TECHNOLOGIES[1]

	1 1980 GROSS INVESTMENT	2 HIGH BTU GAS	3 LOW BTU GAS	4 GAS TURBINE CYCLE	5 NUCLEAR STEAM
1 LIVESTOCK & PRODUCTS	1245.114	34.700	28.700	28.000	28.600
2 OTHER FARM PRODUCTS	2352.267	60.700	42.700	45.200	47.600
3 FORESTRY & FISHERY PROD	596.802	22.800	21.500	14.200	15.400
4 FARM, FOREST, FISH SERV	196.546	6.400	5.000	4.900	5.100
5 FERROUS METAL MINING	908.453	72.600	66.900	43.300	53.800
6 NONFERROUS METAL MINING	829.229	62.000	61.100	47.600	50.400
7 COAL MINING	557.817	95.400	31.000	25.400	28.300
8 CRUDE OIL AND NATURAL GA	1893.433	97.200	97.300	69.000	73.500
9 STONE & CLAY MINING	1729.521	82.600	75.600	52.000	53.500
10 MINERAL MINING	250.456	13.300	9.600	7.600	7.900
11 NEW CONSTRUCTION	74246.000	3427.800	0.0	2036.999	2178.000
12 MAINT & REPAIR CONST	2018.491	84.100	75.300	63.300	68.700
13 ORDNANCE, ACCESSORIES	514.234	6.800	5.000	6.400	6.100
14 FOOD & KINDRED PRODUCTS	1596.358	72.400	61.400	60.500	60.600
15 GRAIN MILLING	354.786	13.200	11.700	10.900	11.200
16 TOBACCO MANUFACTURES	79.502	3.000	2.700	2.600	2.600
17 FABRIC,YARN,THRD MILLS	1752.846	30.700	25.300	24.200	25.900
18 MISC. TEXTILE GOODS	1055.147	17.600	14.300	15.100	15.500
19 APPAREL	1123.331	12.600	11.900	10.300	10.800
20 MISC FAB TEXTILE PRODUCT	301.085	5.900	5.000	4.700	5.300
21 LUMBER & WOOD PRODS	6901.891	301.100	289.400	184.600	200.100
22 WOODEN CONTAINERS	93.019	4.000	2.800	2.400	2.900
23 HOUSEHOLD FURNITURE	980.092	22.900	4.900	13.300	15.300
24 OTHER FURN & FIXTURES	3031.101	22.100	7.800	14.300	33.000
25 PULP MILLS	323.972	12.600	10.400	10.700	10.800
26 PAPER & ALLIED PRODS	3679.293	156.900	129.000	134.600	136.400
27 PAPER CONTAINERS, BOXES	1455.152	57.800	44.600	51.600	52.200
28 PRINTING & PUBLISHING	3304.084	165.500	191.400	168.200	186.200
29 INDUSTRIAL CHEMICALS	4525.859	261.200	152.000	134.800	138.800
30 FERTILIZERS	215.492	7.600	5.400	5.000	5.300
31 AGR & MISC CHEMICALS	1044.232	50.200	37.700	33.200	36.300
32 PLASTICS & SYNTH MTRL	3524.737	108.400	91.800	90.300	89.200
33 DRUGS, CLNG, TOILET PREP	1015.727	27.900	24.700	20.500	21.600
34 PAINTS & PRODUCTS	1081.208	47.900	26.700	33.600	35.800
35 PETROLEUM REFINING	2851.601	144.700	150.500	104.200	109.400
36 PAVING MIXTURES	241.670	11.100	24.000	6.800	7.200
37 ASPHALT FELTS, COATINGS	243.745	11.000	5.000	6.700	7.200
38 RUBBER & PLASTIC PRODS	5232.516	151.700	117.800	127.200	127.600
39 LEATHER TANNING PROD	85.020	1.700	1.200	1.400	1.600
40 FOOTWEAR & LEATHER PROD	174.455	1.900	1.400	1.600	1.600
41 GLASS & GLASS PRODS	1156.903	42.500	26.200	26.400	35.000
42 CEMENT, HYDRAULIC	1280.672	62.600	69.400	41.800	41.000
43 LIME	174.346	11.100	12.200	6.900	7.800
44 STONE & CLAY PRODS	7045.766	354.700	537.800	251.000	234.700
45 PRIMARY STEEL	12092.387	1066.000	976.800	616.000	791.399
46 IRON & STEEL FOUNDRIES	2197.927	119.700	220.900	125.200	121.600
47 IRON & STEEL FORGINGS	809.594	42.200	35.000	57.300	50.400
48 PRIMARY NON-FER METAL	2678.872	217.200	213.900	169.600	178.700
49 MISC NON-FER METALS	9161.438	635.900	750.099	507.800	521.500
50 METAL CONTAINERS	362.656	9.600	6.500	6.400	7.100
51 PLUMBING&STRUCTURAL META	8246.813	2880.900	1726.200	1040.800	2051.300
52 HEATING EQUIP EXC ELEC	931.823	53.500	21.200	28.500	35.200
53 SCREWS & METAL STAMPINGS	2450.377	106.600	85.300	110.500	105.600

1 See Figure 3.7 for details of comparison

F I G U R E 3.8b (continued)

	1 1980 GROSS INVESTMENT	2 HIGH BTU GAS	3 LOW BTU GAS	4 GAS TURBINE CYCLE	5 NUCLEAR STEAM
54 OTHER FAB METAL PRODS	5416.906	518.700	246.400	434.300	332.700
55 ENGINES & TURBINES	1844.124	336.900	38.400	2182.200	1722.600
56 FARM MACHINERY & EQUIP	3800.325	18.400	12.800	33.100	30.100
57 CONSTRUCTION&MINING EQUI	4242.563	215.800	123.200	79.700	73.500
58 MATERIAL HNDLG MACH	1962.979	122.800	181.100	28.600	50.400
59 METALWORKING MACH	4998.625	92.200	65.200	104.000	94.600
60 SPECIAL INDUSTRY MACH	4295.875	29.700	19.500	16.900	249.500
61 GENERAL INDUSTRY MACH	6040.668	1130.699	981.600	304.600	388.500
62 MACHINE SHOP PRODUCTS	1454.148	66.100	52.000	139.600	119.100
63 OFFICE COMP MACH	14845.250	56.500	62.200	77.700	63.800
64 SERVICE INDUSTRY MACH	1785.515	176.900	88.900	8.000	34.600
65 REFRIG MACHINERY	3875.425	99.000	15.400	54.000	60.900
66 ELECTRICAL INDUSTRY	8900.211	517.000	569.800	1342.800	490.800
67 HOUSEHOLD APPLIANCES	1729.170	57.100	5.900	35.700	38.300
68 ELEC LIGHTING EQUIP	2489.535	113.500	105.600	79.000	159.200
69 RADIO,TV & COMM EQUIP	9918.234	39.300	75.500	48.800	36.400
70 ELEC COMP & ACCESS	8150.855	93.500	91.700	116.100	83.800
71 ELEC MACH EQP & SUPPLIES	1283.881	27.200	23.000	60.000	52.100
72 MOTOR VEHICLES & EQUIP	23308.406	102.500	76.200	137.200	128.500
73 AIRCRAFT & PARTS	4635.531	44.500	32.300	44.600	43.600
74 OTHER TRANSPORT EQUIP	4957.094	36.900	25.500	37.100	36.800
75 SCIENTIFIC & CONTROL INS	3593.236	121.700	36.000	53.300	109.400
76 OPTICAL & PHOTO EQUIP	4436.969	25.300	25.200	23.100	25.000
77 MISC MANUFACTURING	1891.696	45.000	38.700	36.500	39.100
78 RAILROAD TRANSPORTATION	4777.672	198.000	181.000	138.300	151.700
79 LOCAL PASSENGER TRANSPOR	378.335	17.500	15.600	15.200	14.900
80 TRUCK TRANSPORTATION	5657.574	243.100	223.200	167.700	177.600
81 WATER TRANSPORTATION	524.238	93.900	63.700	62.300	63.200
82 AIR TRANSPORTATION	763.482	33.300	29.100	29.500	28.700
83 MISC TRANSPORTATION	248.760	12.400	12.000	9.000	9.500
84 COMMUNICATIONS EXC RAD&T	4907.117	175.800	172.500	148.500	163.900
85 RADIO & TV BROADCASTING	419.160	23.000	29.600	24.800	28.100
86 ELECTRIC UTILITIES	4464.074	251.700	217.000	181.500	198.800
87 GAS UTILITIES	2810.033	172.500	156.800	117.800	131.100
88 WATER & SANITARY SERV	625.264	31.300	28.000	23.100	24.900
89 WHOLESALE TRADE	20424.211	918.800	730.000	725.500	745.699
90 RETAIL TRADE	14032.719	427.100	308.300	340.100	356.800
91 FINANCE AND INSURANCE	4295.273	334.200	273.100	245.500	313.600
92 REAL ESTATE & RENTAL	9513.367	253.200	222.000	198.600	216.800
93 HOTEL, PERS & REPAIR SER	907.874	43.700	36.900	34.600	37.400
94 BUSINESS SERVICES	14151.500	779.699	1003.500	840.199	951.000
95 RESEARCH AND DEVELOPMENT	246.112	13.100	5.800	11.100	11.100
96 AUTO REPAIR & SERVICE	1823.969	90.700	73.400	62.600	69.100
97 AMUSEMENTS	481.924	18.200	21.000	18.400	20.200
98 MEDICAL & EDUCATION SERV	495.789	24.900	20.100	19.400	20.500
99 FED GOVT ENTERPRISES	1024.691	46.600	46.400	43.300	46.100
100 STATE&LOCAL GOVT ENTERPR	776.073	39.000	36.600	28.600	30.800
101 IMPORTS	10506.219	460.200	399.500	401.700	409.600
102 BUSINESS TRAVEL, GIFTS	2857.302	133.200	118.100	116.700	113.900
103 OFFICE SUPPLIES	625.369	30.500	28.000	27.500	29.100
104 SCRAP, SECONDHAND GOODS	-990.000	0.0	0.0	0.0	0.0
105 TOTAL OUTPUT	418798.313	20345.102	14103.156	16213.645	16975.855

difference could subtract \$1.5 billion from the total. The conventions followed in deriving the capital coefficients are described much more fully in the Appendices.

It is more meaningful to compare capital expenditures for equal energy capacity investments in the new technologies. Figure 3.9 summarizes the total capital expenditures required for equal capacity expansions of five trillion BTU/day (the size of 10 Hygas plants). The impacts of these expenditures are described in Figure 3.10.

The most obvious point about these figures is the difference in size of the total impacts. On the surface, there is a range of over a factor of ten (\$1.278 billion to \$13.973 billion). This is a little bit like comparing apples and oranges though. For a true comparison with nuclear generation the capital costs of the low BTU gas plant and the gas turbine topping cycle should be added. The resulting \$6 billion cost reduces the price range to a factor of two, which is still considerably above the ratio of 1.25 which currently exists between conventional fossil and nuclear plants. Nuclear plants cost so much for two reasons. (1) The pressure vessel and reactor core cost much more than the corresponding boiler for a fossil fired plant. (2) Because of the radioactivity involved, everything must be of very high quality, which means inspected, x-rayed, etc. All of this costs much money, and typically a valve for a nuclear plant will cost 2-3 times as much as one for a fossil steam plant. The high BTU gas plant cannot be compared directly to the electric plants since different forms of energy are involved. What is striking about such a comparison though is the difference in capital involved for energy in gaseous versus electric form. Note that this has only slight bearing on the actual cost differences between the energy forms because the price of raw fuel, transportation, etc., are ignored. An even more striking difference appears between the capital

FIGURE 3.9

EXPENDITURES FOR 5 TRILLION BTU/DAY CAPACITY OF EACH NEW TECHNOLOGY

	Hygas	Low Gas	Gas Turbine	Nuclear
Year of Estimate	1970	1970	1970	1968
Nominal Plant Size	500 BB/ day[2]	147 BB/ day	1000 MW	1000 MW
Nominal Plant Cost (millions of dollars)	$354.8	$27.5	$94.0	$24.0
Equivalent Number[1]	10	43	41	41
Total Investment (millions of current dollars)	$3548	$1182	$3854	$9840
Total Investment[3] (1958 Dollars)	$2741	$913	$2978	$8374

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[1] See footnote 19

[2] BB/day = Billions of BTU/day

[3] Deflated by total non-residential GPDI deflator for appropriate year

FIGURE 3.10

OUTPUTS REQUIRED TO SUPPORT INVESTMENT IN EQUAL CAPACITIES OF NEW TECHNOLOGIES[1]

(5 Trillion BTUs/Day)

	1 1980 GROSS INVESTMENT	2 HIGH BTU GAS	3 LOW BTU GAS	4 GAS TURBINE CYCLE	5 NUCLEAR STEAM
1 LIVESTOCK & PRODUCTS	1245.114	9.514	2.602	8.197	23.542
2 OTHER FARM PRODUCTS	2352.267	16.643	3.871	13.232	39.182
3 FORESTRY & FISHERY PROD	596.802	6.252	1.949	4.157	12.677
4 FARM, FOREST, FISH SERV	196.546	1.755	0.453	1.434	4.198
5 FERROUS METAL MINING	908.453	19.906	6.064	12.676	44.285
6 NONFERROUS METAL MINING	829.229	17.000	5.539	13.934	41.487
7 COAL MINING	557.817	26.156	2.810	7.436	23.295
8 CRUDE OIL AND NATURAL GA	1893.433	26.651	8.820	20.199	60.501
9 STONE & CLAY MINING	1729.521	22.648	6.853	15.222	44.038
10 MINERAL MINING	250.456	3.647	0.870	2.225	6.503
11 NEW CONSTRUCTION	74246.000	939.868	0.0	596.311	1792.820
12 MAINT & REPAIR CONST	2018.491	23.059	6.826	18.530	56.550
13 ORDNANCE, ACCESSORIES	514.234	1.864	0.453	1.874	5.021
14 FOOD & KINDRED PRODUCTS	1596.358	19.851	5.566	17.711	49.883
15 GRAIN MILLING	354.786	3.619	1.061	3.191	9.219
16 TOBACCO MANUFACTURES	79.502	0.823	0.245	0.761	2.140
17 FABRIC,YARN,THRD MILLS	1752.846	8.418	2.293	7.084	21.320
18 MISC. TEXTILE GOODS	1055.147	4.826	1.296	4.420	12.759
19 APPAREL	1123.331	3.455	1.079	3.015	8.890
20 MISC FAB TEXTILE PRODUCT	301.085	1.618	0.453	1.376	4.363
21 LUMBER & WOOD PRODS	6901.891	82.559	26.234	54.040	164.712
22 WOODEN CONTAINERS	93.019	1.097	0.254	0.703	2.387
23 HOUSEHOLD FURNITURE	980.092	6.279	0.444	3.893	12.594
24 OTHER FURN & FIXTURES	3031.101	6.060	0.707	4.186	27.164
25 PULP MILLS	323.972	3.455	0.943	3.132	8.890
26 PAPER & ALLIED PRODS	3679.293	43.020	11.694	39.403	112.278
27 PAPER CONTAINERS, BOXES	1455.152	15.848	4.043	15.105	42.968
28 PRINTING & PUBLISHING	3304.084	45.378	17.350	49.239	153.271
29 INDUSTRIAL CHEMICALS	4525.859	71.618	13.779	39.461	114.253
30 FERTILIZERS	215.492	2.084	0.490	1.464	4.363
31 AGR & MISC CHEMICALS	1044.232	13.764	3.418	9.719	29.880
32 PLASTICS & SYNTH MTRL	3524.737	29.722	8.322	26.434	73.425
33 DRUGS, CLNG, TOILET PREP	1015.727	7.650	2.239	6.001	17.780
34 PAINTS & PRODUCTS	1081.208	13.134	2.420	9.836	29.469
35 PETROLEUM REFINING	2851.601	39.675	13.643	30.503	90.053
36 PAVING MIXTURES	241.670	3.044	2.176	1.991	5.927
37 ASPHALT FELTS, COATINGS	243.745	3.016	0.453	1.961	5.927
38 RUBBER & PLASTIC PRODS	5232.516	41.595	10.679	37.237	105.034
39 LEATHER TANNING PROD	85.020	0.466	0.109	0.410	1.317
40 FOOTWEAR & LEATHER PROD	174.455	0.521	0.127	0.468	1.317
41 GLASS & GLASS PRODS	1156.903	11.653	2.375	7.728	28.810
42 CEMENT, HYDRAULIC	1280.672	17.164	6.291	12.237	33.749
43 LIME	174.346	3.044	1.106	2.020	6.421
44 STONE & CLAY PRODS	7045.766	97.255	48.752	73.478	193.193
45 PRIMARY STEEL	12092.387	292.286	88.547	180.328	651.440
46 IRON & STEEL FOUNDRIES	2197.927	32.821	20.025	36.651	100.095
47 IRON & STEEL FORGINGS	809.594	11.571	3.173	16.774	41.487
48 PRIMARY NON-FER METAL	2678.872	59.554	19.390	49.649	147.097
49 MISC NON-FER METALS	9161.438	174.357	67.997	148.653	429.272
50 METAL CONTAINERS	362.656	2.632	0.589	1.874	5.844
51 PLUMBING&STRUCTURAL META	8246.813	789.914	156.480	304.684	1688.527
52 HEATING EQUIP EXC ELEC	931.823	14.669	1.922	8.343	28.975
53 SCREWS & METAL STAMPINGS	2450.377	29.229	7.732	32.348	86.925

F I G U R E 3.10 (continued)

	1 1980 GROSS INVESTMENT	2 HIGH BTU GAS	3 LOW BTU GAS	4 GAS TURBINE CYCLE	5 NUCLEAR STEAM
54 OTHER FAB METAL PRODS	5416.906	142.222	22.336	127.137	273.862
55 ENGINES & TURBINES	1844.124	92.375	3.481	638.817	1417.958
56 FARM MACHINERY & EQUIP	3800.325	5.045	1.160	9.690	24.777
57 CONSTRUCTION&MINING EQUI	4242.563	59.170	11.168	23.331	60.501
58 MATERIAL HNDLG MACH	1962.979	33.671	16.417	8.372	41.487
59 METALWORKING MACH	4998.625	25.280	5.910	30.445	77.870
60 SPECIAL INDUSTRY MACH	4295.875	8.143	1.768	4.947	205.376
61 GENERAL INDUSTRY MACH	6040.668	310.026	88.982	89.169	319.793
62 MACHINE SHOP PRODUCTS	1454.148	18.124	4.714	40.866	98.037
63 OFFICE COMP MACH	14845.250	15.492	5.638	22.746	52.517
64 SERVICE INDUSTRY MACH	1785.515	48.504	8.059	2.342	28.481
65 REFRIG MACHINERY	3875.425	27.145	1.396	15.808	50.130
66 ELECTRICAL INDUSTRY	8900.211	141.756	51.652	393.091	404.002
67 HOUSEHOLD APPLIANCES	1729.170	15.656	0.897	10.451	31.527
68 ELEC LIGHTING EQUIP	2489.535	31.121	9.573	23.126	131.045
69 RADIO,TV & COMM EQUIP	9918.234	10.776	6.844	14.286	29.963
70 ELEC COMP & ACCESS	8150.855	25.637	8.313	33.987	68.980
71 ELEC MACH EQP & SUPPLIES	1283.881	7.458	2.085	17.564	42.886
72 MOTOR VEHICLES & EQUIP	23308.406	28.104	6.908	40.164	105.775
73 AIRCRAFT & PARTS	4635.531	12.201	2.928	13.056	35.889
74 OTHER TRANSPORT EQUIP	4957.094	10.118	2.312	10.861	30.292
75 SCIENTIFIC & CONTROL INS	3593.236	33.369	3.263	15.603	90.053
76 OPTICAL & PHOTO EQUIP	4436.969	6.937	2.284	6.762	20.579
77 MISC MANUFACTURING	1891.696	12.339	3.508	10.685	32.185
78 RAILROAD TRANSPORTATION	4777.672	54.290	16.408	40.486	124.872
79 LOCAL PASSENGER TRANSPOR	378.335	4.798	1.414	4.450	12.265
80 TRUCK TRANSPORTATION	5657.574	66.656	20.233	49.092	146.191
81 WATER TRANSPORTATION	524.238	25.746	5.774	18.238	52.023
82 AIR TRANSPORTATION	763.482	9.131	2.638	8.636	23.624
83 MISC TRANSPORTATION	248.760	3.400	1.088	2.635	7.820
84 COMMUNICATIONS EXC RAD&T	4907.117	48.203	15.637	43.472	134.914
85 RADIO & TV BROADCASTING	419.160	6.306	2.683	7.260	23.130
86 ELECTRIC UTILITIES	4464.074	69.014	19.671	53.132	163.642
87 GAS UTILITIES	2810.033	47.298	14.214	34.485	107.915
88 WATER & SANITARY SERV	625.264	8.582	2.536	6.762	20.496
89 WHOLESALE TRADE	20424.211	251.926	66.174	212.383	613.822
90 RETAIL TRADE	14032.719	117.107	27.947	99.561	293.700
91 FINANCE AND INSURANCE	4295.273	91.634	24.757	71.868	258.140
92 REAL ESTATE & RENTAL	9513.367	69.425	20.124	58.138	178.459
93 HOTEL, PERS & REPAIR SER	907.874	11.982	3.345	10.129	30.786
94 BUSINESS SERVICES	14151.500	213.786	90.967	245.960	782.815
95 RESEARCH AND DEVELOPMENT	246.112	3.592	0.888	3.249	9.137
96 AUTO REPAIR & SERVICE	1823.969	24.869	6.654	18.326	56.880
97 AMUSEMENTS	481.924	4.990	1.904	5.386	16.628
98 MEDICAL & EDUCATION SERV	495.789	6.827	1.822	5.679	16.875
99 FED GOVT ENTERPRISES	1024.691	12.777	4.206	12.676	37.947
100 STATE&LOCAL GOVT ENTERPP	776.073	10.693	3.318	8.372	25.353
101 IMPORTS	10506.219	126.182	36.215	117.594	337.162
102 BUSINESS TRAVEL, GIFTS	2857.302	36.522	10.706	34.163	93.757
103 OFFICE SUPPLIES	625.369	8.363	2.538	8.050	23.954
104 SCRAP, SECONDHAND GOODS	-990.000	0.0	0.0	0.0	0.0
105 TOTAL OUTPUT	418798.313	5578.398	1278.456	4746.379	13973.676

involved in low BTU gas production and that for high BTU gas production. Here it must also be remembered that even though both are gaseous fuels, they are vastly different in properties and that low BTU gas is not economical to transport very far. Also the differences in capital costs are softened somewhat by differences in efficiencies so that the high BTU plant has a lower fuel cost. It is definitely true though that the high BTU gas will cost more, perhaps twice as much.

3.2 Impacts of Capital Expenditures for High BTU Coal Gasification

There are three parameters that determine the magnitude of the economic impact of capital spending for coal gasification. These factors are (1) how much is spent per plant, (2) how many plants must be built, and (3) how rapidly these plants must be built. Of course, a fourth factor would be the regional density of such plants that would determine the local impacts of such capital expenditures. A fifth factor which could be considered is that of the feedback effect of growth in a particular sector of the economy. The impact of this last factor is best illustrated with two examples. First, the expansion of electric generation facilities typically requires the concomitant expansion of transmission facilities if not distribution and administrative facilities. Second, industries which supply products to the growing industry (for example, coal mining in the case of electric generation) must expand their capacity in order to be able to supply the increased needs of the growing sector. In this chapter the impacts of the rate of capital spending in coal gasification or in the other new technologies will not be discussed. Because so-called economic acceleration effects and the feedback effects of growth are being ignored, the numbers which follow must be regarded as the minimum economic impacts of these expenditures. To properly deal with these impacts, one needs a dynamic input-output model. The next chapter will discuss dynamic model simulations and results. Because a national aggregate model was used, local and regional effects were washed out. We will attempt to indicate what some of the regional impacts will be by looking at the probable location of many of these plants utilizing new energy technology.

The cost of a high BTU coal gasification plant by the time the technology becomes commercially available is very difficult to predict. Because the figures are in constant dollars, inflation is not a problem but there are still many technological uncertainties involved in the processes.

For this report the capital costs derived in Appendix D will be used. Thus, a new high BTU coal gasification plant utilizing the IGT electrothermal hydrogasification process is expected to cost $354.8 billion dollars in 1970. This cost is expected to escalate by 5 to 10 percent for each year of delay beyond 1971. This price deflates to $274.2 million in 1958 prices. If one allows for a 20 percent contingency factor as some people at IGT have recommended, then the cost of the plant in 1958 dollars is $329.0 billion. The more optimistic and lower figure will be used here.

To find the number of plants required per year, it was assumed that commercialization of high BTU coal gasification would not take place until 1980. This is certainly true for the Hygas process. The gasification plant that El Paso plans to have in production for 1976 may start a snowballing of new plants but presumably most of the industry will wait to see how El Paso fares before jumping into plant construction. The FPC estimates that 1.4 trillion cubic feet of synthetic gas will be supplied in 1985 and that 13.7 trillion cubic feet must be obtained from presently unknown sources. [18, p. 5]. These estimates form the basis for the two high BTU coal gasification scenarios summarized in Figure 3.11. The low estimate implies

F I G U R E 3.11

HIGH BTU COAL GASIFICATION SCENARIOS

Low Capacity: Enough investment in Hygas process to meet FPC estimate of 1.4 trillion cu. ft of synthetic gas from coal in 1985

Total Investment[1]: $2,340 million (8.5 plants)

Yearly Investment: $468 million (1.7 plants)

High Capacity: Enough investment in Hygas process to meet FPC estimate of 13.7 trillion cu. ft. of unfilled demand for gas in 1985

Total Investment: $22,889 million (83.5 plants)

Yearly Investment: $4,578 million (16.7 plants)

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[1] All figures in 1958 dollars

that almost nine 500,000 MCF/day high BTU gas plants must be constructed between 1980 and 1985. Assuming that these come on line at the rate of 1.75 per year and that the time distirbution of the plant investment is uniform, Figure 3.12 describes the economic impacts (the Low Capacity column) and compares this to the impact of the total 1980 GPDI. The most significant impact is in sector 51, plumbing and structural metal products (produces boilers and pressure vessels) where 1.6% of the total investment is for high BTU gas plants. This is hardly a significant result, but then 1.75 plants per year represents less than $600 million (1958 dollars) out of a total GPDI of $184 billion and a total GNP of $1.155 trillion.

Column 3 presents data for the high capacity future. In this future, it becomes national policy not to depend on overseas sources for natural gas. If high BTU coal gasification is to make up the gap between domestic production and consumption, over 85 of the standard 500,000 MCF plants must be constructed between 1980 and 1985. This amounts to over 17 plants per year. Under this crash program, sector 51 (Plumbing and Structural Metal) again gets the most impact (16%). In fact the crunch is somewhat worse than appears here because most of the impact occurs among boiler makers and pressure vessel manufacturers, which amount to about 15% of the total sector. Thus these sub-industries might have to expand by almost 100% if such a crash program were undertaken.

The other way, of course, for this difficulty to arise is if all of the new energy technologies expand moderately fast. Since all of these technologies require large inputs from sector 51, the combined impact could be quite significant.

To get some idea of the regional impacts, estimated reserves by state are provided in Figure 3.13. It can be readily seen North Dakota, Montana, Wyoming, and many of the Rocky Mountain States have substantial coal deposits. Much

FIGURE 3.12

MAJOR[1] IMPACTS[2] OF LOW AND HIGH CAPACITY SCENARIOS FOR HIGH BTU COAL GASIFICATION
(millions of 1958 dollars)

	Sector	1980 GPDI	Low Capacity	High Capacity
5	Ferrous Metal Mining	908	$ 3.4	$ 34 (3.7%)
6	Non Ferrous Metal Mining	829	2.9	29 (3.5%)
7	Coal Mining	558	4.6	45 (8.0%)
11	New Construction	74246	164.5	1609 (2.2%)
44	Stone & Clay Products	7045	17.0	166 (2.4%)
45	Primary Steel	12092	51.0	500 (4.1%)
48	Primary Non-Ferrous Metals	2679	10.4	102 (3.8%)
49	Misc. Non-ferrous Metals	9161	30.5	299 (3.3%)
51	Plumbing & Structural Metals	8247	138.2	1353 (16.4%)
54	Other Fabricated Metals	5417	24.9	244 (4.5%)
55	Engines & Turbines	1844	16.2	158 (8.6%)
61	General Ind. Machinery	6040	54.3	531 (8.8%)
64	Service Ind. Machinery	1786	8.5	83 (4.6%)
66	Electrical Ind. Machinery	8900	24.8	243 (2.7%)
81	Water Transportation	524	4.5	44 (8.4%)
89	Wholesale Trade	20424	44.1	431 (2.1%)
90	Retail Trade	14033	20.5	200 (1.4%)
91	Finance and Insurance	4295	16.0	157 (3.7%)
94	Business Services	14151	37.4	366 (2.6%)
101	Imports	10506	22.1	216 (2.1%)

---

[1] Major is defined as over $160 million or over 3% of GPDI impact for High Capacity Scenario.

[2] Impacts defined as total sales ($\underline{X}^I$) required to support given level of investment $\underline{Y}^I$ or $\underline{X}^I = (\underline{I}-\underline{A})^{-1} \underline{Y}^I$

FIGURE 3.13

COAL RESERVES OF THE UNITED STATES BY STATES (MILLIONS OF TONS)

	Bituminous Coal	Total	Est. total Remaining resources in the ground 0-3,000 ft. overburden	Est. total Remaining resources in the ground 0-6,000 ft overburden
Alabama	13,518	13,538	33,538	39,538
Alaska	19,415	130,089	260,089	265,089
Arkansas	1,640	2,420	6,420	6,420
Colorado	62,389	80,715	226,715	371,715
Georgia	18	18	78	78
Illinois	139,756	139,756	239,756	239,756
Indiana	34,779	34,779	56,779	56,779
Iowa	6,519	6,519	20,519	20,519
Kansas	18,686	18,686	22,686	22,686
Kentucky	65,952	65,952	117,952	117,952
Maryland	1,172	1,172	1,572	1,572
Michigan	205	205	705	705
Missouri	23,359	23,359	23,359	23,359
Montana	2,299	221,701	378,701	378,701
New Mexico	10,760	61,479	88,479	109,479
N. Carolina	110	110	130	135
N. Dakota	0	350,680	530,680	530,680
Ohio	41,864	41,864	43,864	43,864
Oklahoma	3,299	3,299	23,299	33,299
Oregon	48	332	432	432
Pennsylvania	57,533	69,650	79,650	79,650
S. Dakota	0	2,031	3,031	3,031
Tennessee	2,652	2,652	4,652	4,652
Texas	6,048	12,926	26,926	26,926
Utah	32,100	32,250	80,250	115,250
Virginia	9,710	10,045	13,045	13,145
Washington	1,867	6,183	36,183	51,183
W. Virginia	102,034	102,034	102,034	102,034
Wyoming	12,699	120,710	445,710	545,710
Other States	618	4,721	5,721	5,721
TOTAL	671,049	1,559,875	2,872,955	3,210,060

Source: 1970 Keystone Coal Industry Manual [30] p, 303.

of this is low-sulfur coal and readily strip mineable. Illinois, Iowa, Missouri, and parts of Kansas and Oklahoma also have significant coal deposits. And of course there are the old strip mining states of Pennsylvania, Ohio, West Virginia, and Kentucky. Much of the current activity for coal gasification pilot plants is centered in North Dakota and Illinois. Because of the increasingly strict sulfur regulations on power plant emissions, eastern coals which are relatively high sulfur content are in danger of losing their market. The eastern coal companies are deparately looking for new markets and new desulfurization methods. The East then will be a prime target for both high BTU and low BTU coal gasification methods. Because of the proximity to significant energy use centers, low BTU coal gasification may be more economical in the East than in the West where transmission distances are longer. The only economical way to open up the vast western reserves of low-sulfur coal may be a high BTU coal gasification method. Transportation costs for these high-volume low heating value coals (70% of F.O.B. mine value for bituminous) would be very high while transportation cost for pipeline gas are much less. Thus, not only will high BTU goal gasification be used to supplement our dwindling natural gas supplies, but it may also prove to be the most economical method of transporting the low-sulfur western coal to the east and midwest load centers.

The problems of constructing and operating the three hundred and fifty million dollar plant in relatively unpopulated North Dakota, for example, can easily be imagined. Construction labor would undoubtedly have to be imported for this task which is going to significantly raise the cost of such a plant. If the importation of construction labor was indeed required, the local economic effects would be lessened since much of the laborer's money would be channeled out of the area to his home. Since equipment purchases are already made outside of the local area, the combined effect is to significantly reduce the amount of money injected into the local economy. Roughly one third to one quarter of total cost of the plants represents equipment cost. Another 10-14% consists of interest charges. Thus if construction used a local labor pool, 50-60% of the total plant cost would be circulated in the community. Because of the distribution effect, every billion dollars of construction activity employs about 46,700 workers in the construction industry but about 102,700 in all industries (about 3/4 of which would be located in the proximity of the construction site). The average trade margin for personal consumption expenditures is 21.6% and the value added fraction for retail trade is .733. Thus in current dollars every Hygas Plant constructed at $354.8 million could result in ($354.8 x .5 x .75 x 1.216 x .733) $118.6 million of GNP generation in the vicinity of the plant.

The local effects of the operation of the plant will be discussed in Chapter 4.

3.3 Low BTU Coal Gasification

Low BTU coal gasification cannot be used to supply synthetic gas over very long distances. Because of its low heat content (typically 150 to 200 BTU/SCF as compared to natural gas at 1000 BTU/SCF, the effective diameter or carrying capacity of the pipeline is diminished by a factor of between five and seven. This is just not an economical way to ship gas. However, because of the ease of cleaning up hydrogen sulfide from relatively concentrated gas volumes as compared with cleaning SO_2 from stack gases in relatively dilute volumes, low BTU coal gasification definitely has a place. A very natural place for it is in the electric utility industry where the low BTU, high-volume gas will mesh very nicely with new gas turbine electric generation techniques.

To illustrate the economic impacts in more detail, the two scenarios of figure 3.14 concentrate the projected low BTU gas market share on the coal-using sector of the electric utility unit. Figure 3.15 illustrates the impact of the two different market shares for the low BTU gas. The second column of Figure 3.15 represents a 5% market share of the coal-using electric generation plants in 1985. Such a market share corresponds to the addition of 3.6 plants every year. Column three represents a 20% market share for the low BTU gas. This market share corresponds to the addition of slightly over 14 plants per year between 1980 and 1985. Considering the 1975 emission standards for electric generation plants, this may be a very conservative projection of the coal-using electric utility market share. For example, Commonwealth Edison is currently installing a first-generation low efficiency Lurgi gasification plant on an experimental basis to help it to meet the 1975 SO_2 emission standards. Growth in coal-fired plants alone could require 12 plants per year but because of the low cost of these plants (only $27.5 million per plant in current dollars), even the high capacity scenario has almost no economic impact.

3.4 The Gas Turbine Topping Cycle (COGAS Cycle)

Assuming that the gas turbine technology develops as expected and at somewhat close to the predicted prices, the combined gas-steam cycle for electric power generation look extremely attractive. This is especially true when used in conjunction with a low BTU coal gasification plant because the gas turbines allow one to extract much of the sensible heat contained in the low BTU gas as well as the chemical energy.

F I G U R E 3.14

LOW BTU COAL GASIFICATION SCENARIOS

Low Capacity: Enough investment to have 5% share of 1985 coal-burning electric utility market (which FPC estimates is 13.86 quadrillion BTU or 370 low BTU gas plants)

Total Investment[1]: $393 million (18.5 plants)[2]

Yearly Investment[1]: $78.6 million (3.65 plants)

High Capacity: Enough investment to have 20% share of 1985 coal-burning electric utility market

Total Investment[1]: $1572 million (74 plants)

Yearly Investment[1]: $314.4 million (14.6 plants)

---

[1] All investments in 1958 dollars.

[2] Plant sizes are described in Figure 3.6

FIGURE 3.15

MAJOR[1] IMPACTS[2] OF LOW AND HIGH CAPACITY SCENARIOS[3] FOR LOW BTU COAL GASIFICATION
(millions of 1958 dollars)

	Sector	1980 GPDI[4]	Low Capacity	High Capacity
45	Primary Steel	12092	7.5	29.9 (0.25%)
51	Plumbing & Structural Metal Prods.	8247	13.2	52.8 (0.64%)
61	General Industrial Machinery	6041	7.5	30.0 (0.50%)
94	Business Services	14151	7.7	30.7 (0.22%)

---

[1]Major means any impact over $30 million or over 0.5% of the GPDI impact for each sector by the High Capacity scenario.

[2]Impacts refers to total sales of each sector required to sustain the indicated level of investment.

[3]For definitions of scenarios see Figure 3.14.

[4]Gross Private Domestic Investment

The two scenarios for COGAS are summarized in Figure 3.16 while Figure 3.17 illustrates the economic impact of the capital expenditures for these numbers of gas turbine topping cycle plants. The figures in column 2 assume that gas turbine topping cycle power stations capture 6% of all electric generation capacity growth between 1980 and 1985. The FPC estimates that 184,000 MW of fossil and 140,000 MW of nuclear generation will be added between these years. This amounts to approximately 4 COGAS plants of one thousand megawatt capacity coming on line per year. Column 3 presents similar figures under the assumption that 25% of all growth between '80 and '85 will be captured by the gas turbine topping cycle type of station. This later fraction may be quite high, however at this point in time, the economics of the topping cycle look extremely attractive and it has the additional advantage of being very low in thermal pollution, (because of the increased efficiency and because the gas turbine part of the power cycle is air cooled).

The major impact for this case occurs in Engines and Turbines (sector 55). This is to be expected considering the nature of the gas turbine topping cycle plant. The small impact on the boiler makers reflects the fact that much of the power is generated in the topping cycle and the waste heat boiler is of much simpler construction than a typical modern supercritical, water-wall, once-through boiler. If the gas-turbine in this plant had been assigned to Aircraft and Parts (sector 73, because it may be a modified aircraft engine) instead of to Engines and Turbines, the impact would have been even less significant percentage-wise because of the larger size of sector 73. Even though turbines for electric generation base load are a new product for the Aircraft industry, the significance is lost because of the aggregation level of the input-output table. Even at 110 order this problem

FIGURE 3.16

GAS TURBINE TOPPING CYCLE (COGAS) SCENARIOS

Low Capacity: Enough investment to make up 6% of expected (FPC estimated) growth in electric generation capacity between 1980 and 1985. Total expected growth of 324,000 MW of which 140,000 MW will be nuclear.

Total Investment[1]: $1489 million (20.5 plants)[2]

Yearly Investment: $298 million (4.1 plants)

High Capacity: Enough investment to make up 25% of expected growth in electric generation capacity between 1980 and 1985.

Total Investment: $5957 million (82 plants)

Yearly Investment: $1191 million (16.4 plants)

---

[1]All investments in 1958 dollars.

[2]Plant sizes are described in Figure 3.6.

FIGURE 3.17

MAJOR[1] IMPACTS[2] OF THE LOW AND HIGH CAPACITY SCENARIOS FOR COGAS (GAS TURBINE TOPPING CYCLE)

	Sector	1980 GPDI[3]	Low Capacity	High Capacity
		(millions of 1958 dollars)		
11	New Construction	74246	59.6	239 (0.32%)
44	Stone & Clay Products	7046	7.3	29 (0.42%)
45	Primary Steel	12092	18.0	72 (0.60%)
49	Misc. Non-Ferrous Metals	9161	14.9	59 (0.65%)
51	Plumbing & Structural Metal Products	8247	30.5	122 (1.48%)
54	Other Fabricated Metal Products	5417	12.7	51 (0.94%)
55	Engines & Turbines	1844	63.9	256 (13.86%)
61	General Industrial Machinery	6041	8.9	36 (0.59%)
62	Machine Shop Prods	1454	4.1	16 (1.12%)
66	Electrical Industry Equip.	8900	39.3	157 (1.77%)
81	Water Transportation	524	1.8	7.3 (1.39%)
89	Wholesale Trade	20424	21.2	85.0 (0.42%)
90	Retail Trade	14033	9.9	39.8 (0.28%)
91	Finance and Insurance	4295	7.2	28.7 (0.67%)
94	Business Services	14151	24.6	98.4 (0.70%)
101	Imports	10506	11.8	47.0 (0.45%)

[1]Major refers to impacts over 24 million or over 1% of GPDI impact on each sector by High Capacity scenario.

[2]Impacts refer to the total sales of each sector required to sustain the indicated level of investment.

[3]Gross Private Domestic Investment.

of lack of detail exists because the major impacts of the new technologies occurs on one particular subindustry of a larger sector. Thus the impact gets "averaged down."

Regional impacts of the construction of gas turbine topping cycle generation plants are very similar to those for the construction of the various coal gasification plants. The differences are that while the gas turbine topping cycle plants will tend to be associated with the low BTU gasification plants, they are very natural candidates for construction anywhere in the country because of the increased efficiency of these plants.

3.5 Nuclear Steam Generation

Figure 3.18 describes the scenarios for the addition of nuclear capacity, while Figure 3.19 illustrates the results of these scenarios. The FPC estimates that 140,000 MW of nuclear generation will be added between 1980 and 1985. Low expenditures refer to 7,000 MW per year being added (25% of projected), while high refers to 28,000 MW being added (100% of projected). As the chart indicates, there are likely to be capacity constraints in several industries such as Plumbing and Structural Metal Products (sector 51 which manufactures pressure vessels), and Engines and Turbines (sector 55 which manufactures turbogenerators). This could be especially pronounced because all of the new technologies that we have discussed impact on these two industries. The combined effect will be quite large if the industries grow as expected. It must be remembered that part of the reason that nuclear generation plants are so expensive is that assemblies (especially the pressure vessel) must be tested quite extensively for leaks. This particular capability is not possessed by many manufacturers so the resulting "crunch" could be

FIGURE 3.18

NUCLEAR GENERATION SCENARIOS

Low Capacity: Enough investment to yield 25% of the FPC estimate of 140,000 MW of nuclear capacity additions between 1980 and 1985.

Total Investment[1]: $7149 million (35 plants)[2]

Yearly Investment: $1430 million (7 plants)

High Capacity: Enough investment to yield 100% of the estimated 140,000 MW of nuclear capacity additions between 1980 and 1985

Total Investment: $28596 million (140 plants)

Yearly Investment: $5719 million (28 plants)

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[1]All figures in 1958 dollars.

[2]Plant sizes are described in Figure 3.6

F I G U R E 3.19

MAJOR[1] IMPACTS[2] OF LOW AND HIGH CAPACITY SCENARIOS FOR NUCLEAR GENERATION

	Sector	1980 GPDI[3]	Low Capacity	High Capacity
		(millions	of 1958	dollars)
5	Ferrous Metal Mining	908	7.7	31 (3.49%)
6	Nonferrous Metal Mining	829	7.3	29 (3.50%)
28	Printing & Publishing	3304	26.8	107 (3.25%)
45	Primary Steel	12092	114.0	456 (3.77%)
46	Iron & Steel Foundries	2197	17.5	70 (3.19%)
47	Iron & Steel Forgings	809	7.3	29 (3.59%)
48	Primary Non-ferrous Metal	2679	25.7	103 (3.84%)
49	Misc. non-ferrous Metals	9161	75.1	300 (3.28%)
51	Plumbing & Structural Metals	8247	295.5	1182 (14.33%)
54	Other Fab Metal Prods	5416	47.9	192 (3.54%)
55	Engines & Turbines	1844	248.1	993 (53.82%)
60	Special Industry Mach.	4296	35.9	144 (3.35%)
61	General Industry Mach.	6041	55.9	224 (3.70%)
62	Machine Shop Prods.	1454	17.1	68 (4.72%)
68	Elec. Lighting Equip.	2489	22.9	91 (3.69%)
81	Water Transportation	524	9.1	36 (6.95%)
91	Finance & Insurance	4295	45.1	181 (4.21%)
94	Business Services	14152	137.0	548 (3.87%)

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[1] Major refers to impacts over 24 million or over 1% of GPDI impact on each sector by High Capacity scenario.

[2] Impacts refer to the total salesof each sector required to sustain the indicated level of investment.

[3] Gross Private Domestic Investment.

very severe unless plans are made to avert it. Hopefully private industry is willing to expand to take care of this expected demand but the risks are quite large.

Chapter 4 Impacts of New Technology Plant Operations and Energy Price Rises

4.1 Overview of Chapter

This chapter consists of two major sections. The first describes the major economic impacts of operating the new energy technology plants.[21] Three new technologies are discussed in this chapter:

1. High BTU coal gasification (Hygas process)
2. Low BTU coal gasification
3. Gas turbine topping cycle electricity generation fueled by low BTU gasified coal (this is a combination of the two processes described in Chapter 3).

Conventional nuclear steam electric generation is again used as a reference. The topping cycle and low BTU coal gasification were combined because this combination represents the most likely utilization of both processes.

It will be shown that only a few industries are significantly affected by the operation of such plants and consequently the fewer comparisons will be made. There will be no calculations of High and Low utilization impacts of the new technologies as there were in Chapter 3.

Any discussion of non-economic impacts (such as SO_2 emissions or employment) that result from operating the plants will be put off until the 1985 projections are presented in Chapter 5.

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21 For definitions of "impacts" and other terms, see Chapter 3

The second section of this chapter describes the major price changes that can be expected to occur over the long run if the prices of various energy sources rise, assuming that no substitution occurs. A firm conclusion that arises is that the price of most non-energy consumer goods[22] will not change very significantly (typically 1% price rise for 50% jump in energy process). The major deficiency of the results is that one cannot tell how the various fuel's market shares will change or how competition between basic materials like steel and aluminum will be affected. It is the assumption of no substitution that weakens the results.

4.2 Impacts of New Technology Operations

4.2.1 Perspective

Before discussing the impacts of operating new technology plants, the current operations of the energy industries should be put into perspective. Figure 4.1 presents various capital and operating ratios of the energy industries. Their large capital/output ratios were discussed in Chapter 3. The size of the value-added coefficient which reflects labor and capital contributions to the value of the product are quite high in general, with the possible exception of petroleum refining which has a very high throughput of material. The employee/output ratio indicates that most of the value-added coefficient is made up of capital costs. The energy industries as a whole make up only 4.5% of GNP when measured by value-added and only 3.5% of GNP when measured by sales to final demand.[23] Despite the fact that the value-added coefficients

22 Consumer goods are things like cars and lampshades that primarily are purchased by Households as opposed to steel ingots or raw plastic that are primarily purchased by industry.

23 GNP can be found by summing either total incomes (value added) or total sales to final consumers (final demand). Hence the size of industries in comparison to GNP can be measured in these two ways

FIGURE 4.1

SELECTED FIGURES FOR THE ENERGY SUPPLY INDUSTRIES

	Employees/ Output Ratios	Capital/ Output Ratios	% of GNP by Value Added	% of GNP by Final Demand	Value Added Coefficient	Fuel Inputs (No trans- portation
Coal Mining	54.0	1.00	.26	.09	.584	--
Crude Petroleum & Natural Gas	25.3	1.40	1.17	-.22	.565	--
Petroleum Refining	8.4	.80	.86	1.75	.232	.470
Electricity	22.4	5.30	1.55	1.22	.594	.279
Natural Gas	22.2	2.50	.68	.66	.354	.535
Totals		--	4.52	3.50	--	--
Averages	34.9	.80	--	--	--	--

Sources: Capital/Output ratios - [21]
Value Added Coefficient
Fuel Input Coefficients - [49]
% of GNP

are so high, fuel inputs to these energy producing and processing industries make up a very significant portion of the remainder of the cost. In fact, when value added and fuel inputs are removed from technological coefficient vectors of the energy industries, less than 25% is usually left to allocate among all of the rest of the industries.

More detail on the electrical industry can be found in Figure 4.2. In this breakdown over 58% of the cost of electricity is made up of fixed costs, primarily capital charges and taxes. Fuel costs make up another 16% of the total costs leaving a mere 26% to be divided among the rest of the operating accounts. Figure 4.3 presents the same graphic picture of capital intensiveness and fuel intensiveness for the gas utility industry. Over 75% of total operating expenses for the gas utilities is made up of the costs of natural gas purchases and total operating expenses make up almost 75% of the cost of gas to the consumer.

4.2.2 Economic Impacts of New Technology Plant Operation

The economic impacts of operating a coal gasification plant are quite different from those of constructing the plant. No capital producing sectors are affected by plant operation. And only the fuel supplying sectors are significantly impacted.

The economic impacts of new technology operations will be illustrated in two ways, similar to those employed in the Chapter 3:

1. Iso - dollar impacts - the outputs of each sector required to support the production of $10 billion worth of energy by each new technology and by nuclear steam electricity generation.

FIGURE 4.2

COST OF ELECTRICITY

1968 Actual

	Mills/Kwhr	% of Category	% of Total Cost
Power Production Costs			
Fuel	2.47	33	16
Other Operating & Maintenance	1.34	18	9
Fixed Charges	3.71	49	24
Total Production Cost	7.52	100%	49%
Transmission Costs			
Operating & Maintenance	.25	13	1
Fixed Charges	1.66	87	11
Total Transmission	1.91	100%	12%
Distribution Costs			
Operating & Maintenance	1.64	32	11
Fixed Charges	3.56	68	23
Total Distribution	5.20	100%	34%
Administration	.79	100%	5%
Total Cost of Power	15.42		100%

Source: [17], p. I-19-10

Breakdown of Fixed Costs (14.2% of Investment or 8.93 mills/Kwhr = 58%)

Cost of Money	8.2%
Depreciation and Replacements	1.2%
Insurance	.2%
Income Taxes	2.2%
Other Taxes	2.4%

Source: [17], p. I-19-6

FIGURE 4.3 a

CLASSIFICATION OF GAS OPERATING EXPENSES AS PERCENT OF TOTAL, ALL NATURAL GAS COMPANIES, 1970

Note: Includes both straight and combination gas companies

Type of Expense	1970 Maintenance	1970 Total Operation & Maintenance
Purchased gas cost	0.0	75.9
Other Production & purch. exp.	0.3	1.6
Production & Purchases, Total	0.3	77.5
Storage	0.2	0.9
Transmission	0.9	4.3
Distribution	2.2	6.3
Customer accounts	---[1]	2.9
Sales	---[1]	1.8
Administrative & General	0.1	6.3
Total Operating Expense	3.8	100.0

1 Less than 0.05 percent.

Source: [1], p. 194

FIGURE 4.3 b

COMPOSITE INCOME ACCOUNTS, TOTAL INVESTOR-OWNED GAS UTILITY INDUSTRY, INTERIM BASIS, 1970

(Millions)

	Amount	%
Total Operating Revenues	$16,380	100.0%
Operating expenses-maintenance	431	2.6
Operating expenses-operation	11,205	68.4
Total Operating Expenses	11,636	71.0
Depreciation, retirements, depletion, amortization, etc.	1,101	6.7
Federal Income Taxes[1]	639	3.9
All Other Taxes	930	5.6
Total taxes	1,569	9.5
Total Operating Expenses	14,306	87.3
Operating income	2,074	12.6
Other income (non-operating)	310	1.8
Gross income	2,384	14.5
Interest on long-term debt	867	5.2
Other income deductions	90	.5
Total income deductions	957	5.8
Net income	1,427	8.7

1 Includes provision for deferred federal income taxes.

Source: [1], p. 172

2. Iso-energy impacts - the outputs of each sector required to support the production of 5 trillion BTU/day (or 25 billion Kwhr/year) by each new technology and by nuclear steam electricity generation.

Before proceeding, it is important to state that the $10 billion of energy were assumed to be purchased at the average consumer price levels for the different fuels that include transportation, distribution, and administration costs. The impacts that will be presented are caused only by that portion of this $10 billion that is used for generation. The generation cost of each new energy source is compared in Figure 4.4 with the average customer cost (average revenue per MMBTU) for fuel. The total energy purchased by $10 billion from each source is indicated in Figure 4.5.

The actual impacts of the $10 billion energy purchases are depicted in Figure 4.6. The first column contains the projected 1980 total output of each sector for comparison. The most obvious impact occurs in coal mining where the coal requirements for the various processes represent 50-75% of the total projected 1980 coal usage.

This impact on coal mining will not mean reopening many old mines and greatly expanded business for other miners however. Since the coal requirements of the gasification schemes are so great, they must be sited near large coal fields[24]. Possible locations of these fields were discussed in Chapter 3 but the gasification plants will most likely require the development of new mines, not the expansion of old mines. Thus the coal mining industry will be forced to expand but it will be a very localized expansion. Other impacts are not nearly as significant as coal with the possible exception of limestone purchase (for SO_2 scrubbing) by the high BTU gas plants.

24 Because of the difference in costs between strip and underground mining, these coal fields must most likely be strip mineable.

FIGURE 4.4

GENERATION COST vs. AVERAGE CUSTOMER COST FOR EACH NEW TECHNOLOGY

Technology	Generation Cost 1970 Dollars	Average Customer Revenue[1] 1970 Dollars
High BTU Coal Gasification	72.6¢/MMBTU	101.7¢/MMBTU (84.8¢/MMBTU)[2]
Low BTU Coal Gasification	37.1¢/MMBTU	66.3¢/MMBTU (55.3¢/MMBTU)
Gas Turbine Topping Cycle	5.5 mills/kwhr	15.4 mills/kwhr (16.1 mills/kwhr)

1 Calculated by assuming any additional generation costs (over the average 1970 generation costs for gas or electricity) were passed on to the customers on a dollar for dollar basis.

2 Numbers in parentheses are deflated to 1958 dollars.

FIGURE 4.5

$10 BILLION ENERGY PURCHASES (AT AVERAGE CUSTOMER COST)

Technology	Generation Portion[1] of Money (Billions)	Energy Purchased
High BTU Coal Gasification	$7.1	15.0 (10^{15} BTU)
Low BTU Coal Gasification	$5.6	18.1 (10^{15} BTU)
Gas Turbine Topping Cycle	$3.6	6.2 (10^{14} kwhr)

1 Impacts are assumed to be caused only by that portion of the $10 billion actually used to generate gas or electricity with new technology. No transportation, distribution, administration changes or profits are included.

F I G U R E 4.6

OUTPUT REQUIRED TO SUPPORT $10 BILLION OF ENERGY PURCHASES FOR NEW TECHNOLOGIES (AT AVERAGE CONSUMER PRICES)[1]

	1 TOTAL OUTPUT	2 HIGH BTU GAS	3 LOW BTU GAS	4 GAS TURBINE CYCLE	5 NUCLEAR STEAM
1 LIVESTOCK & PRODUCTS	44965.242	12.400	11.200	5.900	13.800
2 OTHER FARM PRODUCTS	40234.406	14.700	15.100	6.800	13.900
3 FORESTRY & FISHERY PROD	2558.530	3.000	4.600	2.000	5.100
4 FARM, FOREST, FISH SERV	2166.831	1.300	1.700	0.900	1.200
5 FERROUS METAL MINING	2028.351	4.300	5.300	2.200	19.300
6 NONFERROUS METAL MINING	3096.648	4.300	6.100	2.500	29.900
7 COAL MINING	4328.605	2303.800	3436.699	953.799	23.400
8 CRUDE OIL AND NATURAL GA	22352.023	32.900	39.900	15.000	105.700
9 STONE & CLAY MINING	3839.509	182.500	8.700	5.200	12.200
10 MINERAL MINING	2204.724	4.900	5.400	2.000	89.700
11 NEW CONSTRUCTION	117216.000	0.0	0.0	0.0	0.0
12 MAINT & REPAIR CONST	55136.703	234.500	305.800	335.800	475.600
13 ORDNANCE, ACCESSORIES	8330.141	0.500	0.600	0.300	0.700
14 FOOD & KINDRED PRODUCTS	112436.125	26.300	19.400	12.500	34.500
15 GRAIN MILLING	14706.305	4.300	4.100	2.100	8.600
16 TOBACCO MANUFACTURES	9066.117	1.400	0.700	0.500	1.300
17 FABRIC,YARN,THRD MILLS	26515.930	9.000	11.200	4.000	5.900
18 MISC. TEXTILE GOODS	6102.750	5.900	7.000	2.500	3.400
19 APPAREL	33288.605	2.300	2.700	1.100	2.200
20 MISC FAB TEXTILE PRODUCT	5026.656	1.500	1.400	0.600	1.500
21 LUMBER & WOOD PRODS	17272.375	34.300	45.900	22.800	23.700
22 WOODEN CONTAINERS	485.343	0.400	0.500	0.300	0.600
23 HOUSEHOLD FURNITURE	9045.969	0.400	0.500	0.200	0.300
24 OTHER FURN & FIXTURES	4862.805	0.400	0.500	0.400	0.500
25 PULP MILLS	2798.455	3.200	3.500	1.600	6.500
26 PAPER & ALLIED PRODS	26938.598	39.400	39.200	17.600	48.900
27 PAPER CONTAINERS, BOXES	13082.641	9.800	11.500	5.500	21.000
28 PRINTING & PUBLISHING	31614.461	61.000	51.400	20.500	41.800
29 INDUSTRIAL CHEMICALS	34030.285	111.900	120.000	43.300	2430.399
30 FERTILIZERS	3385.242	2.300	2.500	1.000	19.300
31 AGR & MISC CHEMICALS	7102.125	9.600	30.000	10.200	32.900
32 PLASTICS & SYNTH MTRL	23253.992	29.600	38.100	17.200	118.800
33 DRUGS, CLNG, TOILET PREP	25511.938	7.400	25.600	23.000	68.400
34 PAINTS & PRODUCTS	4758.531	14.700	19.300	18.300	28.900
35 PETROLEUM REFINING	36082.453	52.700	66.900	24.900	165.900
36 PAVING MIXTURES	647.847	2.700	2.300	2.500	3.600
37 ASPHALT FELTS, COATINGS	726.454	2.200	2.700	2.900	5.000
38 RUBBER & PLASTIC PRODS	30365.262	68.800	88.300	29.500	32.900
39 LEATHER TANNING PROD	982.647	1.000	0.300	0.100	0.200
40 FOOTWEAR & LEATHER PROD	4357.785	0.500	0.500	0.200	0.400
41 GLASS & GLASS PRODS	5966.835	4.400	5.500	3.600	10.200
42 CEMENT, HYDRAULIC	2657.411	5.600	4.000	2.900	4.500
43 LIME	496.654	2.600	1.000	0.500	5.200
44 STONE & CLAY PRODS	15424.898	35.300	25.000	16.200	24.500
45 PRIMARY STEEL	31440.578	51.100	66.000	27.400	50.200
46 IRON & STEEL FOUNDRIES	5321.504	9.500	11.100	4.500	5.600
47 IRON & STEEL FORGINGS	2223.343	4.300	5.400	1.900	3.200
48 PRIMARY NON-FER METAL	6155.473	11.900	18.400	7.700	47.900
49 MISC NON-FER METALS	23541.887	38.200	65.500	26.900	51.200
50 METAL CONTAINERS	4157.512	2.400	3.200	2.000	17.000
51 PLUMBING&STRUCTURAL META	14751.953	12.200	16.200	13.800	18.900
52 HEATING EQUIP EXC ELEC	2411.821	3.500	4.600	4.600	6.600
53 SCREWS & METAL STAMPINGS	3770.930	17.500	24.800	8.400	6.200

1 See Figure 4.5 and text for details.

F I G U R E 4.6 (continued)

	1 TOTAL OUTPUT	2 HIGH BTU GAS	3 LOW BTU GAS	4 GAS TURBINE CYCLE	5 NUCLEAR STEAM
54 OTHER FAB METAL PRODS	17430.105	28.400	35.900	18.900	39.900
55 ENGINES & TURBINES	5457.078	5.000	5.600	2.000	2.000
56 FARM MACHINERY & EQUIP	5545.004	2.500	2.900	1.000	0.900
57 CONSTRUCTION&MINING EQUI	7798.469	56.200	123.400	34.900	6.100
58 MATERIAL HNDLG MACH	3341.037	19.600	24.600	7.200	3.400
59 METALWORKING MACH	9562.598	14.800	20.500	6.600	5.300
60 SPECIAL INDUSTRY MACH	7507.047	3.500	4.100	1.600	45.600
61 GENERAL INDUSTRY MACH	10922.773	19.300	24.800	8.200	9.400
62 MACHINE SHOP PRODUCTS	5036.242	6.000	7.500	2.900	4.600
63 OFFICE COMP MACH	24347.691	16.200	15.300	5.700	11.800
64 SERVICE INDUSTRY MACH	2762.851	1.900	1.900	3.200	1.300
65 REFRIG MACHINERY	7592.910	2.100	2.800	2.400	3.300
66 ELECTRICAL INDUSTRY	16691.199	28.300	38.700	13.700	14.500
67 HOUSEHOLD APPLIANCES	12585.078	3.000	3.700	3.100	4.500
68 ELEC LIGHTING EQUIP	6794.098	8.600	11.600	5.900	6.600
69 RADIO,TV & COMM EQUIP	33266.023	5.900	6.200	3.200	5.700
70 ELEC COMP & ACCESS	24512.547	9.300	9.800	4.400	8.500
71 ELEC MACH EQP & SUPPLIES	5483.781	3.300	3.400	1.600	2.100
72 MOTOR VEHICLES & EQUIP	62555.188	19.900	23.700	8.400	7.500
73 AIRCRAFT & PARTS	22727.223	2.700	2.900	1.400	2.400
74 OTHER TRANSPORT EQUIP	10649.742	10.400	14.500	4.400	2.000
75 SCIENTIFIC & CONTROL INS	10984.273	3.100	4.100	3.700	13.400
76 OPTICAL & PHOTO EQUIP	11096.168	7.600	7.000	3.600	8.000
77 MISC MANUFACTURING	18596.305	13.200	14.500	6.400	9.200
78 RAILROAD TRANSPORTATION	25582.105	54.800	34.600	42.300	73.700
79 LOCAL PASSENGER TRANSPOR	8395.000	7.900	4.200	3.200	7.700
80 TRUCK TRANSPORTATION	20935.793	45.900	24.800	12.600	39.100
81 WATER TRANSPORTATION	6563.441	4.600	5.000	2.200	13.800
82 AIR TRANSPORTATION	6948.148	13.200	7.300	5.200	12.600
83 MISC TRANSPORTATION	3174.175	3.900	3.400	1.600	7.800
84 COMMUNICATIONS EXC RADGT	42604.512	47.100	48.700	26.700	52.100
85 RADIO & TV BROADCASTING	2734.529	8.200	7.400	2.600	3.900
86 ELECTRIC UTILITIES	42955.723	174.200	226.300	70.000	101.600
87 GAS UTILITIES	28691.543	39.900	39.900	15.700	144.800
88 WATER & SANITARY SERV	6928.316	145.200	86.000	37.200	15.400
89 WHOLESALE TRADE	107084.438	143.300	252.400	143.500	121.700
90 RETAIL TRADE	133574.313	110.700	83.000	56.500	71.300
91 FINANCE AND INSURANCE	70030.063	337.100	146.700	47.500	53.100
92 REAL ESTATE & RENTAL	165063.313	167.100	241.700	77.700	71.300
93 HOTEL, PERS & REPAIR SER	31238.129	13.200	9.400	5.300	12.500
94 BUSINESS SERVICES	67557.438	278.500	250.000	87.800	133.200
95 RESEARCH AND DEVELOPMENT	2249.450	2.100	2.600	1.200	3.300
96 AUTO REPAIR & SERVICE	20441.254	20.900	18.000	8.500	13.900
97 AMUSEMENTS	12698.379	6.900	5.800	2.400	4.100
98 MEDICAL & EDUCATION SERV	70478.750	10.400	11.900	4.200	6.000
99 FED GOVT ENTERPRISES	7925.773	17.900	16.500	6.300	10.500
100 STATE&LOCAL GOVT ENTERPR	10440.035	55.600	58.800	25.300	16.700
101 IMPORTS	-3653.488	67.100	67.300	27.800	191.500
102 BUSINESS TRAVEL, GIFTS	14070.516	60.300	31.700	23.900	59.000
103 OFFICE SUPPLIES	5540.324	13.800	9.200	6.400	19.000
104 SCRAP, SECONDHAND GOODS	1466.000	0.0	0.0	0.0	0.0
105 TOTAL OUTPUT	2241678.000	5761.152	6753.609	2616.086	5626.555

Next, the impacts of purchases of 5 trillion BTU/day (16.4×10^{14} BTU/yr. at 90% load factor) of gas or 25 billion kwhr. of electricity (which requires 16.4×10^{14} BTU/yr. input) Figure 4.7. This comparison provides a good example of some problems with an input-output table at this level of aggregation using dollars to measure product flow. The dollar amounts of coal purchases for high and low BTU gas are about equal but, since the high BTU gas plant is purchasing lignite at approximately 12¢/10^6 BTU while the low BTU plant is using bituminous at 20¢/10^6 BTU, the coal purchases in terms of BTU's are quite different. This can be a problem whenever products are not homogeneous.

An example of a problem caused by the aggregation level (indeed even the 365 order table is not fine enough to solve this problem) is that the $58 million worth of purchases of Crude Oil and Natural Gas (sector 8) by the nuclear generating plants is caused largely by purchases of fuel reprocessing services from Industrial Chemicals (sector 29). Since many industrial chemicals require a petroleum feedstock, the technical coefficients for the aggregate Industrial Chemicals sector show a significant input from Petroleum Refining (sector 35) which causes the demand on Crude Oil. Fuel reprocessing cannot be purchased alone because it is not a separate sector. Perhaps in 10 to 15 years when it grows in size, it may become one. This growth of new industries within old sectors is a natural result of standard industrial classification schemes. Such schemes cannot be expected to foresee all new industries. Carter has noted both of these problems previously in Reference 6, p. 8 and p. 12.

Because of the limited economic impacts of operating the new technology plants, further discussion of the operations will be put off until the 1985 projections are presented in Chapter 5. Non-economic impacts will also be described there.

F I G U R E 4.7

OUTPUTS REQUIRED TO SUPPORT PURCHASES OF 5 TRILLION BTU/DAY FROM NEW TECHNOLOGIES

	1 TOTAL OUTPUT	2 HIGH BTU GAS	3 LOW BTU GAS	4 GAS TURBINE CYCLE	5 NUCLEAR STEAM
1 LIVESTOCK & PRODUCTS	44965.242	1.729	1.220	2.391	5.591
2 OTHER FARM PRODUCTS	40234.406	2.050	1.645	2.755	5.632
3 FORESTRY & FISHERY PROD	2558.530	0.418	0.501	0.810	2.066
4 FARM, FOREST, FISH SERV	2166.831	0.181	0.185	0.365	0.486
5 FERROUS METAL MINING	2028.351	0.600	0.577	0.891	7.820
6 NONFERROUS METAL MINING	3096.648	0.600	0.664	1.013	12.115
7 COAL MINING	4528.605	321.219	374.346	386.456	9.481
8 CRUDE OIL AND NATURAL GA	22352.023	4.587	4.346	6.078	42.827
9 STONE & CLAY MINING	3839.509	25.446	0.948	2.107	4.943
10 MINERAL MINING	2204.724	0.683	0.588	0.810	36.344
11 NEW CONSTRUCTION	117216.000	0.0	0.0	0.0	0.0
12 MAINT & REPAIR CONST	55136.703	32.696	33.310	136.058	192.701
13 ORDNANCE, ACCESSORIES	8530.141	0.070	0.065	0.122	0.234
14 FOOD & KINDRED PRODUCTS	112436.125	3.667	2.113	5.065	13.979
15 GRAIN MILLING	14706.305	0.600	0.447	0.851	3.485
16 TOBACCO MANUFACTURES	9666.117	0.195	0.076	0.203	0.527
17 FABRIC,YARN,THRD MILLS	26515.930	1.255	1.220	1.621	2.391
18 MISC. TEXTILE GOODS	6102.750	0.823	0.762	1.013	1.378
19 APPAREL	33268.605	0.321	0.294	0.446	0.891
20 MISC FAB TEXTILE PRODUCT	5626.656	0.209	0.152	0.243	0.608
21 LUMBER & WOOD PRODS	17272.375	4.782	5.435	9.238	9.603
22 WOODEN CONTAINERS	485.043	0.056	0.054	0.122	0.243
23 HOUSEHOLD FURNITURE	9045.969	0.056	0.054	0.081	0.122
24 OTHER FURN & FIXTURES	4662.805	0.056	0.054	0.162	0.203
25 PULP MILLS	2798.495	0.446	0.381	0.648	2.634
26 PAPER & ALLIED PRODS	25938.598	5.494	4.270	7.131	19.813
27 PAPER CONTAINERS, BOXES	10082.641	1.366	1.253	2.228	8.509
28 PRINTING & PUBLISHING	51614.461	8.505	5.599	8.306	16.936
29 INDUSTRIAL CHEMICALS	34030.285	15.602	13.071	17.544	984.737
30 FERTILIZERS	5585.242	0.321	0.272	0.405	7.820
31 AGR & MISC CHEMICALS	7102.125	1.339	3.268	4.133	13.330
32 PLASTICS & SYNTH MTRL	23253.992	4.127	4.150	6.969	48.135
33 DRUGS, CLNG, TOILET PREP	25511.938	1.032	2.789	9.319	27.714
34 PAINTS & PRODUCTS	4758.531	2.050	2.102	7.415	11.710
35 PETROLEUM REFINING	30082.453	7.348	7.287	10.089	67.219
36 PAVING MIXTURES	647.847	0.376	0.251	1.013	1.459
37 ASPHALT FELTS, COATINGS	726.454	0.307	0.294	1.175	2.026
38 RUBBER & PLASTIC PRODS	50569.262	9.593	9.618	11.953	13.330
39 LEATHER TANNING PROD	982.547	0.139	0.033	0.041	0.081
40 FOOTWEAR & LEATHER PROD	4357.785	0.070	0.054	0.081	0.162
41 GLASS & GLASS PRODS	5966.836	0.613	0.599	1.459	4.133
42 CEMENT, HYDRAULIC	2657.411	0.781	0.436	1.175	1.823
43 LIME	496.654	0.363	0.109	0.203	2.107
44 STONE & CLAY PRODS	15424.898	4.922	2.723	6.564	9.927
45 PRIMARY STEEL	31440.573	7.125	7.189	11.102	20.340
46 IRON & STEEL FOUNDRIES	5521.504	1.325	1.209	1.823	2.269
47 IRON & STEEL FORGINGS	2223.343	0.600	0.588	0.770	1.297
48 PRIMARY NON-FER METAL	6155.473	1.659	2.004	3.120	19.408
49 MISC NON-FER METALS	25541.687	5.326	7.135	10.899	20.745
50 METAL CONTAINERS	4157.512	0.335	0.349	0.810	6.888
51 PLUMBING&STRUCTURAL META	14751.953	1.701	1.765	5.591	7.658
52 HEATING EQUIP EXC ELEC	2411.821	0.488	0.501	1.864	2.674
53 SCREWS & METAL STAMPINGS	6770.930	2.440	2.701	3.403	2.512

F I G U R E 4.7 (continued)

	1 TOTAL OUTPUT	2 HIGH BTU GAS	3 LOW BTU GAS	4 GAS TURBINE CYCLE	5 NUCLEAR STEAM
54 OTHER FAB METAL PRODS	17430.105	3.960	3.910	7.658	16.166
55 ENGINES & TURBINES	5457.073	0.697	0.610	0.810	0.810
56 FARM MACHINERY & EQUIP	5645.004	0.349	0.316	0.405	0.365
57 CONSTRUCTION&MINING EQUI	7798.469	13.413	13.441	14.141	2.472
58 MATERIAL HNDLG MACH	3341.037	2.733	2.680	2.917	1.378
59 METALWORKING MACH	9362.593	2.064	2.233	2.674	2.147
60 SPECIAL INDUSTRY MACH	7507.047	0.488	0.447	0.648	18.476
61 GENERAL INDUSTRY MACH	10922.773	2.691	2.701	3.322	3.809
62 MACHINE SHOP PRODUCTS	5036.242	0.837	0.817	1.175	1.864
63 OFFICE COMP MACH	24547.691	2.259	1.667	2.309	4.781
64 SERVICE INDUSTRY MACH	2762.851	0.265	0.207	1.297	0.527
65 REFRIG MACHINERY	7592.910	0.293	0.305	0.972	1.337
66 ELECTRICAL INDUSTRY	16691.199	3.546	4.215	5.551	5.875
67 HOUSEHOLD APPLIANCES	12585.078	0.418	0.403	1.256	1.823
68 ELEC LIGHTING EQUIP	6794.093	1.199	1.264	2.391	2.674
69 RADIO,TV & COMM EQUIP	35266.023	0.823	0.675	1.297	2.309
70 ELEC COMP & ACCESS	24512.547	1.297	1.067	1.783	3.444
71 ELEC MACH EQP & SUPPLIES	5483.781	0.460	0.370	0.648	0.851
72 MOTOR VEHICLES & EQUIP	82555.138	2.775	2.582	3.403	3.039
73 AIRCRAFT & PARTS	22727.223	0.376	0.316	0.567	0.972
74 OTHER TRANSPORT EQUIP	10645.742	1.450	1.579	1.783	0.810
75 SCIENTIFIC & CONTROL INS	10984.273	0.432	0.447	1.499	5.429
76 OPTICAL & PHOTO EQUIP	11096.168	1.060	0.762	1.459	3.241
77 MISC MANUFACTURING	18596.305	1.840	1.579	2.593	3.728
78 RAILROAD TRANSPORTATION	23382.105	13.218	3.769	17.139	29.861
79 LOCAL PASSENGER TRANSPOR	8395.000	1.101	0.457	1.297	3.120
80 TRUCK TRANSPORTATION	26935.793	6.400	2.701	5.105	15.842
81 WATER TRANSPORTATION	8963.441	0.641	0.545	0.891	5.591
82 AIR TRANSPORTATION	8948.148	1.840	0.795	2.107	5.105
83 MISC TRANSPORTATION	3174.175	0.544	0.370	0.648	3.160
84 COMMUNICATIONS EXC RADGT	42004.512	6.567	5.305	10.818	21.110
85 RADIO & TV BROADCASTING	2734.529	1.143	0.806	1.053	1.590
86 ELECTRIC UTILITIES	42955.723	24.289	24.650	28.362	41.166
87 GAS UTILITIES	28691.543	5.563	4.346	6.361	58.669
88 WATER & SANITARY SERV	6928.316	20.245	9.368	15.073	6.240
89 WHOLESALE TRADE	107084.438	19.980	27.493	58.143	49.310
90 RETAIL TRADE	153574.313	15.435	9.041	22.892	28.889
91 FINANCE AND INSURANCE	70030.063	47.002	15.979	19.246	21.515
92 REAL ESTATE & RENTAL	185063.313	23.299	26.327	31.482	28.889
93 HOTEL, PERS & REPAIR SER	31238.129	1.840	1.024	2.147	5.065
94 BUSINESS SERVICES	87557.438	38.831	27.231	35.574	53.969
95 RESEARCH AND DEVELOPMENT	2249.450	0.293	0.283	0.486	1.337
96 AUTO REPAIR & SERVICE	20441.254	2.914	1.961	3.444	5.632
97 AMUSEMENTS	12598.379	0.962	0.632	0.972	1.661
98 MEDICAL & EDUCATION SERV	70478.750	1.450	1.296	1.702	2.431
99 FED GOVT ENTERPRISES	7925.773	2.496	1.797	2.553	4.254
100 STATE&LOCAL GOVT ENTERPR	10440.035	13.330	6.405	10.251	6.766
101 IMPORTS	-3553.488	9.356	7.331	11.264	77.591
102 BUSINESS TRAVEL, GIFTS	14070.516	8.408	3.453	9.684	23.905
103 OFFICE SUPPLIES	5340.324	1.924	1.002	2.593	7.698
104 SCRAP, SECONDHAND GOODS	1466.000	0.0	0.0	0.0	0.0
105 TOTAL OUTPUT	2241078.000	803.272	740.010	1059.964	2279.786

4.3 Price Changes

Price changes caused by a rise in the real cost of energy, for example, are quite simple to calculate within the input-output framework, given the assumptions that are made. The basic assumption made is that price changes are passed on to the buyer of each industry's goods. Since the input-output table already embodies the interactions between all the sectors of the economy, tracing the effects of a rise in the price of electricity to the steel industry and the effects of both these price changes on automobile manufacturers is quite simple.

The basic formula that relates prices to value-added (the labor and capital components of each price) is easily derived. Using the previously defined symbols, the price of each good i is equal to the value added for that good plus the costs of all purchased goods and services that make up that good, or

$$p_i = v_i + c_i \qquad (4.1)$$

but the cost of materials, c_i, equals the sum of the unit price of each material used times the quantity used or

$$c_i = \sum_{j=1}^{N} a_{ji}\, p_j \qquad (4.2)$$

where a_{ji} = the amount of good j used per unit of good i (the technological coefficients). Substituting this in the above equation

$$p_i = v_i + \sum_{j=1}^{N} a_{ji}\, p_j \qquad (4.3)$$

Rewriting in matrix notation yields

$$\underline{P} = \underline{V} + \underline{A}^T\underline{P} \qquad (4.4)$$

Solving for P results in the familiar equation

$$\underline{P} = (\underline{I} - \underline{A}^T)^{-1}\ \underline{V} \qquad (4.5)$$

This equation can be used to calculate price changes. Once these price changes are calculated, it is possible to measure the effect of these price changes on personal consumption expenditures for that good. This effect is calculated using the price elasticity for that good.

Price elasticity has a deceptively simple definition, i.e., the percentage change in the quantity of a good sold in response to a one percent change in price of that good, other things being equal. The problem with such a definition is that time is not mentioned, i.e., over what time period does the change in quantity occur. Once time is introduced the "other-things-being-equal" assumption goes out the window. The world just does not cooperate in changing only one variable at a time.

Economists have traditionally resorted to multiple regression analysis to sort out the various factors. This technique has resulted in quite a bit of success when the data contains enough variation to allow identification of the various parameters of the demand equation. This is very analogous to the system identification problem in electrical engineering except that in the case of economic problems, one is not allowed to apply any external excitations to the system. Also, in a dynamic situation, the concept of price elasticity begins to lose some of its clarity because now one has to specify the time behavior of the change in sales. At the very least one can distinguish two forms of price elastic behavior, the very short run changes and the very long run changes. The medium term effects presumably are some blend of the short and long run effects. Of course, for the purposes of a true dynamic model of this changing situation one must specify how rapidly the price change effects take hold, i.e., the time constants involved in changing behavior.

In addition, there are many other parameters that affect the elasticity of the good. For example, the price elasticity of the good will probably change with the quantity of the good used (as a luxury good becomes a "necessity"), with the price of any substitutes for that good, with the foibles of a fashion conscious public, etc. A sophisticated analysis of the demand for a product will include as many of the quantifiable variables as are needed to explain the past behavior.

Despite these difficulties, many people have estimated price elasticities for various components of personal consumption expenditures. Unfortunately while consumers make up about 65 percent of final demand for most goods, they purchase less than 31% of total energy. Industrial and commercial usage represents a very high percentage of total energy use. Since no elasticities are available for other final demand components or for any industrial uses of energy, the resulting price effects calculated for final demand represent the minimum possible effect that would result from a price change. Without elasticities for the industrial and commercial sectors one can draw very few conclusions about total price effects. The actual pricing calculations and energy use decisions that go on in the economy and especially in the industrial and commercial sector are quite subtle. For example, an electric utility contemplating whether or not it can switch from coal to oil as its primary fuel must consider such things as the transportation cost involved in getting the fuel to the electric utility, the price of possible fuel substitutes, the capital costs associated with changing fuels (for new burners and storage facilities, etc.), how stable such prices will be over the long run, whether there are any availability constraints, etc.

Price rises and long-term declines in Household purchases (PCE), caused by the effects of price elasticities, were calculated for six separate cases. Five of the cases were generated by doubling the value-added component of each of the five energy supplying sectors separately. The sixth case involved doubling the value-added components of all energy supplying sectors simultaneously. All material inputs were assumed to remain constant.

Doubling value-added corresponds to doubling the labor, depreciation, and profits of a sector. This form of price change was used because both pollution abatement and scarcer resources tend to have their greatest impacts on the capital (depreciation) and labor costs (value-added) of a particular sector. A 1964 estimate by International Research and Technology ([25], p. V-6) stated that these two items accounted for over 67% of the annual costs associated with air pollution control. Whether limestone scrubbing will change this estimate appreciably is not clear, but our assumption of changes only in the value-added component of energy prices should be a reasonable approximation. The calculations assume that twice as much capital and labor must be used by the energy industries to produce the same output as presently.

The results of the price change calculations are presented in Figures 4.8 through 4.13. Some conclusions that can be drawn from these figures are:

FIGURE 4.8

SIGNIFICANT (1% OR GREATER) PRICE RISES CAUSED BY DOUBLING THE VALUE ADDED OF COAL

	Sector	Percentage Price Rise[2]	Long-term Change in Household (PCE) Purchases[3]	Household (PCE) Purchases as % of Total[4]
7	Coal Mining	71.3%	-15.8%	2.3%
42	Cement, Hydraulic	1.1	-1.9	0.0
45	Primary Steel	1.4	-0.5	1.3
86	Electric Utilities	2.8	-0.6	29.5

1 See text for definition of value-added and the calculation procedure

2 If x_i is the % price rise and p_i is the old price then the new price $P_i^1 = (X_i/100+1)P_i$.

3 Calculated using the University of Maryland's [ ] long-term residential price elasticities. See text for discussion

4 This column indicates what percentage Household (PCE) purchases of each sector's goods are of the total output (sales) at that sector.

FIGURE 4.9

SIGNIFICANT (1% OR GREATER) PRICE RISES CAUSED BY DOUBLING THE VALUE ADDED OF CRUDE OIL AND NATURAL GAS

	Sector	Percentage Price Rise[2]	Long-term Change in Household (PCE) Purchases[3]	Household (PCE) Purchases as % of Total[4]
2	Other Farm Products	1.1%	-0.4%	9.5%
8	Crude Oil and Natural Gas	57.1	0.0	0.0
17	Fabric, Yarn, Thread Mills	1.1	0.0	6.2
26	Paper & Allied Products	1.0	-0.2	9.5
29	Industrial Chemicals	2.6	0.0	0.7
30	Fertilizers	1.4	-0.2	1.8
31	Agriculture & Misc. Chemicals	2.2	-0.0	4.3
32	Plastics & Synthetic Material	1.6	-0.4	0.1
34	Paints and Products	1.2	-0.5	1.1
35	Petroleum Refining	17.5	-2.6	40.2
36	Paving Mixtures	7.1	0.0	0.0
37	Asphalt Felts, Coatings	5.1	0.0	0.0
42	Cement, Hydraulic	1.3	-2.3	0.0
47	Iron & Steel Forgings	1.1	-0.4	0.0
48	Primary Non-Ferrous Metal	1.2	-0.1	0.0
79	Local Passenger Transportation	1.4	-0.1	66.7
80	Truck Transportation	1.1	-0.6	22.3
82	Air Transportation	2.2	-0.8	37.5
86	Electric Utilities	1.0	-0.2	29.5
87	Gas Utilities	13.1	0.0	25.3
88	Water & Sanitary Services	1.2	0.0	39.7
100	State & Local Government Enterprises	1.2	0.0	9.9

See Figure 4.14 for all footnotes

FIGURE 4.10

SIGNIFICANT (1% OR GREATER) PRICE RISES CAUSED BY DOUBLING THE VALUE ADDED OF OIL

	Sector	Percentage Price Rise[2]	Long-term Change in Household (PCE) Purchases[3]	Household (PCE) Purchases as % of Total[4]
2	Other Farm Products	1.1%	-0.2%	5.0%
29	Industrial Chemicals	2.1	0.0	0.6
30	Fertilizers	1.1	-0.2	1.8
31	Agriculture & Misc. Chemicals	1.7	-0.0	4.3
32	Plastics & Synthetic Materials	1.3	-0.3	0.1
34	Paints & Products	1.0	-0.4	1.0
35	Petroleum Refining	28.9	-2.7	40.1
35	Paving Mixtures	7.2	0.0	0.0
37	Asphalt Felts, Coatings	5.1	0.0	0.0
79	Local Passenger Transportation	1.4	-0.1	66.7
80	Truck Transportation	1.0	-0.6	22.3
82	Air Transportation	2.3	-0.8	37.5

See Figure 4.14 for all footnotes

FIGURE 4.11

SIGNIFICANT (1% OR GREATER) PRICE RISES CAUSED BY DOUBLING THE VALUE ADDED OF NATURAL GAS

	Sector	Percentage Price Rise[2]	Long-term Change in Household (PCE) Purchases[3]	Household (PCE) Purchases as % of Total[4]
6	Non-Ferrous Metal Mining	1.1%	0.0%	0.0%
9	Stone & Clay Mining	1.0	-0.3	1.2
10	Mineral Mining	2.0	-0.5	0.0
17	Fabric, Yarn, Thread Mills	1.0	0.0	6.2
25	Pulp Mills	1.8	-0.9	0.0
26	Paper & Allied Products	1.6	-0.3	9.5
29	Industrial Chemicals	2.5	0.0	0.6
30	Fertilizers	1.7	-0.3	1.8
31	Agriculture & Misc. Chemicals	1.4	-0.0	4.3
32	Plastics & Synthetic Material	1.5	-0.4	0.1
34	Paints & Products	1.0	-0.4	1.1
35	Petroleum Refining	1.2	-0.1	40.1
36	Paving Mixtures	1.3	0.0	0.0
37	Asphalt Felts, Coatings	1.3	0.0	0.0
41	Glass & Glass Products	2.3	0.0	5.1
42	Cement, Hydraulic	4.6	-8.0	0.0
43	Lime	2.8	-4.9	0.0
44	Stone & Clay Products	2.1	-1.3	3.1
45	Primary Steel	2.5	-0.8	0.1
46	Iron & Steel Foundries	1.6	-0.5	0.0
47	Iron & Steel Forgings	2.8	-0.9	0.0
48	Primary Non-Ferrous Metal	2.0	-0.2	0.0
50	Metal Containers	1.2	0.0	0.0
86	Electric Utilities	2.2	-0.5	29.5
87	Gas Utilities	60.7	0.0	25.3
88	Water & Sanitary Services	1.9	0.0	39.7
100	State & Local Government Enter-Prises	2.0	0.0	9.9

See Figure 4.14 for all footnotes

FIGURE 4.12

SIGNIFICANT (4% OR GREATER) PRICE RISES CAUSED BY DOUBLING THE VALUE ADDED OF ELECTRICITY

	Sector	Percentage Price Rise[2]	Long-term Change in Household (PCE) Purchases[3]	Household (PCE) Purchases as % of Total[4]
5	Ferrous Metal Mining	5.0	0.0	0.0
6	Non-Ferrous Metal Mining	6.1	0.0	0.0
7	Coal Mining	4.9	-1.1	2.3
9	Stone & Clay Mining	4.9	-1.5	1.3
26	Paper & Allied Products	4.4	-0.8	9.5
45	Primary Steel	4.7	-1.5	0.1
46	Iron & Steel Foundries	4.4	-1.4	0.0
47	Iron & Steel Forgings	4.8	-1.6	0.0
48	Primary Non-Ferrous Metal	7.0	-0.6	0.0
86	Electric Utilities	78.6	-16.8	29.5

See Figure 4.14 for all footnotes

FIGURE 4.13

SIGNIFICANT (5% OR GREATER) PRICE RISES CAUSED BY DOUBLING THE VALUE ADDED OF ALL ENERGY FUELS

	Sector	Percentage Price Rise[2]	Long-term Change in Household (PCE) Purchases[3]	Household (PCE) Purchases as % of Total[4]
5	Ferrous Metal Mining	7.5%	0.0%	0.0%
6	Non-Ferrous Metal Mining	8.8	0.0	0.0
7	Coal Mining	77.3	-17.2	2.3
8	Crude Oil & Natural Gas	59.3	0.0	0.0
9	Stone & Clay Mining	7.5	-2.3	1.2
10	Mineral Mining	6.5	-1.6	0.0
17	Fabric, Yarn, Thread Mills	6.3	0.0	6.2
25	Pulp Mills	6.1	-3.2	0.0
26	Paper & Allied Products	8.1	-1.5	9.5
29	Industrial Chemicals	11.2	0.0	0.7
30	Fertilizers	8.2	-1.2	1.8
31	Agriculture & Misc. Chemicals	8.5	-0.2	4.3
32	Plastics & Synthetic Material	7.4	-1.9	0.1
34	Paints & Products	5.6	-2.2	1.0
35	Petroleum Refining	59.2	-5.6	40.1
36	Paving Mixtures	18.7	0.0	0.0
37	Asphalt Felts, Coatings	14.2	0.0	0.0
41	Glass & Glass Products	5.7	0.0	5.1
42	Cement, Hydraulic	14.5	-25.5	0.0
43	Lime	8.2	-14.4	0.0
44	Stone & Clay Products	7.2	-4.5	3.1
45	Primary Steel	9.9	-3.2	0.1
46	Iron & Steel Foundries	7.4	-2.4	0.0
47	Iron & Steel Forgings	10.0	-3.3	0.0
48	Primary Non-Ferrous Metal	11.5	-0.9	0.0
50	Metal Containers	5.1	0.0	0.0
79	Local Passenger Transportation	5.3	-0.4	66.7
82	Air Transportation	5.6	-2.1	37.5
86	Electric Utilities	85.0	-18.2	29.5
87	Gas Utilities	74.8	0.0	25.3
88	Water & Sanitary Services	7.5	0.0	39.7
100	State & Local Government Enter.	7.5	0.0	9.9

See Figure 4.14 for all footnotes

1. Price rises in almost all cases for non-energy supplying sectors are quite small, typically less than 1%.

2. Price rises for electricity cause larger price changes in more sectors than any other single fuel source.

3. Doubling the value-added component of all energy sectors will cause less than a 5% price rise in most other sectors.

4. Those sectors that do experience significant price rises, other than energy sectors, sell only a small percentage of their total output to Households (PCE). These are the sectors for which long-term residential (PCE) price elasticities provide little information.

These calculations also indicate which fuels are most sensitive to labor and capital charges. Electricity is the clear leader with almost a 79% price rise resulting from a doubling of value added. Coal is not far behind with 71%, followed at a distance by natural gas with 61%, and crude petroleum and natural gas mining with 57%. Refined petroleum is the lowest of the group with a 29% price rise. This is slightly higher than the price rise associated with refined petroleum caused by doubling the value added of crude oil.

On the assumption that high BTU gasified coal will be used to supplement other sources initially and that some sort of average pricing will be followed, the impact of this high cost gas can be found by examining the response of natural gas prices to doubling the value added of crude oil and natural gas mining (whose price rises by 60.7%). A 60% price rise corresponds to about 20% use of 72¢/MCF high BTU gas and 80% use of 17¢/MCF gas (19¢/MCF is the current average price paid for gas). This results in a price rise to consumers of 13%

The price changes required of most industrial products to compensate for energy price increases are quite low, simply because energy is still quite cheap relative to other commodities. Even aluminum would need only a 6% price rise to compensate for doubling the real price of electricity. What really matters is how relative prices increase and here the non-ferrous metals (including aluminum) are clearly more sensitive than the ferrous metals to the price of energy. This is the primary usefulness of the input-output approach to price changes. Government leaders and businessmen in the affected industries are quite concerned about the price of U.S. goods relative to foreign competition and relative to each other. The tables presented in this chapter, while they do not provide much information on the magnitude of the price elestic effects of energy cost increases, do lay out quite clearly the relative price sensitivities of various industrial products to energy price increases.

To be able to assess the impact on the energy supplying industries of price rises is much more difficult than calculating price changes. At the present time there is not enough data to calculate more than the minimum effect.

Chapter 5 1985 Projections

5.1 Scope

This chapter describes a series of 1985 projections that illustrate various economic impacts of different energy use growth rates and the additional impacts that might result from the introduction of coal gasification or the gas turbine topping cycle. These projections must be considered illustrative only since they were made using relatively crude assumptions. However, the conclusions that are drawn from these projections are based on a differential analysis that is quite insensitive to the exact assumptions employed. Hence the conclusions are fairly reliable.

5.2 Procedure

Three basic projections were made corresponding to high, medium, and low energy growth rates from 1980 to 1985. Medium energy use growth rate refers to a continuation of the projected 1970-80 growth rates. High and low are defined accordingly.

The starting basis for the projections was the 1980 technical coefficient matrix of the BLS (as modified to 104 order) and their 1980 final demand vector. Figure 5.1 describes the modifications to each for the high, medium and low projections. In all cases, the Istvan [27] electric utility technical coefficient vector was substituted for that of the BLS. This was done so that the relative weights of different generation processes (e.g. fossil vs. nuclear) could be varied. The BLS vector does not allow this variation. Figure 5.2 summarizes Istvan's electric utility process information. This is the only modification to the technical coefficients of the medium projection.

F I G U R E 5.1

1980-1985 MODIFICATIONS

	Low Energy	Medium Energy	High Energy
Technical Coefficients	Standard 1980 (BLS) coefficients used except (1) 1980 electric utility vector of Istvan [27] substituted for 68.01 (2) Electric conversion efficiency increased by 1.4% for all fuels[1] (3) Conversion efficiency of buses, trolleys, and taxis (65.02) increased by 1% for oil[2]	Standard 1980 (BLS) coefficients used except (1) 1980 electric utility vector of Istvan [27] substituted for 68.01 column	Standard 1980 (BLS) coefficients used except (1) 1980 electric utility vector of Istvan [27] substituted for 68.01 column (2) Industrial electric and gas usage increased 6.75%[3] (3) Industrial usage of plastics [28] and rubber [32] increased 4.5%
Initial Final Demand (GNP = $1.34 trillion in 1958 dollars)	Projection of 1980 final demand (1-4 order with 5 components) at 1970-80 growth rate of individual elements, except (1) consumption of oil, electricity, and gas reduced 6%[5] Investment recalculated (see text)	Projection of 1980 final demand at 1970-80 growth rate of individual elements Investment recalculated (see text)	Projection of 1980 final demand at 1970-80 growth rate of individual elements except (1) consumption of oil, gas and electricity increased 4% Investment recalculated (see text)

[1] Dollar based coefficients reduced by 4%.

[2] Dollar based coefficients reduced by 4%.

[3] Technical coefficients (dollar based) of all industries increased by 6.75% for electricity.

[4] Technical coefficients (dollar based) of all industries increased by 4.5% for plastics and rubber.

[5] Dollar based final demand for electricity, gas and oil reduced by 6%.

F I G U R E 5.2

ISTVAN'S ELECTRIC UTILITY

TECHNICAL AND CAPITAL COEFFICIENT INFORMATION[1]

Seven Technological Processes

- Fossil Steam Generation
- Nuclear Steam Generation
- Hydro Generation
- Other Generation
- Transmission
- Distribution
- Administration

1980 Technical Coefficients for Each Process

1980 Capital Coefficients for Each Process

1980 Suggested Relative Process Weights

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[1]Taken from [27]

The high projection increases the industrial usage of electricity, natural gas, plastics, and rubber at one half the rate of increase that BLS used for 1970-80. This was done by increasing the input coefficients of these commodities for all industries. Mathematically the rows corresponding to these supply industries in the technical coefficient matrix were multiplied by the growth factor. The low projection involved merely increasing the conversion efficiency of electric generation and of car and bus engines. The increased electric conversion efficiency corresponds to the introduction of more efficient plants (such as gas turbine topping cycles, HTGR's and other modern baseload plants) and the retirement of older plants. It represents a continuation of historical trends. The increased efficiency of auto engines, etc., represents a break with past trends. This would require either a spontaneous taxi fleet owner shift toward smaller, less gas-consuming cars or a government regulation requiring a certain minimum mileage performance on cars and buses.

The initial medium final demand projection was achieved by allowing each non-investment item of the 1980 final demand to grow by its projected 1970-80 growth rate. Figure 5.3 summarizes the final demand projection process. The investment component was then recalculated to correspond to the actual 1980-85 growth rates in total output. This was done as follows:

Let $\underline{X}_1$ = total output in 1985

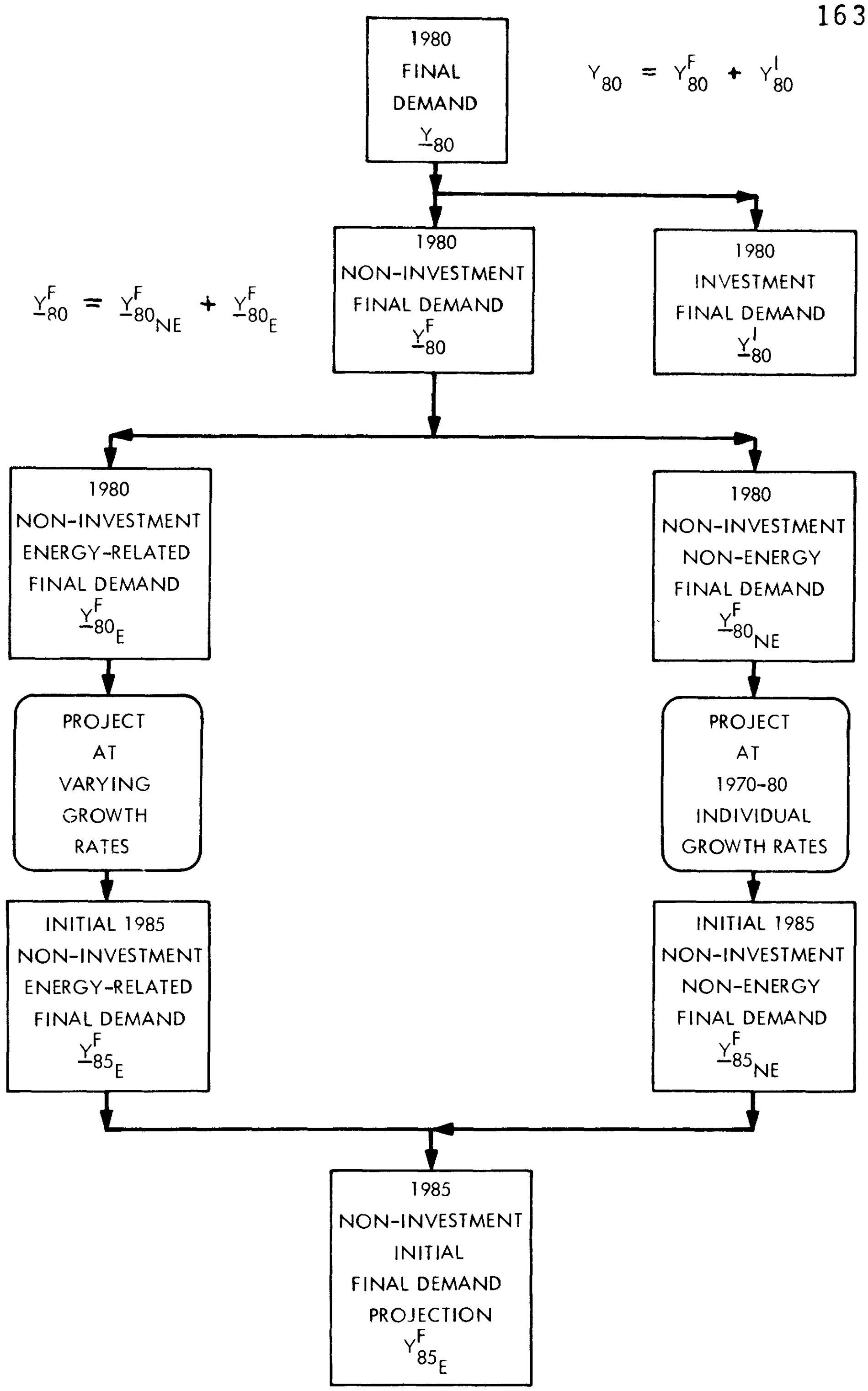
$\underline{X}_0$ = total output in 1980

$\underline{Y}_F = Y - Y_I$ = 1985 final demand less investment

$\underline{Y}_I$ = 1985 investment

$\underline{B} = (I - A)^{-1}$ = 1985 inverse coefficient matrix

$\underline{C}$ = 1980-85 capital/output matrix



1985 INITIAL FINAL DEMAND PROJECTION

FIGURE 5.3

Then $\underline{X}_1 = (\underline{I} - \underline{A})^{-1} \underline{Y} = \underline{B}\ \underline{Y} = B(Y_F + Y_I)$ (5.1)

$= \underline{B}\ [\underline{Y}_F + \underline{C}\ (\underline{X}_1 - \underline{X}_0)]$ (5.2)

Solving for $\underline{X}_1$ and $\underline{Y}_I$

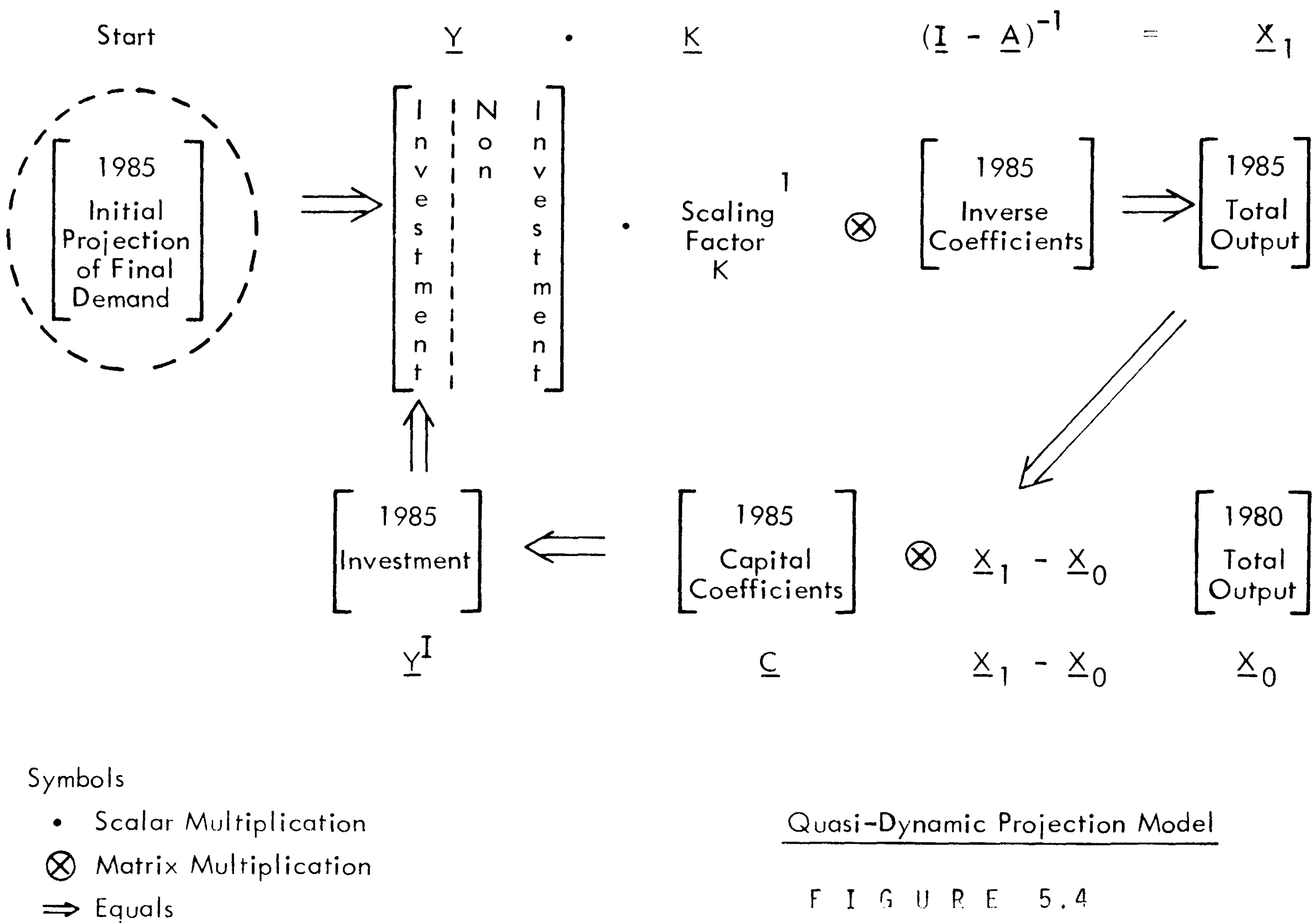
$\underline{X}_1 = [\underline{I} - \underline{A} - \underline{C}]^{-1}\ (\underline{Y}_F - \underline{C}\ \underline{X}_0)$ (5.3)

$\underline{Y}_I = \underline{C}\ (\underline{X}_1 - \underline{X}_0)$ (5.4)

This procedure was followed for all of the 1985 final demand projections. The capital matrix $\underline{C}$ used in the calculations was the projected 1975 Battelle matrix [21] modified by the substitution of the Istvan [27] 1980 electric utility vector. Since the investment component of the BLS final demand contains items other than producers durable equipment (PDE) and since the Battelle matrix $\underline{C}$ represents only PDE purchases, all other items (such as residential housing and inventory change) of investment were transferred to $\underline{Y}_F$ for the calculation procedure. See Figure 5.4 for the overall model.

The low energy growth final demand was projected the same as the medium demand case except that electricity, gas and oil consumption was reduced by 6%. This represents the effect of such changes as more efficient air conditioners and automobile engines (or smaller cars and mass transit), the use of heat pumps, and better thermal insulation. The high energy growth case was similarly projected except that electricity, oil, and gas consumption are increased by 4% over the medium case.

The first new technology modification of the high demand case involved substituting gasified coal for 5% of the total BTU production of natural gas (approximately 10% in dollar terms) and summing the weighted capital/output vectors for natural gas utilities and coal gasification. This latter convention is equivalent to the assumption that coal gasification expenditures are over and above any expenditures for



Quasi-Dynamic Projection Model

FIGURE 5.4

1 Scaling factor is chosen so that GNP = $|\underline{Y}| = \Sigma_i Y_i = \$1.34$ trillion.

pipelines, pumps, and other equipment associated with gas transmission. There is also a small amount of duplication involved but this is not expected to result in serious bias because gas wells themselves are included in a different sector. It also assumes that 25% of future gas production will come from coal gasification.

The second new technology modification involved both the above coal gasification substitution and the use of the gas turbine topping cycle (with low BTU coal gasification). Approximately 38% of the 1985 fossil generation (23% of total generation) was assumed to be the gas turbine cycle and approximately 50% of the new fossil capacity additions (or 15% of total capacity additions). Figure 5.5 summarizes these modifications.

When new capital investment requirements were calculated for each of the alternative projections and substituted for the final demand investment components, the resulting GNP did not in general equal the desired $1.34 trillion. To correct this and develop a balanced set of 1985 projections that had the proper GNP and relationship between investment and consumption, a three part procedure was used. This procedure is described in Figure 5.6 and summarized below:

1. The initial set of final demand projections was scaled to the right GNP. This scaling was done by multiplying all components of final demand by a constant factor. There was no allowance made for differing income elasticities of various sectors of PCE, such as between food and recreation. Purchases from all sectors were treated alike.

FIGURE 5.5

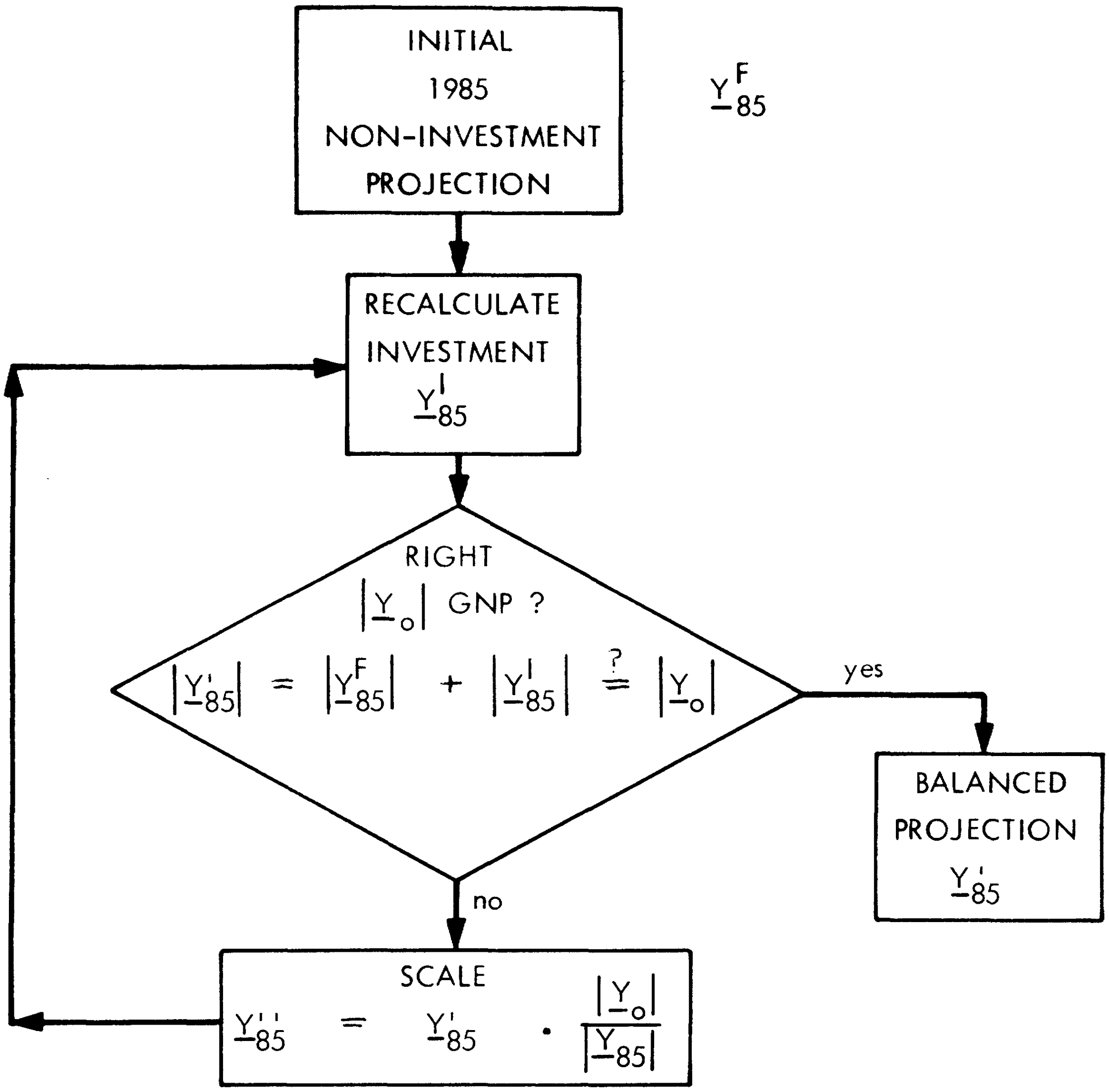
1985 NEW TECHNOLOGY MODIFICATIONS

	Capital	Operating
Hygas (Coal Gasification)[1]	25% of new capacity (gas) will be in form of coal gasification	5% of natural gas demand supplied by coal gasification
Gas Turbine Topping Cycle (combined with Low BTU coal gasification)[2]	50% of fossil generation (15% of total generation) capacity will be added in form of gas turbine topping cycle.	38% of fossil generation (23% of total generation) will be added by gas turbine topping cycle.

---

1 High + Hygas Future: High energy growth future is modified by the indicated addition of high BTU coal gasification.

2 High + Hygas + GT (Gas Turbine) Future: High energy growth future is modified by the addition of both new technologies indicated above. Note that low BTU coal gasification is used in conjunction with the gas turbine (COGAS) plant.



BALANCED 1985 PROJECTION PROCEDURE

FIGURE 5.6

2. New capital investment requirements were calculated for the scaled final demand projections of step one and substituted for its investment component. These scaled projections now had GNP's that were not equal to $1.34 trillion.[25]

3. A linear combination of the initial and the scaled projections of final demands was chosen so that, when the required capital investment was recalculated and substituted, the resulting GNP would equal $1.34 trillion. This third step can be viewed as performing interactions around the loop of the projection model indicated in Figure 5.4 until convergence is obtained. An analytical procedure accomplishes the same result with much less computer time. This procedure is discussed in the Appendices.

5.3 Issues

There are a number of issues involving capital matrices raised by the above projection procedures, other than questions of accuracy and data reliability. This section will not give definitive answers to these problems but merely indicate how they were handled in this model.

The Battelle capital matrix [21] is derived under the assumption of balanced expansion, i.e., if capacity of a particular industry must be doubled, then the expansion occurs by increasing the number of buildings, machines, parking lots, etc., uniformly, rather than just buying more machines. There are many problems associated with defining and measuring capital stocks or capital flows. These issues are avoided in the Battelle matrix by using, essentially, an engineering approach and computing what purchases are necessary to double an

25 $1.34 trillion represents 4.4% per year growth from 1950.

industry's capacity using the newest technology and ignoring what year the purchases occur in. Thus in our model, all purchases for new capacity are assumed to occur in one year. Given that the model assumes a continuation of past growth rates, such that new capacity must be added each year in larger amounts, the assumption may result in understanding actual capital investment in any one year.

The model assumes that industry always operates at 100% of capacity so that if output increases, new capacity must be added. There is no provision for reserve capacity except as it is treated in the Battelle capital/output ratios and there is no provision for changes in the average transmission distance of pipelines, etc. Because this assumption is constant over all projections and because the conclusions are based on differential effects, this is not expected to bias the answers.

Another problem which is inadequately handled by the capital matrix is depreciation and equipment replacement. Depreciation is related to the size of the capital stock, its average age, the useful lifetime of the capital items, etc. Since most of this data was unavailable, the outputs of the new capacity calculations were scaled upward by "two-thirds" to represent depreciation and replacement purchases. However, new technology purchases were not scaled upward. Thus, if the typical industry grows 4% per year, an additional 8/3% were added to its total capital purchases to represent replacement purchases. The percentage was selected because it gave approximately the same gross investment as a percentage of GNP that has occurred over the years.

A major issue that the projections deal with very crudely involves the determination of the split between consumption, investment, and government spending. The model projects consumption and government spending and then calculates the investment required to meet this demand and scales the total final demand to some constant GNP. This is not a bad procedure unless total investment is too large a percentage of GNP. When investment becomes large, consumers or government must forego spending in order to direct resources to satisfying investment demand. But the very act of foregoing spending reduces demand for goods which was the major reason for increased investment in the first place. The projections ignore changes in interest rates, fiscal policy, and the income elasticity of consumer goods. They also ignore price increases or rationing as a means of limiting demand to a given supply. With much more work than was justified for our purposes, better estimates could be made of these effects. It is hoped the economists will look at this problem in more detail in the future.

5.4 Projections

The major results of these projections will be summarized in three figures in this section. Figure 5.7 describes the basic unscaled projections that started from the same 1985 final demand with only the three energy components modified. The resulting differences in GNP are due entirely to differences in the investment required to meet the various energy growth rates. The introduction of coal gasification worsens the investment situation while the introduction of the gas turbine topping cycle helps slightly.

Figure 5.8 describes the scaled projections before investment was recalculated. All five alternative futures now result in a constant GNP of $1.34 trillion (1958 dollars). Also the differences in energy use are much less significant now. The differences have been reduced so much that the large variations in investment are no longer justified.

FIGURE 5.7

SUMMARY OF ALTERNATIVE 1985 FUTURES

	Basic Unscaled Projection			High Plus Hygas	High+ Hygas + Gas Turbine
	Low	Medium	High		
GNP (10^9 $ 1958)	$1296.3	$1321.1	$1394.9	$1421.4	$1404.8
PCE (% of GNP)	72.5%	71.1%	67.3%	66.1%	66.8%
Investment (%)	14.3	15.7	20.2	21.5	20.5
Government (%)	14.2	13.9	13.2	13.0	13.1
Total Output (10^9 $ 1958)					
Coal Mining	$ 4.8	5.0	5.4	6.8	6.8
Plumbing, Structural Metals	16.5	17.7	21.5	23.2	22.3
Engines & Turbines	7.0	7.3	8.5	8.8	8.7
Construction Equipment	7.7	9.8	16.9	19.2	17.6
Private Employment (10^6)	96.0	97.6	103.1	104.8	103.6
Energy Use (10^{15}BTU)					
Coal	20.3	20.9	22.9	27.6	27.3
Oil	28.8	29.4	31.1	31.6	31.2
Gas	44.7	46.0	50.3	51.2	50.3
Electricity	21.7	22.3	24.1	24.5	22.3

FIGURE 5.8

SUMMARY OF ALTERNATIVE 1985 FUTURES

	Scaled Projection			High + Hygas	High + Hygas + Gas Turbine
	Low	Medium	High		
GNP (10^9 $ 1958)	$1340.0	$1340.0	$1340.0	$1340.0	$1340.0
PCE (% of GNP)	72.5%	71.1%	67.3%	66.1%	66.8%
Investment (%)	14.3	15.7	20.2	21.5	20.5
Government (%)	14.2	13.9	13.2	13.0	13.1
Total Output (10^9 $ 1958)					
Coal Mining	$ 5.0	$ 5.1	$ 5.2	$ 6.5	$ 6.5
Plumbing, Structural Metals	17.1	17.9	20.6	21.9	21.2
Engines & Turbines	7.2	7.5	8.1	8.3	8.3
Construction Equipment	7.9	9.9	16.2	18.1	16.8
Private Equipment (10^6)	99.3	99.0	99.0	98.8	98.8
Energy Use (10^{15}BTU)					
Coal	21.0	21.2	22.0	24.4	24.4
Oil	29.8	29.8	29.9	29.8	29.8
Gas	46.2	46.6	48.3	48.2	48.0
Electricity	22.4	22.6	23.2	23.1	23.1

Figure 5.9 summarizes the result of recalculating the investment for the high BTU scaled future. As can be seen total investment drops considerably. This process of scaling and recalculating investment would converge to a balanced final demand eventually in which investment would have the proper relationship to energy demand and a given GNP level. Alternatively it could be calculated analytically. These iterations are not necessary because it is clear that investment is very sensitive to energy demand growth and to changes in the capital-output ratios that may be caused by new technology such as coal gasification. However it may be enlightening to see how a slight scaling of overall PCE with its attendant small change in energy consumption can result in a balanced GNP of $1.34 trillion. Figure 5.10 summarizes these balanced projections.

The actual total outputs and final demands by sector for all five alternative futures (both the initial projection and balanced projection) are included in the Appendices.

5.5 Sensitivity of Investment

To give some idea of the sensitivity of total output to changes in final demand, Figure 5.11 presents the column sums of $(I - A - C)^{-1}$. These column sums indicate by how much aggregate total output (i.e. the sum of all total outputs) is affected by a given dollar change in any final demand component.

Figure 5.12 weights these column sums by the projected high energy growth final demand values (scaled so that final demand sums to 100). These numbers then represent the relative effects on aggregate total output of equal percentage changes in each final demand component or alternatively of a change in the growth rate of any component.

F I G U R E 5.9

REQUIRED INVESTMENT

1985 HIGH ENERGY USE GROWTH ALTERNATIVE

PROJECTION TYPE	TOTAL INVESTMENT (GPDI) (Billions of 1958$)
Initial	281.7 (20.2%)[1]
Scaled	270.5 (20.2%)
Recalculated Scaled	45.8 (4.1%)
Balanced	234.5 (17.5%)

[1]Number in parentheses indicate total investment as a percentage of total GNP

FIGURE 5.10

SUMMARY OF ALTERNATIVE 1985 FUTURES

	Balanced 1985 Projections				
	Low	Medium	High	High + Hygas	High + Hygas + Gas Turbine
GNP (10^9 $ 1958)	$1340.8	$1340.0	$1339.0	$1340.9	$1341.0
PCE (% of GNP)	70.2%	70.0%	69.6%	69.3%	69.4%
Investment (%)	16.6	16.8	17.5	17.7	17.5
Government (%)	13.8	13.8	13.5	13.6	13.6
Total Output ($10^7$$ 1958)					
Coal Mining	$ 5.0	$ 5.1	$ 5.2	$ 6.5	$ 6.6
Plumbing, Structural Metals	18.2	18.5	19.3	20.0	19.7
Engines & Turbines	7.5	7.6	7.9	8.0	8.0
Construction Equipment	11.1	11.5	12.5	12.9	12.6
Private Employment (10^6)	99.2	99.2	99.2	99.2	99.2
Air Pollution (10^6tons)					
Particulates	48.6	49.0	50.0	50.2	50.1
Hydrocarbons	91.7	92.2	92.3	92.3	92.1
SO_2	75.2	76.1	78.2	78.2	78.2
CO	122.7	123.9	124.8	124.8	124.2
NO	30.4	31.8	32.6	32.6	32.5
Steel Usage (10^6tons)	194.0	195.0	198.1	199.6	198.6
Water Usage (10^{12}gals)					
Gross	278.1	280.6	286.7	290.2	266.5
Cooling	126.0	128.3	134.3	137.8	117.8
Energy Use (10^{15}BTU)					
Total					
Coal	24.9	25.3	26.0	28.5	28.5
Oil	43.0	43.9	44.5	44.4	44.4
Gas	46.1	46.7	48.5	48.5	48.2
Electricity	33.0	33.8	34.9	34.8	34.8

F I G U R E 5.11

SENSITIVITY OF TOTAL OUTPUTS TO UNIT CHANGES IN FINAL DEMAND

Column Sums of $(\underline{I}-\underline{A}-\underline{S})^{-1}$

1	Livestock and products	18.65840
2	Other Farm Products	14.85533
3	Forestry & Fishery Prod.	12.19288
4	Farm, Forest, Fish Services	13.51105
5	Ferrous Metal Mining	15.70643
6	Nonferrous Metal Mining	18.20599
7	Coal Mining	11.47688
8	Crude Oil and Natural Gas	14.00945
9	Stone and Clay Mining	13.96455
10	Mineral Mining	12.67214
11	New Construction	17.72350
12	Maint & Repair Construction	9.13693
13	Ordnance, Accessories	13.46187
14	Food & Kindred Products	15.93798
15	Grain Milling	16.74574
16	Tobacco Manufactures	8.81227
17	Fabric, Yarn, Thread Mills	23.81117
18	Misc. Textile Goods	19.64737
19	Apparel	14.26675
20	Misc. Fab Textile Products	19.74478
21	Lumber and Wood Products	13.52460
22	Wooden Containers	13.43886
23	Household Furniture	13.22536
24	Other Furn and Fixtures	12.90964
25	Pulp Mills	16.03960
26	Paper and Allied Products	21.87537
27	Paper Containers, Boxes	16.00166
28	Printing and Publishing	14.58542
29	Industrial Chemicals	17.44373
30	Fertilizers	18.56674
31	Agr. & Misc. Chemicals	23.41426
32	Plastics and Synthetic Material	24.00975
33	Drugs, Clng, Toilet Preps.	12.16224
34	Paints and Products	17.93840
35	Petroleum Refining	16.91321
36	Paving Mixtures	18.78841
37	Asphalt Felts, Coatings	19.01521
38	Rubber and Plastic Prods.	19.41870
39	Leather Tanning Prod.	7.98675
40	Footwear & Leather Prod.	10.65441
41	Glass & Glass Prods.	12.09027
42	Cement, Hydraulic	13.24632
43	Lime	11.80795
44	Stone and Clay Prods.	14.94532
45	Primary Steel	18.23187

F I G U R E 5.11

SENSITIVITY OF TOTAL OUTPUTS TO UNIT CHANGES IN FINAL DEMAND
Column Sums of $(\underline{I}-\underline{A}-\underline{S})^{-1}$

46	Iron and Steel Foundries	16.56320
47	Iron and Steel Forgings	21.54393
48	Primary Non-ferrous Metals	19.99780
49	Misc. Non-ferrous Metals	12.20046
50	Metal Containers	13.80157
51	Plumbing & Structural Metals	12.19877
52	Heating Equipment Exc. Elec.	13.03160
53	Screws & Metal Stampings	11.92606
54	Other Fab. Metal Prods.	12.54787
55	Engines and Turbines	10.71254
56	Farm Machinery & Equipment	11.99155
57	Construction & Mining Equipment	11.66178
58	Material Handling Machinery	13.11768
59	Metalworking Machinery	12.45534
60	Special Industry Machinery	13.14226
61	General Industry Mach.	12.50017
62	Machine Shop Products	11.33579
63	Office Comp Mach.	13.19545
64	Service Industry Mach.	12.38284
65	Refrig. Machinery	11.50376
66	Electrical Industry	14.08364
67	Household Appliances	12.92294
68	Elec. Lighting Equip,	10.83581
69	Radio, TV and Comm. Equipment	12.57507
70	Elec. Comp & Access.	13.67235
71	Elec. Mach. EQP & Supplies	12.12055
72	Motor Vehicles & Equipment	12.51066
73	Aircraft and Parts	9.49392
74	Other Transport Equipment	13.04907
75	Scientific & Control Ins.	11.57233
76	Optical and Photo Equipment	11.45626
77	Misc. Manufacturing	13.18522
78	Railroad Transportation	22.62575
79	Local Passenger Transportation	9.87313
80	Truck Transportation	10.06053
81	Water Transportation	14.17960
82	Air Transportation	10.94290
83	Misc. Transportation	34,23575
84	Communications Exc. RAD&T	24,65044
85	Radio and TV Broadcasting	15.04803
86	Electric Utilities	15.99566
87	Gas Utilities	32.72917
88	Water & Sanitary Serv.	18.08472
89	Wholesale Trade	13.07471
90	Retail Trade	11.48821

F I G U R E 5.11

SENSITIVITY OF TOTAL OUTPUTS TO UNIT CHANGES IN FINAL DEMAND
Column Sums of $(\underline{I}-\underline{A}-\underline{S})^{-1}$

91	Finance and Insurance	9.24389
92	Real Estate and Rental	4.80630
93	Hotel, Pers & Repair Serv.	16.45775
94	Business Services	13.45441
95	Research and Development	2,72724
96	Auto Repair and Service	27,04779
97	Amusements	14.15501
98	Medical and Education Serv.	16.22133
99	Fed. Government Enterprises	9.59608
100	State & Local Govt. Enterprises	7.54229
101	Imports	1.00000
102	Business Travel, Gifts	13.99725
103	Office Supplies	16.64554
104	Scrap, Secondhand Goods	1.00000

F I G U R E 5.12

SENSITIVITY OF TOTAL OUTPUTS TO PERCENTAGE CHANGES IN FINAL DEMANDS-WEIGHTED COLUMN SUMS OF $(\underline{I}-\underline{A}-\underline{C})^{-1}$

1	Livestock and Products	4.24016
2	Other Farm Products	14.44524
3	Forestry & Fishery Prod.	0.23320
4	Farm, Forest, Fish Serv.	-0.56441
5	Ferrous Metal Mining	0.56301
6	Nonferrous Metal Mining	0.64827
7	Coal Mining	0.80682
8	Crude Oil and Natural Gas	0.08703
9	Stone and Clay Mining	0.26611
10	Mineral Mining	0.25417
11	New Construction	68.52844
12	Maint. & Repair Const.	8.81534
13	Ordnance, Accessories	9.39001
14	Food & Kindred Products	112.24187
15	Grain Milling	6.48835
16	Tobacco Manufacturers	5.27951
17	Fabric, Yarn, Thread Mills	4.38415
18	Misc. Textile Goods	5.06492
19	Apparel	32.42346
20	Misc. Fab. Textile Products	5.79106
21	Lumber and Wood Prods.	1.20031
22	Wooden Containers	0.05730
23	Household Furniture	8.42636
24	Other Furn & Fixtures	1.77864
25	Pulp Mills	1.42266
26	Paper & Allied Prods.	8.47561
27	Paper Containers, Boxes	0.46497
28	Printing & Publishing	10.69535
29	Industrial Chemicals	7.59621
30	Fertilizers	1.08858
31	Agr. & Misc. Chemicals	3.77434
32	Plastics & Synthetic Material	5.27936
33	Drugs, Clng, Toilet Prep.	18.38039
34	Paints and Products	0.25631
35	Petroleum Refining	27.57567
36	Paving Mixtures	0.01059
37	Asphalt Felts, Coatings	0.01584
38	Rubber & Plastic Prods.	9.49042
39	Leather Tanning Prods.	0.04246
40	Footwear & Leather Prods.	3.04775
41	Glass & Glass Prods.	0.78309
42	Cement, Hydraulic	0.01018
43	Lime	0.00298
44	Stone & Clay Prods.	1.40699

F I G U R E 5.12

SENSITIVITY OF TOTAL OUTPUTS TO PERCENTAGE CHANGES IN FINAL DEMANDS-WEIGHTED COLUMN SUMS OF $(\underline{I}-\underline{A}-\underline{C})^{-1}$

45	Primary Steel	1.78862
46	Iron and Steel Foundries	0.14493
47	Iron and Steel Forgings	0.06218
48	Primary Non-ferrous Metal	1.13659
49	Misc. Non-ferrous Metals	0.58775
50	Metal Containers	0.04848
51	Plumbing & Structural Metal	0.70032
52	Heating Equipment Exc. Elec.	0.28390
53	Screws & Metal Stampings	1.73025
54	Other Fab Metal Prods	2.51447
55	Engines & Turbines	2.53056
56	Farm Machinery & Equipment	1.37445
57	Construction & Mining Equipment	2.43193
58	Material Handling Machinery	0.72524
59	Metalworking Mach.	1.07645
60	Special Industry Mach.	1.17531
61	General Industry Mach.	1.19933
62	Machine Shop Products	0.34495
63	Office Comp Mach.	5.72519
64	Service Industry Mach.	0.47415
65	Refrig. Machinery	1.28910
66	Electrical Industry	2.35941
67	Household Appliances	10.23641
68	Electric Lighting Equipment	1.31911
69	Radio, TV & Comm. Equipment	22.13908
70	Electric. Comp & Access.	3.82029
71	Elec. Mach Equip. & Supplies	2.09359
72	Motor Vehicles & Equip	40.81441
73	Aircraft & Parts	8.59172
74	Other Transport Equip.	5.32102
75	Scientific & Control Ins.	4.23872
76	Optical & Photo Equip.	3.54419
77	Misc. Manufacturing	14.45973
78	Railroad Transportation	14.37457
79	Local Passenger Transportation	5.87717
80	Truck Transportation	7.55813
81	Water Transportation	7.09230
82	Air Transportation	5.11922
83	Misc. Transportation	2.88323
84	Communications Exc. RAD&T	45.59076
85	Radio & TV Broadcasting	0.21022
86	Electric Utilities	22.63258
87	Gas Utilities	22.95432
88	Water & Sanitary Serv.	4.18774
89	Wholesale Trade	58.75487
90	Retail Trade	112.48943
91	Finance and Insurance	26.96211

F I G U R E 5-12

SENSITIVITY OF TOTAL OUTPUTS TO PERCENTAGE CHANGES IN FINAL DEMANDS-WEIGHTED COLUMN SUMS OF $(\underline{I}-\underline{A}-\underline{C})^{-1}$

92	Real Estate and Rental	61.56100
93	Hotel, Pers & Repair Ser.	37.64803
94	Business Services	10.67370
95	Research and Development	0.18202
96	Auto Repair and Service	23.53889
97	Amusements	8.80626
98	Medical & Education Serv.	102.43959
99	Federal Govt. Enterprises	2.43741
100	State and Local Govt. Enterprises	1.40059
101	Imports	-5.26911
102	Business Travel, Gifts	0.0
103	Office Supplies	2.00924
104	Scrap, Secondhand Goods	-0.00215

The unweighted components vary from a low of 4.8 for Real Estate (ignoring summary industries) to a high of 34.2 for Miscellaneous Transportation (primarily pipelines). Gas utilities have about twice the impact of petroleum refining or electric utility on a dollar per dollar growth basis. The variation of weighted sums is much greater than that of the unweighted sums. The negative sum for Forestry and Fishery Products is simply explained by the fact that the government sells these products and hence the final demand entry is negative. New Construction is seen to have the fourth highest value on a weighted basis. This is the key to the high sensitivity of investment to changes in capital intensive industries. Capital purchases by such industries have a high percentage of construction in them and a high dollar value. The resulting large change in construction activity has a very large effect on aggregate total output. This in turn requires more expansion and more construction etc.

Figure 5.13 summarizes the investment sensitivity of the Medium BTU projection to 4% changes in the final demand consumption of the three energy sources. Each change was computed separately. Note that a 4% change corresponds to different dollar amounts for the three cases.

FIGURE 5.13

INVESTMENT SENSITIVITY TO CHANGES IN FINAL ENERGY DEMAND[1]
(1985 Medium Projection)

	$\frac{\Delta \text{ Investment}}{\Delta \text{ Energy Demand}^{2}}$	$\frac{\Delta \text{ Total Output}^{3}}{\Delta \text{ Energy Demand}}$
Electricity[4] (4%)	6.7	16.6
Natural Gas (4%)	11.5	28.2
Petroleum	6.7	17.8

$$\Delta \text{ Total Output} = |\underline{X}| = |[I - A - C]^{-1} Y|$$

$$\Delta \text{ Investment} = \Delta |\underline{Y}_{-1}| = |\underline{C} \; \Delta \; \underline{X}|$$

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[1] See text for explanation.

[2] Change in final demand component of indicated energy sector

[3] Change in the sum of total outputs of all sectors ($\Delta \Sigma X_i = \Delta |\underline{X}|$)

[4] Calculated by using a 4% increase in final demand of each fuel separately.

Chapter 6: Conclusions and Recommendations

6.1 Conclusions

Capital expenditures for new energy technology are going to have their greatest effect on the makers of boilers and pressure vessels (BEA sector 40.06) since all of the technologies that have been discussed require either high pressure vessels or boilers or both. Engines and Turbines (BEA sector 43.0) will also get a significant boast from the increasing number of turbo-generator units that must be installed. Depending upon whether the gas turbines used in the topping cycle are purchased from the Engines and Turbine sector of the economy or from the Aircraft Parts, either or both of these sectors will receive an extra spurt of investment from the combined cycle plants that may be built.

All of the new technologies require significant amounts of steel, but the major crunch will occur in the manufacturing sectors that must transform the steel into other components such as pressure vessles. Pollution effects and employment changes caused by these capital expenditures are comparatively minor although the regional impact of the construction of these plants may be significant.

The major operating impacts of these plants are on the coal mining industry and, in the case of the electric generation plants that burn char, on the limestone and lime producing industries (if this form of SO_2 control is chosen). These particular effects are likely to be much more pronounced on the regional level because both the coals and the limestone are comparatively high-volume, low-value materials and hence cannot be shipped long distances. Water usage for the various coal gasification processes represents very heavy consumptive use of this water. This again could have some regional impact but not a significant national impact. The major problem here of course is that coal gasification represents an actual consumptive use of water; it is not merely heated and returned to the stream--the water is actually changed chemically and becomes part of the methane output of the gas plants. Energy usage will increase a bit more rapidly as the conversion losses of coal gasification come into play. Air pollution will increase as a result of the operation of the coal gasification plants, decrease as a result of the use of coal gasification to feed electric generation plants instead of coal and will increase relative to the emissions of natural gas wells themselves.

The procedure illustrated in Chapter 2 to derive capital and operating coefficients for new technologies is perhaps deceptively simple. Appendices C through H hopefully dispell the notion of simplicity from this derivation. Conceptually it is quite clear what needs to be done, but the practical implementation of the scheme is much more difficult.

Perhaps the most important results of this study are:

1. Total capital investment is very sensitive to changes in the energy use growth rate and to the introduction of new energy technology:
2. It is also sensitive to very slight changes in the growth rate of total personal consumption expenditures and government spending; and
3. Another feedback mechanism between the demand for investment funds and the interest rate has been identified. The traditional mechanism views an increase in interest rate as causing marginally profitable projects to become unprofitable and hence total investment falls. The new mechanism notes that an increase in interest rate will induce people to

save more money with the result that consumption cannot grow as rapidly. Hence capacity does not have to expand as fast and total investment slackens.

The introduction of high BTU coal gasification will aggravate the demand for investment funds over what it would be if natural gas were available domestically. However it may not require more investment than other available processes such as liquified natural gas or pipelines to Alaska. These processes were not investigated nor was the possibility of oil or electricity taking over part of the natural gas market. Thus the absolute numbers for the size of the impacts may not be correct, but the sensitivity statements are true.

The introduction of the gas turbine topping cycle as part of a combined gas and steam cycle for electricity generation will lessen the demand for investment funds. This will be true whether or not low BTU coal gasification is used with it. However this conclusion is sensitive to the actual efficiencies and costs that can be obtained on the second generation turbines and gas production process, and to any unforeseen problem of integrating the gas and steam cycles. Since these costs (in real dollars) are unlikely to go down and may go up, it is important to recognize that rising costs may actually reverse this conclusion.

To summarize the three major points of this study, we have demonstrated:

a. that new technology can be explicitly included within the input-output framework and this framework used for projection of future impacts

b. that input-output analysis can be used to study energy use, air pollution, employment and other variables in which we may be interested, and

c. that the major new technology economic impacts will be on investment spending.

6.2 Implications for Energy Policy

It has been shown that the major impacts of introducing coal gasification and combined gas and steam cycle plants will be on Boiler Makers and Turbogenerator Manufacturers and Coal Mining. All of these sectors will have to significantly expand their capacities over the projected 1980 levels to be able to meet the 1985 demands if new technology grows as expected. Only very slight reductions in the rate of growth of Household purchases (PCE) and/or government spending is needed to satisfy the huge investment demands of these technologies. There are many possible mechanisms, such as interest rates and taxes, that can achieve the balance between consumption, investment, and government spending.

It is therefore recommended that to insure that the expansion of manufacturing and mining capacity and the siting of the new technology plants takes place in an orderly and non-damaging (to the environment or the economy) manner. Such incentives and regulations can range from manpower training progrsms to ensure a sufficient supply of skilled heavy construction labor to requiring minimum standards of strip mine restoration to providing separate money markets for home construction financing which might be hurt by high interest rates.

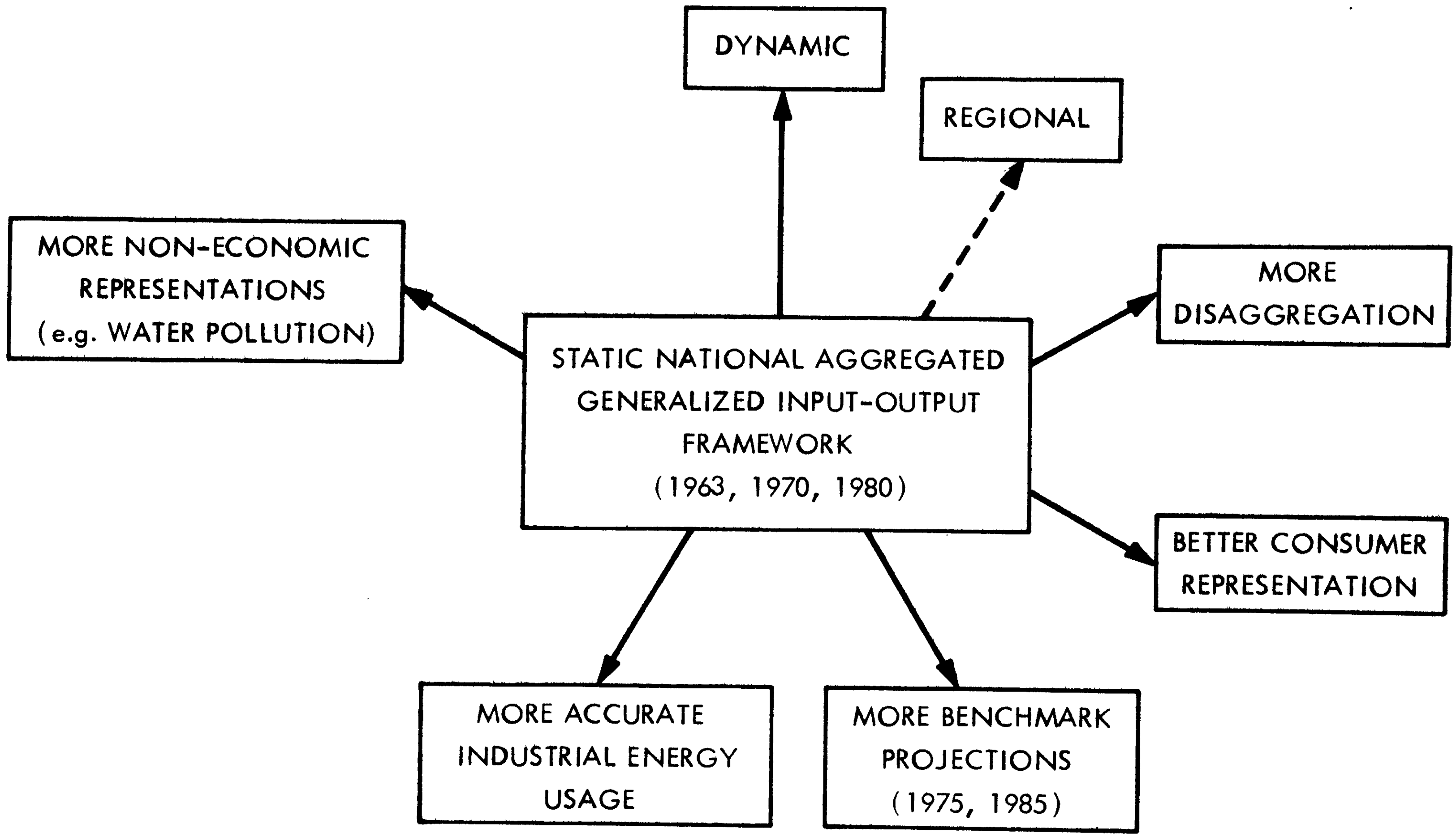
6.3 Further Research Suggestions

The limitations of the present generalized input-output model have been discussed in Chapter 2. For example, the model does not include regional representations, industrial price elasticities or consumer demand functions. The suggestions for further research are designed to overcome these limitations.

Figure 6.1 summarizes the types of development that should be undertaken. Regional and state I/O tables have become available [35, 36]. These can be used to construct a small energy oriented multiregional (e.g. 9 regions) model of the U.S. In addition, more detailed models of a particular state might be useful for certain energy and environmental impact studies. The problem with regional models is that either the number of regions or the number of sectors must be severely restricted to keep the model manageable (in terms of both costs of computation and understanding).

Better representation of consumer (PCE) behavior is badly needed. If I/O is to be useful, one must be able to predict the response of consumer spending to changes in air-conditioner efficiencies, to higher interest rates, and to other policy variables (i.e. variables that can be changed by industry or government regulations or action). Capital Stock models of energy demand may be very fruitful here.

At the national level, more disaggregation of energy-related industries (like Boiler-Makers) is needed. In some cases, this may require a study to determine the technological and capital coefficients of new industries like Nuclear Fuel Reprocessing. More new technologies should be studied such as other high BTU coal gasification processes, the high temperature gas-cooled reactor (HTGR), or shale oil extraction schemes. It should also be easy to incorporate more non-economic variables, such as water pollution, into the database.



MODEL DEVELOPMENT

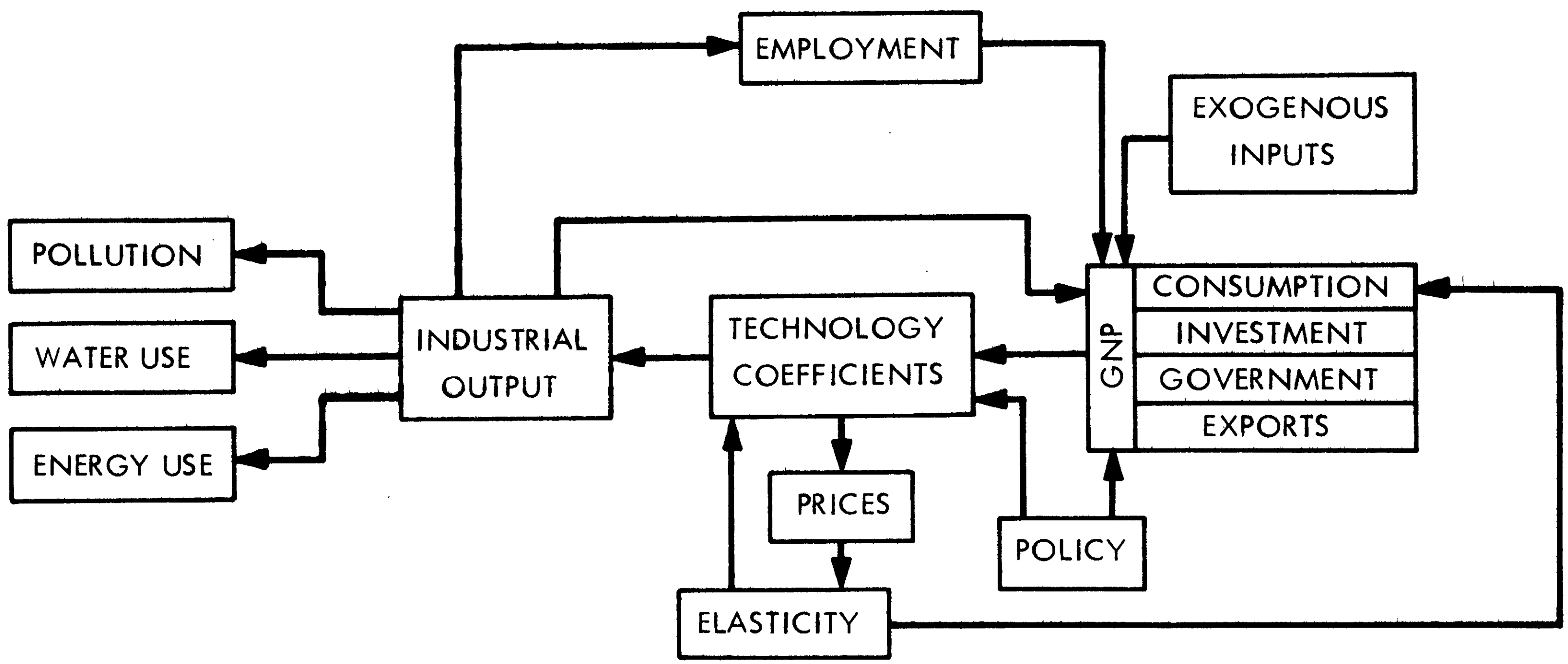
FIGURE 6.1

It is also extremely important to begin introducing industrial price elasticities into the I/O framework. If fuel prices change, not only will the technological coefficients for these fuels change but also those for competing materials like steel and aluminum will change. Since fuel prices are expected to rise and since gas supplies are not meeting demand, some mechanism for modifying the technological coefficients must be used. This can be done either with price elasticities or with engineering studies. Certainly engineering studies will be needed to predict the impacts of various pollution control technologies. Figure 6.2 illustrates one possible form of such a dynamic input-output model. Pure changes must be able to affect both industrial and personal consumption and there must be explicit policy variables, besides government spending.

To summarize, econometric and engineering techniques must be brought to bear on the input-output framework to enable it to cope with price changes, new technologies, and policy regulation. Above all, policy-makers must be encouraged and educated in the use of generalized input-output analysis. Toward this end, the next section describes several important studies that could be undertaken now.

6.4 Suggestions for Policy Studies

Generalized input-output analysis can be used as either a forecasting tool or an assessment tool. As a forecasting tool it can predict detailed electricity-usage, total sales, SO_2 emissions, etc. As an assessment tool, it can predict the economic and environmental impacts (on a large scale) of various new technologies, government spending programs, policy decisions, etc.



DYNAMIC GENERALIZED INPUT OUTPUT MODEL

FIGURE 6.2

Three specific areas have been identified that both are important from a policy decision point of view and are areas where input-output analysis can contribute uniquely. Obviously more techniques than just input-output would be needed to answer the whole question, but input-output will play the central integrating role in these studies. These areas are:

(1) Impacts of Capital Expenditures for Environmental Quality. There is a question of whether the 1975 air quality standards could be met (especially by the electric utilities) even if the technology were now available because of capacity constraints on the production of such equipment. What is the best that can be done environmentally at reasonable cost? This study would require knowledge of the production capacity of the many sectors of the economy, and the various options (like fuel switching or SO_2 control) available to meet the different levels of emissions standards. This study could be performed at the national level but regional studies would be more useful. This would entail obtaining all of the above information in regional form and the use of regional I/O tables which are now available [36].

(2) Impacts of Multiple Investment Programs (e.g. Energy and Pollution Controls). Both the government and industry have goals which entail large investment programs as in the industries attempts to meet energy demand and the government attempts to control pollution. Generalized input-output analysis is valuable for examining the combined impacts of these various programs on different sectors of the economy. This is another form of bottleneck analysis and requires information similar to that described above.

(3) Impacts of Alternative Methods of Meeting Oil and Gas Demand. Two extreme cases are possible: (a) the U.S. can rely on a massive oil and gas import program to meet its growing energy needs or (b) the U.S. can stimulate oil and gas development internally. The economy, in terms of employment and sizes of various industries, will be quite different in these two cases. A first approximation to answering these questions could be obtained by ignoring the effects of any price changes in oil or gas products and focusing on the different final demands and industrial structures that might result.

These are important questions and the techniques developed in this study can help to answer parts of them. More research is needed to expand the applications of generalized input-output analysis, but hopefully this report has shown that there is a value to such research.

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A P P E N D I C E S

Appendix A Data Sources

The estimated 1980 input-output coefficients and final demands were obtained from the Bureau of Labor Statistics (see [51]). These numbers were published at 86 order. Various manipulations on this data, which are described in Reference 29, were performed to disaggregate the data to 104 order. Reference 51 describes the exact procedure used to perform the 1980 projections. Basically GNP was projected by using labor force and labor force productivity. Then the 1958 input-output table was projected to 1980 using 1965 as an intermediate reference year. Readers are referred to [51] for more information.

The air pollution coefficients for 1967 and the improved 1980 coefficients were obtained from International Research and Technology (see Reference 25). These coefficients were derived as part of a two-step process. The first step estimated air pollution coefficients from heat and power generation within the particular industry. The second stage estimated pollution coefficients from industrial processes within each particular sector. These coefficients were usually derived by looking at the major process used within the industry and assuming that all sectors or all sub-industries of that industry used that process. Therefore these coefficients may not be completely representative of the actual pollution of each sector: however, they should be reasonably close. Unless an extremely detailed industry by industry method is used, it is unlikely that any of these coefficients will be closer than perhaps a factor of 2 of the real number. In addition, the study mentioned did not consider any air pollution from mining sectors other than that of coal refuse fires, nor any pollution resulting from service sectors. These were not judged to be serious deficiencies.

Energy use coefficients were derived in a multi-step process. First, 1963 actual energy flows in BTU's for coal, crude oil, refined petroleum, natural gas and electricity were obtained from a Battelle Memorial Institute report (see Reference 37). Next, the BTU flows within each individual sector were compared to the dollar flows in the 1963 input-output table to yield a BTU per dollar coefficient. These coefficients were then applied to the projected constant dollar 1980 input-output table. By applying these conversion coefficients directly to the 1980 technical coefficient matrix one was able to obtain a BTU per dollar of output coefficient. In the near future it should be possible to do an even better job of projecting energy flows because Oak Ridge National Laboratories is preparing 365 order energy flows for the 1963 matrix. Battelle's work was done at 40 order.

An analagous procedure was used to derive steel use coefficients. First, the steel usage by the various sectors was obtained from the Census of Manufacturers and Census of Mining for 1963. This was supplemented by information from the Annual Statistical Report of the American Iron and Steel Institute. Reference 29 describes in more detail the derivation of these coefficients and provides similar information for the derivation of gross water usage and cooling water usage coefficients. Gross water usage is in this case defined as the total water required if no re-circulation were used. Thus it does not correspond to water intake figures. The consumptive use of this water is usually a few percent of the gross figure.

Employment coefficients were derived from the Bureau of Labor Statistics projections that went along with their 1980 input-output projections. Reference 51 provides more information on these coefficients.

The price elasticities of consumer demand for various products was obtained from the University of Maryland Inter-Industry Forecasting Project. This work is documented in References 1, 2 and 3.

Appendix B Some New Energy Technologies[26]

B-1 Gas from Coal

Gaseous fuels have many desirable properties and the market for such fuels seems quite large in the future, even at prices significantly above their current costs (natural gas at the wellhead sells for about 26¢/MMBTU average transport costs, and to customers for 36¢ to $1.00/MMBUT while liquified natrual gas will cost in the neighborhood of $1.00/MMBTU at the ports). However natural gas is in short supply at the moment. Even the vast reserves of the North Slope of Alaska will probably amount to less than two year's total domestic consumption of natural gas ([18], p. 3). While some of the problems associated with the lack of discoveries of natural gas can be laid at the foot of its artificially maintained low price, there are many who doubt that much more natural gas will be found even at higher prices. However, geological evidence indicates that there are still substantial quantities to be found in the contiguous U.S. Alaska may ultimately yield a ten to twenty supply, but that will not be available for some time. Where is the additional gas to come from in the short term.

One obvious source is to import it, whether by pipeline from Canada or Mexico or by LNG tanker from the Middle East, where it is just flared for lack of a market, or even from the U.S.S.R. Figure B.1 summarizes the world's production and reserves in map-format. It also indicates the location of the world's giant gas fields by rank. To what extent it

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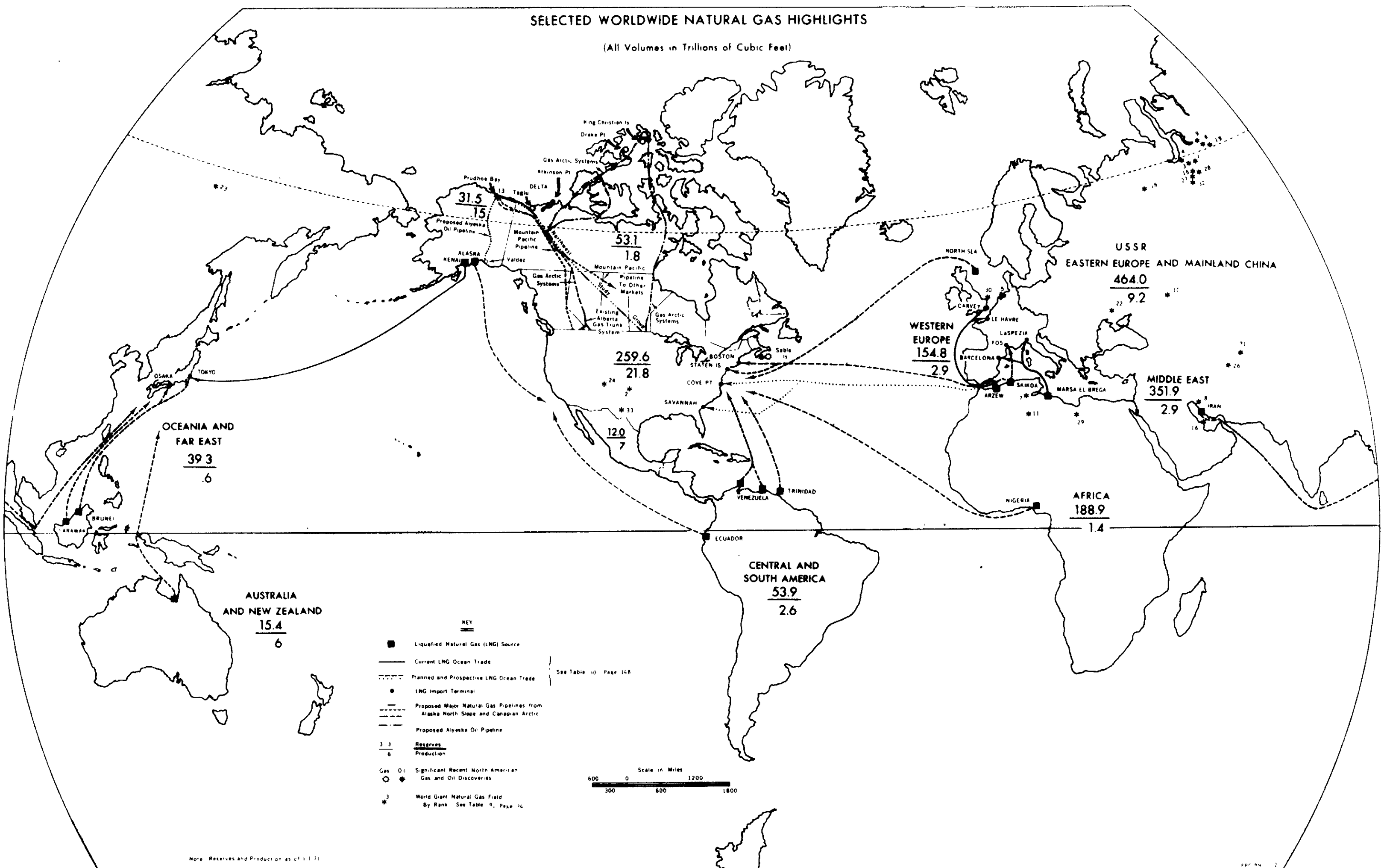
26 Much of the material for this chapter is drawn from two excellent publications, Energy Research Needs [38] and New Energy Technology [23].

FIGURE B.1



Source: [18], p. 4

will be national policy to depend on overseas sources for much of our energy supplies is uncertain. Much of Europe and certainly Japan does already depend on foreign supplies almost completely. There is an economic choice to be made. How much is the U.S. willing to pay to remain domestically self-sufficient for natural gas or oil? Figure B.2 summarizes the FPC's estimates of natural gas imports.

The alternative strategy is to gasify other fossil fuels, in particular coal or oil. Coal gasification seems most likely to arrive first although naptha is being gasified now. Technology for producing a low-BTU gas (about 450 BTU/ft^3) exists now. By catalytically methanating it (not commercially proven yet), one can achieve a pipeline quality gas. On August 19, 1971 El Paso Natural Gas Company announced its plans to construct such a facility in New Mexico, near 900 million tons of recoverable coal that El Paso acquired. First deliveries from this plant are expected in 1976 at a cost of $0.85 to $1.10 per thousand cubic feet. (Mcf)

There are many technologies being developed for the production of both low BTU and high BTU gas from coal. Two of these technologies will be discussed next.

B.2 Hygas-Electrothermal

The Institute of Gas Technology (IGT) has been developing a process known as the Hygas Electrothermal process. This is illustrated in Figure B.3. The main units are a two stage, fluidized bed hydrogasifier and an electrothermal, fluidized bed synthesis gas generator. Caking coal is pretreated by partial devolatilization in another fluidized bed reactor to solve the caking problem (if lignite is used, this step is not needed). This coal is then mixed with a light oil (e.g. benzene) and pumped as a slurry to the drying bed, (also fluidized).

FIGURE B.2

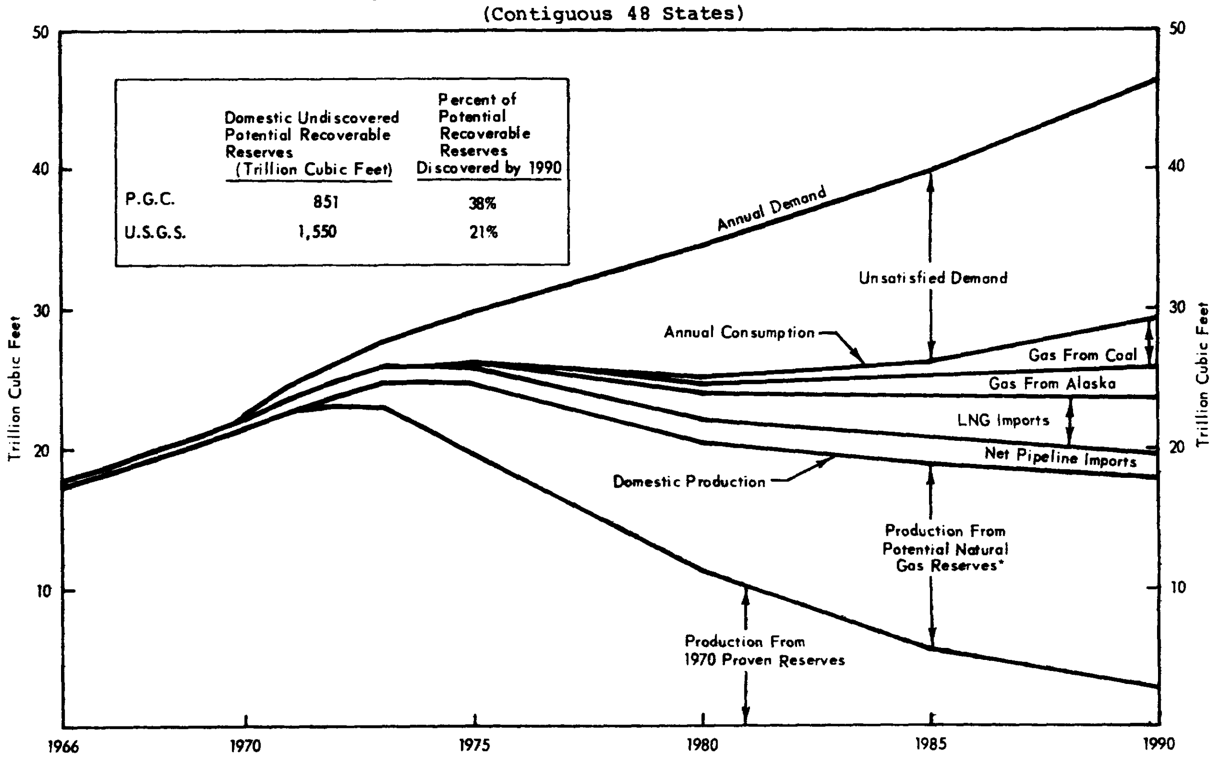
FPC NATURAL GAS ESTIMATES

UNITED STATES GAS SUPPLY-DEMAND BALANCE
Actual 1966-1970; Projected 1971-1990
(All Volumes in Trillions of Cubic Feet @ 14.73 Psia and 60° Fahrenheit)

Year	Annual Demand 1/	Net Pipeline Imports	LNG Imports	Gas From Coal	Gas From Alaska	Gas From Liquid Hydrocarbons	Domestic Production	Annual Consumption	Un-Satisfied Demand	Reserve Additions	Year-end Reserves	R/P Ratio
1966	17.9	0.4	-	-	-	-	17.5	17.9	0.0	19.2	286.4	16.4
1967	18.8	0.5	-	-	-	-	18.4	18.8	0.0	21.1	289.3	15.8
1968	19.9	0.6	*	-	-	-	19.3	19.9	0.0	12.0	282.1	14.6
1969	21.3	0.7	*	-	-	-	20.6	21.3	0.0	8.3	269.9	13.1
1970	22.6	0.8	*	-	-	-	21.8	22.6	0.0	11.1	259.6	11.9
1971	24.6	0.9	*	-	-	-	22.8	23.7	0.9	12.0	248.8	10.9
1972	26.1	1.0	*	-	-	**	23.8	24.8	1.3	13.0	238.0	10.0
1973	27.7	1.1	*	-	-	**	24.7	25.8	1.9	14.0	227.3	9.2
1974	28.8	1.1	*	-	-	**	24.8	25.9	2.9	15.0	217.4	8.8
1975	29.8	1.2	0.3	-	-	**	24.7	26.2	3.6	16.0	208.7	8.4
1980	34.5	1.6	2.0	0.3	0.7	**	20.4	25.0	9.5	17.0	186.1	9.1
1985	39.8	1.9	3.0	1.4	1.3	**	18.5	26.1	13.7	17.0	175.4	9.5
1990	46.4	1.9	4.0	3.3	2.3	**	17.8	29.3	17.1	17.0	170.4	9.6
1971-1990 Totals	707.6	31.1	38.0	17.3	20.6	**	414.2	521.2	186.4	325.0	-	-

* Very small volumes
** Insufficient data for quantitative projection: unsatisfied demand will be reduced by the amount of SNG actually produced.
1/ Contiguous 48 states.

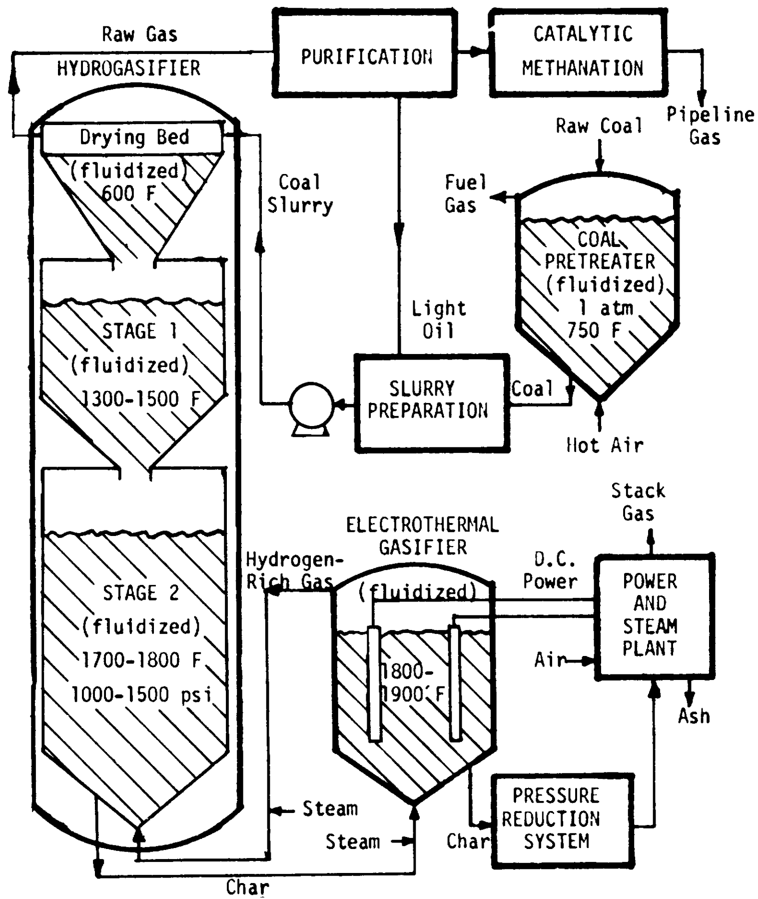
UNITED STATES GAS SUPPLY-DEMAND BALANCE
(Contiguous 48 States)



*U.S. Natural Gas Reserve Additions (1971-1990) Total 325 Trillion Cubic Feet.

Source: [18] p, 3.

FIGURE B.3



Hygas-Electrothermal Process for Making Pipeline Gas from Coal

Source: [23] p. 111.

The problem of feeding solids into a high pressure vessel is usually solved with a slurry or with pressurized lock hoppers. The slurry method is preferred but there are durability problems with the slurry pumps.

"Hydrogasification is carried out in two stages, with gases and solids passing countercurrent to each other between stages. In the first stage, a low-temperature reactor acts as a concurrent transport reactor in which fresh lignite reacts with the hot effluent from the second-stage hydro-gasifier. The latter is a fluidized bed in which char from the first stage reacts with steam and 1900° F raw synthesis gas, which is produced in the electrogasifier fueled by spent hydrogasifier char.

The electrogasifier is also a fluidized-bed reactor, with steam as the gasifying medium for the spent char. Resistance heating is supplied by electric current passing through the fluidized bed. The hot, spent char is transferred into this vessel, and the synthesis gas goes directly to the hydrogasifier. The use of synthesis instead of hydrogen for hydrogasification of lignite has been successfully demonstrated in the pilot plant.

In the hydrogasifier 53% of the carbon in the lignite feed is gasified. In the electrogasifier 18.3% is converted to synthesis gas. The electrogasifier residue, containing 82.7% of the feed carbon, together with all the ash, is used as fuel for power and high-pressure process steam in the MHD-steam power section." ([42], p. 2)

It should be added that the electrogasifier residue will contain about 25 - 50% of the sulfur in the original coal (essentially all of the non-organic sulfur and none of the organic sulfur). The residue will be burned at the power station. Low sulfur lignite will not present much of an emissions problem, but high sulfur bituminous coals may require extensive stack gas cleaning equipment at the power station. In fact the major problem with the published Hygas reports is that little or no provision is made for stack gas cleaning equipment, waste water treatment, or even sulfur recovery. The report contains the somewhat glib statement that revenues from the sale of sulfur will cover the cost of equipment needed for sulfur recovery. The other problems are not addressed at all. Since the Hygas process is the one selected for use in this report, some correction had to be made for this oversight. This correction is discussed in Appendices C and D. It basically consisted of adding SO_2 scrubbers, cooling towers, and water pollution control facilities.

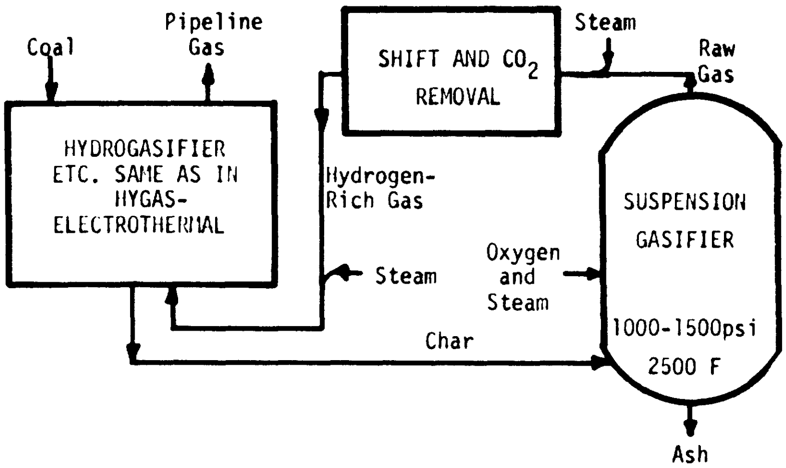
To give some idea of the size of the proposed 500 million cubic feet per day plant, it consumes as much coal as four 1000 MW electric generation plants. It processes as much energy per day as a very large 120,000 barrel per day refinery. (The largest oil refinery in the U.S., Humble Oil's Baytown, Texas refinery, has a 345,000 barrel per day capacity and consists of four crackers.) The electric generation plant needed to heat the gasifier produces 750 MW, 90% of which is consumed by the gasifier above.

The Hygas process is the most advanced of all the processes. A 1.5 million cubic feet/day pilot plant is operating in Chicago. This project, which is supported by the Office of Coal Research and the American Gas Association (AGA) uses both Montana lignite and Illinois high volatility bituminous coal. In addition, the AGA is supporting both a preliminary engineering study for a one-third to one-sixth commercial size demonstration plant and a study to identify potential coal gasification sites in the U.S.

A variant of the Hygas-Electrothermal process is known as the Hygas-Oxygen process. It replaces the electrothermal hydrogen source with a fluidized-bed synthesis gas generator. The synthesis gas is then passed through a hydrogen purification system. This process is illustrated in Figure B.4. IGT is quite interested in this process as the economics look slightly better than those for the Hygas-Electrothermal process. The possible difficulties include the fact that a 750 MW generation plant is well with the state of the art of construction techniques, but an oxygen plant of the proper size may not be.

FIGURE B.4

HYGAS-OXYGEN PROCESS FOR MAKING PIPELINE GAS FROM COAL



Source: [23], p. 115

In this case the Hygas-Oxygen process is not as bad off as some of the other gasification processes (e.g. Bigas) because it adds oxygen in a separate reactor and hence requires less.

B.3 Low BTU Coal Gasification

The first question to be answered is why anyone would be interested in a low BTU gas anyway. The answer lies in the combined economics of production, transportation, and utilization technology for gas. Low BTU gas can be produced more cheaply per BTU than high BTU gas, but it costs more per BTU to transport. In addition, extensive modifications must be made to burners that are designed for natural gas (high BTU content) if they are to burn low BTU gas efficiently. Thus if the gas can be used at or near the point of gasification (e.g., in large industrial plants), low BTU gas may have an economic advantage. However, if it must be shipped long distances to small consumers, then high BTU gas is a necessity.

Note that if the large user happens to be an electric utility, then the cost of electrical transmission to the load centers must be weighted against the costs of shipping a higher cost high BTU gas to the load center. Two other factors weigh very heavily on the economics of large scale electric utility use of low BTU gas at minemouth. The first of these is the 1975 air quality standards. The Federal government set up sulfur emission standards for new generation plants and required the states to devise implementation plans (including emission standards for old generation plants) to achieve certain specified ambient air quality standards. Many states responded by setting the same emission standards for old generation plants as the Federal government had specified for new ones.

Since it is much easier to remove concentrated H_2S from gasified coal (either with high or low BTU gas) than to remove dilute SO_2 from stack gases, the coal gasification industry had a foot in the door. In fact, desperate utility executives have taken it upon themselves to push low BTU coal gasification. Commonwealth Edison is reported to be building a pilot plant now for such a process.

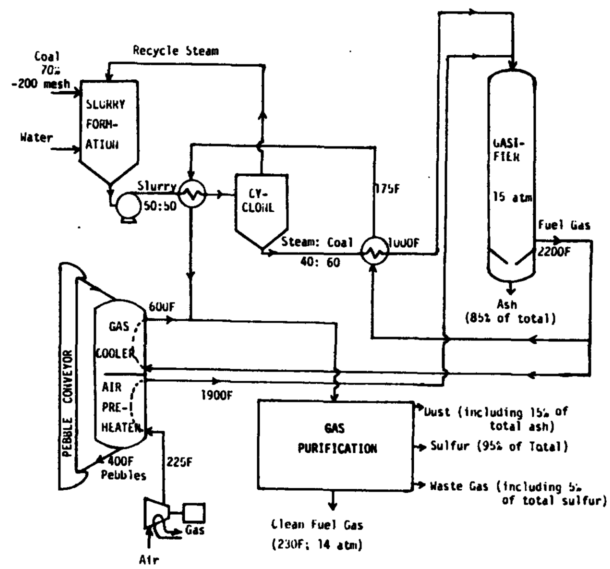
The second factor giving impetus to low BTU coal gasification is the possibility of using a gas turbine topping cycle before the conventional steam cycle. This combined cycle is capable of an efficiency of 47% [39] using current technology, as opposed to the current best figures of 39%. Part of the reason for these high efficiencies is that the gas turbine topping cycle benefits greatly from having a large volume of hot, high pressure gas as a fuel and that is exactly what a low BTU coal gasification plant puts out.

Since the dominant costs in the first generation Lurgi low BTU gasification process are the gasifiers (a large number of which are required because of low reaction rates), the second generation plant reduces the gasifier cost by using high temperature, high pressure, entrained flow, slagging gasifiers that yield higher reaction rates per unit volume. The major savings results from the higher temperatures. Since 2500^{0} F. is above the ash-fusion temperature of the coal, a fluidized bed scheme is necessary.

The United Aircraft report [39] states that the costs of second generation equipment for most processes is almost identical and they choose for illustration the Texaco partial oxidation process with a moving pebble bed heat recovery system and hot carbonate sulfur scrubbing system. This is the process used in the calculations in this report. Investment comparisons between this second generation process and the Lurgi process are given in Appendices E and F. Figure B.5 illustrates

FIGURE B.5

CLEAN FUEL GAS FROM COAL USING TEXACO PARTIAL OXIDATION GASIFIER, HOT-GAS HEAT EXCHANGER, AND GAS PURIFICATION SYSTEM (ROBSON, GIRAMONTI, LEWIS AND GRUBER, 1970)



Source: [23], p. 154

pictorially what the Texaco process will be like. Figure B.6 compares the cost per million BTU of the two processes.

The Texaco process operates by preparing a coal-water slurry and using pressure and heat to form a steam-coal mixture. This mixture is preheated and injected along with preheated air into the gasifier. Approximately 95% of the coal is gasified during the 3-second residence, and about 85% of the ash trapped as slag on the walls. Because of the high temperatures, the slag will flow out of the bottom of the reactor into a pool of water. Satisfactory refractory life under these harsh conditions has yet to be demonstrated. Another technical hurdle is the use of pebble bed heat exchangers with an ash bearing gas. The principle reason for using a pebble bed heat exchanger is to avoid using a special alloy metal (which would be required at these high temperatures) for the heat exchanger. However, the high temperatures will fuse the ash and cause problems in the pebble bed. Perhaps in 10 years this problem will be overcome.

There are, of course, many other possible low BTU gas processes. In particular, most of the high BTU coal gasification schemes could be adapted to such use by eliminating the catalytic methanation, using air for oxygen, operating at lower pressures, or making other modification. Some thought has been given to modifications of both the Bigas and Hygas processes for this purpose.

B.4 The Gas Turbine Topping Cycle

The United Aircraft report [39] discusses five variations of combined gas steam cycle electricity generation. These are:

FIGURE B.6

COST OF ONE MILLION BTU OF CLEAN SYNTHESIS GAS

(Cents/Million BTU)

	Lurgi First Generation Process	Texaco Partial Oxidation Process[2]
Coal cost	26.0[1]	23.0[3]
Gasification & cleaning cost	31.7	17.6
Total cost without sulfur credit	57.7	40.6
Credit for sulfur at $25 long ton	3.0	3.0
Total cost with sulfur credit	54.7	37.6

1 Represents 1.30 x 10^6 BTU coal input. Only 1.0 x 10^6 Btu of the input energy in the coal is contained in the final product. The other 0.30 x 10^6 Btu represents the heat loss of the system. The cost of this loss is 6.0 cents/ million Btu at the assumed coal cost of 20 cents/million Bt. (The above figures are based on gasification efficiency of 77 percent).

2 Since this is a second-generation process, perhaps ten years in the future, costs will undoubtedly have changed by the time it is in operation. Coal costs are likely to be higher and sulfur value less. Costs are presented here on a basis consistent with those shown for the first-generation process for comparative purposes.

3 Represents 1.149 x 10^6 Btu coal input.

Source: [39], p. V-37, V-42.

1) exhaust fired, where the turbine exhaust is funneled into a steam boiler to burn more fuel.
2) waste heat recovery, in which the steam boiler runs off the turbine exhaust alone,
3) conventional supercharged,
4) gas generator supercharged, and
5) two-pressure supercharged.

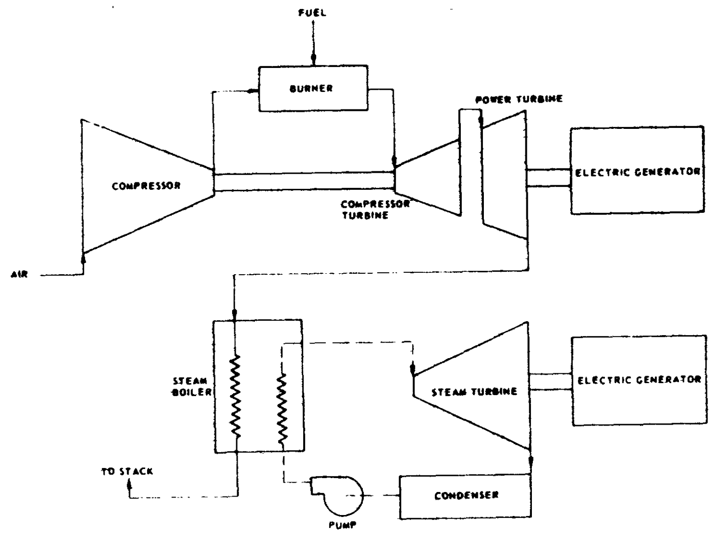
These five were examined in differing degrees of detail, but enough to establish superiority of the waste heat recovery scheme as technology improves (in particular, as allowable turbine inlet temperatures increase). The waste heat recovery system is diagrammed in Figure B.7. The major characteristics of the three generations of combined cycle systems is illustrated in Figure B.8.

The astounding efficiencies are due in part to the high volume of hot high-pressure low BTU gas delivered by the gas plant. The pressurization cost shows up in the fuel price but the advantage shows up in the generator efficiency. If natural gas, or other high BTU fuel, were substituted for the low BTU, the efficiency would drop 2.0 to 2.5%. But raising the fuel temperature 100^{0} F. would increase the efficiency by almost 1%. ([38], p. V-66.)

Part load operation was not studied, but Hottel [23] estimates the drop in efficiency at 80% of its full load value for half load operation. This is becoming increasingly important, since the more efficient a plant becomes, the less useful it usually becomes for part-load operation. In trying for the utmost in performance, more and more parameters must be kept constant. Unfortunately, some utilities are discovering that lots of cheap baseload capacity is fine, but they still have to meet the peak load. In the future, of course, this may

F I G U R E B.7

WASTE HEAT RECOVERY COGAS SYSTEM



Source: [39] p. 333

F I G U R E B.8

PROPOSED COGAS POWER SYSTEMS

Generation	(1970) I	(1980) II	(1990) III
Number of gas turbines.............	3	2	2
Turbine inlet temperature..........	$2,200^{\circ}$F	$2,800^{\circ}$F	$3,100^{\circ}$F
Compressor pressure ratio..........	8	12	20
Precent airflow bled for cooling...	4.7%	8.5%	9.0%
Turbine exhaust temperature........	$1,297^{\circ}$F	$1,514^{\circ}$F	$1,485^{\circ}$F
Compressor-turbine overall length..	33 ft.	27 ft.	26 ft.
Single steam turbine, of size......	431 mw	381 mw	312 mw
Stack temperature..................	314°F	219°F	241°F
System efficiency[1].................	47.0	54.5	57.7
Total capital cost (millions)......	$109.3	$94.0	$89.3

[1]Electric generator losses and auxiliary power requirements not included. Multiply by 0.96 for net efficiency.

Source: [23], p. 281

be done with pumped storage facilities, especially since the "discovery" of underground pumped storage possibilities.

Figure B.9 summarizes the capital and operating costs of an integrated gas plant-electric generation station and compares these with conventional first and second generation steam plants. Costs for a base-load gas turbine plant are also included for comparison. The major savings result from a smaller boiler, less accessory electric equipment and shorter construction time (less escalation and interest).

COST SUMMARY FOR FIRST-GENERATION AND SECOND-GENERATION, COAL FIRED POWER STATIONS

	First-Generation			Second-Generation		
	Steam[1]	Gas Turbine	COGAS	Steam[1]	Gas Turbine	COGAS
Net Power Station Output Mw	1,012	891	918	1,012	910	945
Capital Investment, $1000						
Power System	176,953	77,514	109,261	162,674	60,874	94,005
Fuel Processing System		51,500	44,500		32,000	26,300
Total Station	176,953	129,014	153,761	162,674	92,874	120,305
Net Capital Cost, $/Kw	174.8	144.8	167.5	160.7	102.0	127.3
Annual Owning and Operation Cost mills/kwhr						
Capital Charges[2]	3.990	3.306	3.824	3.668	2.330	2.906
Operation, Supplies, and maintenance						
Power System	0.372	0.786	0.623	0.322	0.767	0.626
Fuel Processing System[3]		0.900	0.700		0.340	0.270
Fuel @ 20¢/million Btu	1.865	2.990	2.170	1.768	1.990	1.440
Busbar Power Cost	6.227	7.982	7.317	5.758	5.427	5.242

[1]Does not include sulfur oxide emission control equipment

[2]Capital charges @ 14¢ per annum @ 70% load factor.

[3]Includes credit for sulfur.

Source: [39], p. 415, 416.

FIGURE B.9

Appendix C Derivation of HIGAS Capital Investment Coefficients

The primary sources of data for this derivation the Cost Estimate of a 500 Billion BTU/Day Pipeline Gas Plant Via Hydrogasification and Electrothermal Gasification of Lignite [42] and Electrothermal Hygas Process Escalated Costs [43]. These books contain detailed equipment lists and costs estimates for an actual Hygas plant. They are still relatively crude engineering studies in that many equipment items are left out and only rough plant layouts are given. The costs are also calculated assuming that the process is actually feasible as planned.

The IGT Hygas process was chosen because it is the furthest along of any of the high BTU processes and is actually at a pilot plant stage. The pilot plant has not run for more than one week continuously at the present time (July 1972). There are still many engineering problems to be solved. However a one-sixth scale demonstration plant is currently undergoing preliminary engineering design by Procon Inc. for IGT. The results of this study are not publicly available now. It is not certain when, or if, it will be available. Consequently some estimation had to be used on the unknown factors in the construction of this plant.

The two major unknowns involved the electrical generation part of the Hygas plant and the air and water pollution control sections of the plant. The reason the former is an unknown is that the original report [42] proposed to use an MHD power system that will just not be available for many years. The second report [43] updated the costs from 1968 to 1971 prices and replaced the MHD system with a conventional steam electric system, fired by the spent char from the gasification part of the plant. However, it did not give a detailed equipment list for the new electrical generation section of the plant. A report by Bechtel [5] for coal fired steam electric generation plants was used to correct this.

The second major uncertainty, pollution control, exists because there is no provision for it, at all, in either of the two reports. Informal communications with the IGT staff and some rough rules of thumb were used to close this gap somewhat.

Figure C.1 illustrates the original IGT estimate. Figure C.2 shows the new estimates. These new estimates were arrived at by multiplying the original gas-plant equipment investment by 1.09 and adding to that the cost of the new power system. The inflation factor of 1.09 is derived from the Nelson "true cost" index and Chemical Engineering magazine's monthly plant cost index. Both of these inflation factors take into account increases in productivity, otherwise the inflation factors would be much higher (6.9% inflation per year instead of 4.4% per year). The problem was now to get all estimates in the same 1970 dollars. Figure C.3 illustrates the on-site conventional steam generation plan.

First the actual 1968 equipment lists for all sections of the plant except the MHD generator were used to derive dollar amounts for each I/O category for this part of the plant. Figures C.4 through C.11 describe this equipment and show what standard BEA 86 order category it was assigned to. Note that the sector numbers are in BEA categories, not in sector numbers that correspond to the model used in the report. Catalyst and packing costs were subtracted from the total equipment costs and allocated separately.

INVESTMENT SUMMARY

500 Billion Btu/Day Pipeline Gas from Lignite

Section	Process Equipment, $	Bare Cost, Installed, $
Lignite Storage and Reclaiming	1,710,000	3,420,000
Lignite Grinding and Drying	5,864,000	11,728,000
Slurry Preparation	1,652,700	4,958,000
Hydrogasification	35,681,700	68,887,000
Prepurification I	4,767,200[1]	8,340,000
CO Shift	1,913,500[2]	3,587,000
Prepurification II	4,130,100[3]	7,888,000
Methanation, Drying	4,117,500[4]	6,706,000
Offsite Equipment	--	86,144,000
Subtotal, Bare Cost		201,658,000
Contractor's Overhead and Profit		15,588,000
Subtotal		217,246,000
Interest During Construction, 5% of Subtotal		10,862,000
Total Fixed Investment		228,108,000
Working Capital		7,085,000
Total Capital Investment		235,193,000

[1] Includes $121,500 tower packing

[2] Includes $240,000 initial catalyst charge.

[3] Includes $372,000 tower packing plus initial zinc oxide and carbon.

[4] Includes $1,811,000 initial catalyst charge.

Source: [42], p. 64

F I G U R E C.1

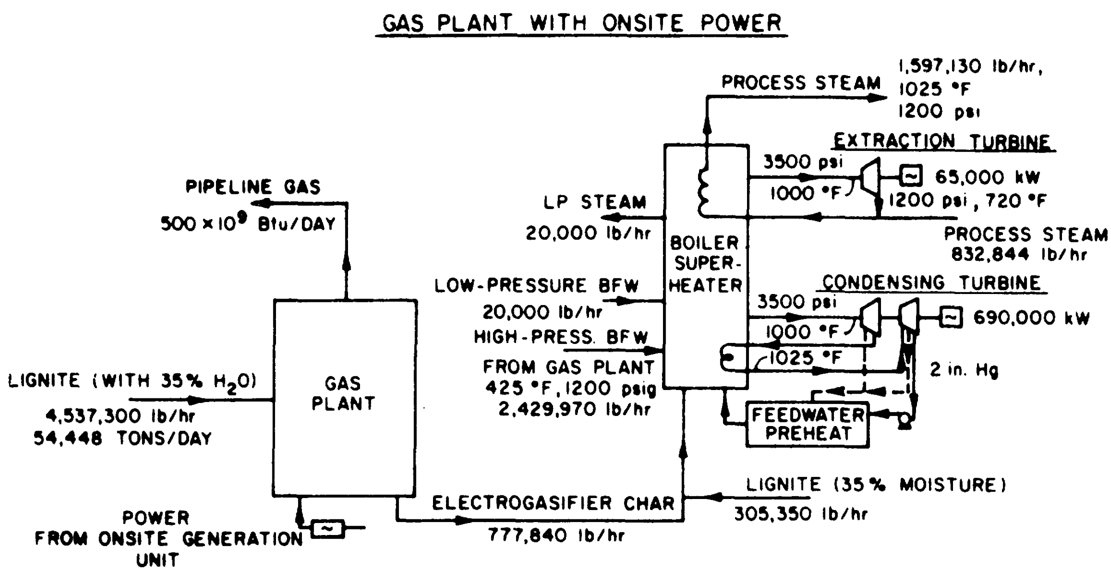
ESCALATED INVESTMENTS FOR HYGAS PROCESS USING ONSITE CONVENTIONAL STEAM-DRIVEN GENERATORS

Coal	- N. Dakota Lignite -	
Plant Capacity, 10^9 Btu/day	500	
Electric Power Source	-Onsite-	-Purchased-
Installed Cost, $\$10^6$		
Gas Plant	136.07	152.0*
Power Plant	117.52	--
Subtotal	253.59	152.0
Total Investment, Base, Case, $\$10^6$	304.8	186.5
$\$/10^6$ Btu per day	610	373

*Includes boiler for process steam.

Source: [43], p. 9.

FIGURE C.2



PLANT UTILITY SUPPLY FOR 500 BILLION Btu/DAY PIPELINE GAS FROM LIGNITE BY ELECTROTHERMAL HYGAS PROCESS

Source: [43], p. 6.

FIGURE C.3

FIGURE C.4

SECTION 100 – LIGNITE STORAGE AND HANDLING EQUIPMENT SUMMARY

Equipment	Equipment No.	Description	No. Required	Cost/Unit, $	Total Equipment Cost, $	BEA Sector Number
Feed Hopper	B-101	30-min supply (1159 tons) 40 ft long x 40 ft wide x 30 ft high, 1/2 in. thick, 60° slope of bottom cone	2	55,000	110,000	40
Feed Conveyor	G-101	60-in. belt conveyor, 2318 tons/hr, 600 ft/min, 300 hp, 250 ft c to c, 110 ft rise	2	100,000	200,000	46
Distributor Conveyor	G-102	60-in. belt conveyor 2318 tons/hr, 600 ft/min, 375 hp, 1850 ft c to c horizontal with tripper	2	400,000	800,000	46
Recovery Conveyor	G-103	48-in. belt conveyor, 1159 tons/hr, 500 ft/min, 150 hp, 2000 ft c to c 40 ft rise, 375 hp	2	270,000	540,000	46
Recovery Feeder	G-104	Rotary plow, 1159 tons/hr, 2000-ft track	2	30,000	60,000	45
				Total	$1,710,000	

Source: [42] 1, p. 15.

FIGURE C.5

SECTION 200 – LIGNITE GRINDING AND DRYING EQUIPMENT SUMMARY

Equipment	Equipment No.	Description	No. Required	Cost/Unit, $	Total Equipment Cost, $	BEA Sector Number
Crusher Feed Hopper	B-201	600-ton capacity hopper, 1/2-hr residence time, 35 ft x 35 ft x 20 ft x 1/2 in. thick: 60° slope of bottom cone	2	39,000	78,000	40
Grinder-Dryer Feed Hopper	B-202	600-ton capacity feed hopper, 1/2-hr residence time, 35 ft x 35 ft x 20 ft x 1/2 in. with 6-60° cones	2	45,000	90,000	40
Crusher	D-201	Precrusher hammer mill to crush 5 in. x 0 mined lignite to 1-1/2 in. size, 1159 tons per hour capacity, 500 hp motor	2	50,000	100,000	45
Grinder-Dryer	D-202	Williams 100-in. roller mill dryer to grind and dry 1.5 in. lignite at 35% moisture to −10 + 100 size at 13% moisture, 189 tons per hour of feed to give 135 tons per hour of product	12	433,000	5,196,000	45
Crushed Lignite Conveyor	G-201	Tube conveyor, 30-in. tube, 48-in. belt, 500 ft/min, 100 hp motor-driven, 1135 tons per hour feeds G-202	2	50,000	100,000	46
Grinder-Dryer Distribution Conveyor	G-202	48-in. belt, 300 ft c-c, 450 ft/min with 6 tripping stations, 100 hp motor-driven, includes tripper	2	90,000	180,000	46
Ground Lignite Conveyor	G-203	Tube conveyor, 16-in. tube, 24-in. belt, 500 ft/min, 40 ft rise 100 ft c-c, 50-hp motor driven, 269 tons per hour	6	20,000	120,000	46
				Total	$ 5,864,000	

Source: [42], p. 18

FIGURE C.6

SECTION 300 — SLURRY MAKEUP AND FEEDING EQUIPMENT SUMMARY

Equipment	Equipment No.	Description	No. Required	Cost/ Unit, $	Total Equipment Cost, $	BEA Sector Number
Lignite Feeder and Feed Hopper	B-301	18 in. x 36 in. rotary air lock feeder with gear motor 1-1/2 hp, 2 required for each feed hopper	12	4,650	55,800	45
		Feed hopper, 50 tons capacity each, 15 ft x 15 ft x 10 ft, 1/4 in. thick	6	8,500	51,000	40
Slurry Makeup Tank	B-302	15 ft ID x 20 ft high baffled tank, 10 psig, 415 tons/hr, 15 min residence time	6	12,000	72,000	40
Slurry Holdup Tank	B-303	25 ft ID x 30 ft high, baffled tank, 10 psig, 1245 tons/hr, 30 min residence time	2	23,000	46,000	40
Slurry Makeup Mixers	D-301	Turbine agitator & hydraulic driver, 150 hp, mixer from Pfaudler	6	25,000	150,000	45
Holdup Suspension Mixers	D-302	Turbine agitator with hydraulic driver 150 hp, mixer from Pfaudler	2	25,000	50,000	45
Slurry Transfer Pump	H-301	Centrifugal slurry pump with motor drive; 200 hp, 1280 gpm or 415 tons/hr Allis-Chalmers 16 x 14 x 21 in.	6 +1 spare	5,900	41,300	49
Slurry Recirculation Pump	H-302	Centrifugal slurry pumps with motor drive, 200 hp, 1280 gpm or 415 tons/hr Allis-Chalmers 16 x 14 x 21 in.	12 + 2 spares	5,900	82,600	49
Slurry Feed Pumps	H-303	Constant speed reciprocating slurry pumps with motor driver, 640 gpm, 7 to 1300 psig, Wilson Snyder single-acting triple x plunger surge pump, 700 hp, motor drive	8 + 2 spares	70,100	701,000	49
Slurry Feed Pumps	H-304	Variable speed, reciprocating slurry pumps, with driver 640 gpm, 7 to 1300 psig, Wilson Snyder single-acting triple x plunger surge pump, 700-hp motor drive	4 + 1 spare	80,600	403,000	49
				Total	1,652,700	

Source: [42] , p. 20

F I G U R E C.7

SECTION 400 – HYDROGASIFICATION INCLUDING ELECTRO-THERMAL GASIFIER, QUENCH TOWER, AND LIGHT OIL RECOVERY EQUIPMENT SUMMARY

Equipment	Equipment No.	Description	No. Required	Cost/ Unit, $	Total Equipment Cost, $	BEA Sector Number
Light Oil Vaporizer	A-401	Fluidized bed contactor, 22.17 ft shell ID x 24 ft OD x 54 ft tan to tan, 3-in. lightweight insulation plus 4-in. hardface refractory lining, 21 ft refractory ID, 1500°- 625°F, 1100 psig	4	--	--	
Hydrogasifier (Low-Temperature Reactor)	A-402	Cocurrent lift reactor; 10 ft shell ID x 11 ft OD overall dimensions with 4-ft lift line, internal paths plus fill insulation, 1500° - 1700°F, 1105 psig.	4	--	--	
Hydrogasifier (High-Temperature Reactor)	A-403	Fluidized bed zone, 25.5-ft shell ID x 27.5-ft OD x 45-ft tan to tan, 8-in. lightweight insulation plus 4-in. hardface refractory lining, 23.5 ft refractory ID, 1700° - 1900°F, 1110 psig	4	--	--	
		Combined cost of vessels A-401, A-402, A-403	4	4,420,000	17,680,000	40
Electrogasifier	A-404	Free fall section, 24 ft shell ID x 26-ft OD x 50-ft tan to tan, 8 in. light weight insulation plus 4 in. hardface refractory lining, 22 ft refractory ID, 1900°F, 1115 psig, cost includes electrodes immersed in fluidized bed for heat input at $850,000	4	2,840,000	11,360,000	40 / 53
Quench Tower	A-405	14-ft 4-in. ID x 77-ft tan to tan x 7-in. thick wall containing 63-ft packed bed of 3-1/2-in. plastic pall rings, 2,985,000 lb/hr water flow rate, 1090 psig, gas cooled down from 625° to 100°F, water heated from 90° to 250°F.	4	887,000 (vessel)	3,660,000*	40 / 36
Tar-Oil-Water Separator	A-406	30-ft OD x 52-ft tan to tan wide x 1-in. wall thickness, 25-ft liquid space, 5-ft gas dome, 1/2-hr. residence time, 250°F, 1085 psig	4	227,000	908,000	40
Oil Settling Tank	B-401	8 ft-OD x 15-ft tan to tan wide x 3/8-in. wall thickness, 15-min residence time, 115°F, 0 psig	1	6,000	6,000	40
Recycle Water Settling Tank	B-402	15 ft OD x 48 ft tan to tan wide x 3/4-in. thick, 10-min residence time, 250°F, 15 psig	4	33,000	132,000	40
Quench Water Cooling Tower	D-401	Cools 23,882 gpm of quench tower water from 250° to 90°F, wet bulb temp 75°F	1	500,000	500,000	40
Light Oil Cooler	E-401	Light oil 250° to 115°F, 50 psig, cooling water 85° to 115°F, 50 psig, total duty 71.188 X 10^6 Btu/hr area/unit = 7000 sq ft	1	25,300	25 300	40
High-Pressure Boiler Feed water Makeup Pump	H-401	3125-gpm, 0 to 25 psig, 60°F, 60-hp motor-driven centrifugal pump	1 + 1 spare	2,500	5,000	49
High-Pressure Boiler Feed water Pump	H-402	1150 gpm deaerated high-pressure boiler feed water 0 to 1300 psig, 215°F, 1200-hp motor-driven centrifugal pump	4 + 1 spare	53,000	265,000	49
High-Pressure Booster Pump	H-403	463-gpm methanation knockout, 100°F, 1000 to 1300 psig, 150-hp motor-driven centrifugal pump	1 + 1 spare	6,200	12,400	49
Low-Temperature Reactor Quench Water Feed Pump	H-404	235-gpm quench water at 100°F, 0 to 1110 psig to low-temp reactors of hydrogasifier, 275-hp motor-driven centrifugal pump	1 + 1 spare	20,500	41,000	49
Light Oil Recycle Pump	H-405	990 gpm of light oil at 115°F, 40 to 100 psig, 50-hp motor-driven centrifugal pump	4 + 1 spare	2,200	11,000	49
Quench Water Cooling Tower Recycle Pump	H-406	10,000 gpm water, 0 to 40 psig, 90°F, 920 hp, recycle mixes with 250°F quench water to give 150°F cooling tower feed, motor-driven centrifugal pump	4 + 1 spare	17,200	86,000	49
Quench Tower Cooling Water Feed Pump	H-407	2980-gpm quench water, 0 to 1100 psig, 90°F multistage centrifugal pump, 2500 hp, driven by hydraulic turbine generating 1420 hp at full load plus electric motor sized for full pumping load-2600 hp.	8 + 2 spares	73,500	735,000	49
Quench water cooling tower feed pump	H-408	6000 gpm of water, 15 to 50 psig, 200°F, 175 hp, motor-driven centrifugal pump	4 + 1 spare	10,500	52,500	49
Quench tower make-up water pump	H-409	910 gpm water, 0 to 1150 psig, 90°F, 850-hp, motor-driven centrifugal pump	4 + 1 spare	40,500	202,500	49
			Total		35,681,700	

* Includes $112,000 for packing.

Sector 53 includes 850,000 for Electrodes

Source: [42] , p. 25

FIGURE C.8

SECTION 500 – PREPURIFICATION I EQUIPMENT SUMMARY

Equipment	Equipment No.	Description	No. Required	Cost / Unit, $	Total Equipment Cost, $	BEA Sector Number
Absorber	A-501	11.5-ft ID X 46-ft tan X 5-3/8-in. thick-wall containing 36-ft packed bed of 3-1/2-in. plastic pall rings, 1115 psia, 240°F	5	158,000 (Vessel)	841,400*	40 36
Regenerator	A-502	9.5 ft-ID X 46-ft tan X 1/4 in., 25 psia, 240°F 36-ft packed bed with 3-1/2-in. pall rings	10	14,900 (Vessel)	219,100+	40 36
Hot Carbonate Circulation Pump I	H-501	4470 gpm, 30% K_2CO_3 solution, 10 to 1100 psig, 240°F, multistage centrifugal pump, stainless steel, 3700 hp; driven by hydraulic turbine generating 2010 hp at full load plus electric motor sized for full pumping load, 3700 hp	10 + 2 spares	119,000	1,428,000	49
Regenerator Condenser	E-501	Stripped acid gas 228° to 100°F, 25 psia, cooling water 85° to 115°F, 50 psig, total duty 867 X 10^6 Btu/hr, area/unit = 7600 sq ft	20	32,400	648,000	40
Knockout Drum (Before Condenser)	B-502	9-ft ID X 27-ft tan X 1/4 in., 25 psia, 230°F	10	7,400	74,000	40
Knockout Drum (After Condenser)	B-503	5.5-ft ID X 16.5 ft tan X 1/4 in., 25 psia, 100°F	10	3,800	38,000	40
Regenerator Reboiler	E-502	30% K_2CO_3 solution, 240°F, 25 psia saturated steam, 115 psia, total duty 137.25 X 10^6 Btu/hr, area/unit = 840 sq ft	10	8,900	89,000	40
Absorber Knockout Drum	B-501	4 ft-ID X 12-ft tan X 2 in., 1105 psia, 240°F	5	10,300	51,500	40
Regeneration Steam Feed Water Pump	H-502	300 gpm, 0 to 200 psig, 218°F, 60 hp	1 + 1 spare	2,500	5,000	49
Regeneration Steam Makeup Water Pump	H-503	898 gpm, 0 to 25 psig, 60°F, 25 hp, motor-driven centrifugal	1 + 1 spare	1,700	3,400	49
Regeneration Steam Condensate Pump I	H-504	1438 gpm, 8 to 25 psig, 100°F, 25 hp, motor-driven centrifugal	1 + 1 spare	2,000	4,000	49
Regeneration Steam Waste Heat Boiler	E-503	Low-pressure steam feedwater at 338°F to steam at 100 psig 338°F, methanation effluent 840° to 363°F, 1030 psig, total duty 30% K_2CO_3 solution, 719.15 X 10^6 Btu/hr, area/unit = 6500 sq ft	12	61,700	740,400	40
Regeneration Steam Waste Heat Boiler	E-504	LP steam feed water at 338°F to steam at 338°F, 100 psig, light oil vaporizer effluent from 625° to 425°F, 1095 psig, total duty 548.543 X 10^6 Btu/hr, area/unit = 6600 sq ft	8	67,000	536,000	40
Deaerator	B-504	Deaerates all plant low pressure steam feedwater	1	Cost included with all feedwater treatment		
Steam Drum	B-505	9.5-ft ID X 28.5 ft X 3/4 in., 100 psig, 338°F	3	29,800	89,400	40
				Total	4,767,200	

*Price includes $ 51,400 for 18,700 cu ft of 3-1/2-in. ceramic pall rings.
+Price includes $ 70,100 for 25,500 cu ft of 3-1/2-in. ceramic pall rings.
} Sector 36

Source: [42], p. 29.

FIGURE C.9

SECTION 600 — CO SHIFT CONVERSION EQUIPMENT SUMMARY

Equipment	Equipment No.	Description	No. Required	Cost/ Unit, $	Total Equipment Cost, $	BEA Sector Number
CO Shift Reactor	A-601	12-ft ID x 25-ft tan x 5-3/4 in., 1070 psig, 770° F, 21.3-ft packed bed with Girdlers G3A 1/4-in. 1/4-in. catalyst pellets	5	76,000 (vessel)	620,000*	40,27 27
CO Shift Feed Preheater	E-601	CO shift feed from 345° to 625°F, 1080 psig, CO shift effluent from 770° to 475°F, 1070 psig, total duty 400.677 X 10^6 Btu/hr, area/unit = 7000 sq ft	10	53,200	532,000	40
High-Pressure Feedwater Preheater	E-602	CO shift effluent from 475° to 340° F, 1067 psig, high-pressure boiler feedwater from 215° to 425°F, 1300 psig, total duty 533 X 10^6 Btu/hr, area/unit = 7300 sq ft	16	40,200	643,200	40
High-Pressure Feedwater Preheater	E-603	CO shift effluent from 340° to 265°F, 1064 psig, high pressure boiler feedwater from 110° to 215°F, 25 psig, total duty 231.962 10^6 Btu/hr, area/unit = 6000 sq ft	2	22,500	45,000	40
High-Pressure Boiler Feedwater Preheater	E-604	CO shift effluent from 265° to 256°F, 1061 psig, high-pressure boiler feedwater from 100° to 215°F, 1300 psig, total duty 26.662 X 10^6 Btu/hr, area/unit = 2000 sq ft	1	11,200	11,200	40
CO Shift Effluent Cooler	E-605	CO shift effluent from 256° to 240°F, 1058 psig, cooling water from 85° to 115°F, 50 psig, total duty 50.304 X 10^6 Btu/hr, area/unit = 2200 sq ft	1	10,600	10,600	40
Knockout Drum	B-601	4-ft ID x 12 ft x 2 in., 1055 psig, 240°F	5	10,300	51,500	40
				Total	1,913,500	

*Includes $240,000 catalyst. Sector 27

Source: [42] , p. 32

FIGURE C.10

SECTION 700 – PREPURIFICATION II EQUIPMENT SUMMARY

Equipment	Equipment No.	Description	No. Required	Cost/ Unit, $	Total Equipment Cost, $	BEA Sector Number
Absorber	A-701	12-ft ID X 47.5-ft tan X 5-1/2-in. thick-wall containing 39.5-ft packed bed of 3-1/2-in. plastic pall rings, 1075 psia, 240°F	5	174,800 (Vessel)	934,900[a]	40, 36
Regenerator	A-702	10.5-ft ID X 38-ft tan X 1/4 in., 25 psia, 240°F 30-ft packed bed with 3-1/2-in. pall rings	5	14,400 (Vessel)	107,300[b]	40, 36
Hot Carbonate Circulation Pump II	H-701	2392 gpm, 30% K_2CO_3 solution, 10 to 1070 psig, 240°F, multistage centrifugal pump, stainless steel, 1900 hp; driven by hydraulic turbine generating 990 hp at full load plus electric motor sized for full load-2000 hp	10 + 2 spares	81,500	978,000	49
Regenerator Condenser	E-701	Stripped acid gas 229° to 100°F, 25 psia, cooling water 85° to 115°F, 50 psig, total duty 587.2 X 10⁶ Btu/hr, area/unit = 6250 sq ft	15	26,600	399,000	40
Knockout Drum (Before Condenser)	B-702	8.5-ft ID X 25.5-ft tan X 1/4 in., 25 psia, 230°F	5	6,800	34,000	40
Knockout Drum (After Condenser)	B-703	5.5 ft-ID X 16.5-ft tan X 1/4 in., 25 psia, 100°F	5	3,800	19,000	40
Absorber Knockout Drum	B-701	4-ft ID X 12-ft X 2 in., 1070 psia, 240°F	5	10,300	51,500	40
Zinc Oxide Tower	A-704	11.5-ft ID X 16.25-ft X 5-1/4-in., 1065 psia, 100°F	2	79,500 (Vessel)	260,600[c]	40, 27
Regeneration Steam Condensate Pump II	H-702	55 gpm, 8 to 25 psig, 100°F, 10 hp, motor-driven centrifugal	1 + 1 spare	1,250	2,500	49
Regenerator Reflux Pump	H-703	439 gpm, 8 to 25 psig, 100°F, 7.5 hp, motor-driven centrifugal	1 + 1 spare	1,000	2,000	49
Hot Carbonate II Effluent Cooler	E-702	Gas stream from 240° to 100°F, 1055 psig, cooling water from 85° to 115°F, 50 psig, total duty 150.11 X 10⁶ Btu/hr, area/unit = 7000 sq ft	3	25,200	75,600	40
Activated Carbon Towers	A-703	10-ft ID X 34-ft tan X 4-3/4-in., 1065 psia, 100°F, 30-ft packed bed, 4 X 10 mesh	6	109,100	828,600[d]	40, 27
Condenser	E-702	Benzene-rich stripping steam, 285° to 100°F, 50 psig, cooling water 85°F to 115°F, 50 psig, total duty 132.696 X 10⁶ Btu/hr, area/unit = 7,750 sq ft	2	33,000	66,000	40
Benzene Separator	B-705	6-ft ID X 18-ft tan X 3/8 in., 50 psig, 100°F, 10-min settling time	2	2,700	5,400	40
Knockout Drum for Absorber Condenser	B-704	4-ft ID X 12-ft X 2 in., 1070 psia, 100°F	5	10,300	51,500	40
Benzene Pump	H-704	67 gpm, 0 to 25 psig, 100°F, 2.5 hp	1 + spare	600	1,200	49
Steam Desuperheating Water Pump	H-705	201 gpm, 0 to 1300 psig, 100°F, 270 hp	1 + spare	14,200	28,400	49
Boiler Feedwater Pump	H-706	41 gpm, 0 to 100 psig, 100°F, 6 hp	1 + spare	800	1,600	49
Activated Carbon Recycle Gas Compressor	H-707	103 lb/min, 0 to 1050 psig, three stages, with coolers after each stage, 2055 hp, centrifugal	1	220,000	220,000	49
Surge Drum	B-706	66-ft ID X 3/8 in., spherical, 0 psig, sized to take contents of activated carbon at depressurization	1	63,000	63,000	40
				Total	4,130,100	

[a] Price includes $ 60,900 for 22,150 cu ft of 3-1/2-in. ceramic pall rings.
[b] Price includes $ 35,300 for 12,830 cu ft of 3-1/2-in. ceramic pall rings.
} Sector 36

[c] Price includes $ 101,600 for 2,540 cu ft of zinc oxide packing.
[d] Price includes $ 174,000 for 14,130 cu ft of activated carbon packing.
} Sector 27

Source: [42] , p. 36

F I G U R E C.11

SECTION 800 – METHANATION AND DRYING EQUIPMENT SUMMARY

Equipment	Equipment No.	Description	No. Required	Cost / Unit, $	Total Equipment Cost, $	BEA Sector Number
Methanation Reactors						
Stage 1	A-801	8.25-ft ID X 25 ft tan X 4 in., 1045 psig, 900°F, 3-in. internal insulation, two 11-ft catalyst beds	1	59,000 (Vessel)	194,000*	40, 27
Stage 2	A-802	11.25-ft ID X 25-ft tan X 5 1/4 in., 1040 psig, 895°F, 3-in. internal insulation, two 11-ft catalyst beds	1	104,700	362,700*	40, 27
Stage 3	A-803	11-ft ID X 25-ft tan X 5 1/4 in., 1035 psig, 895°F, 3-in. internal insulation, two 11-ft catalyst beds	2	100,600 (Vessel)	691,200*	40, 27
Stage 4	A-804	10.75-ft ID X 23-ft tan X 5 in., 1030 psig, 895°F, 3-in. internal insulation, two 10-ft catalyst beds	4	79,600 (Vessel)	1,246,400*	40, 27
Recycle Compressor	C-801	3,780 CF/min, 1015 psia, 100°F, compressed to 1065 psia, 1250 hp, motor drive	2 + 1 spare	158,000	474,000	49
Methanation Knockout Drum	B-801	11-ft ID X 33-ft tan X 5 1/4 in., 1005 psig, 100°F	1	103,000	103,000	40
Feed Preheater	E-801	Methanation first-stage feed 100° to 550°F, 1050 psig, 4th stage effluent 890° to 840°F, 1030 psig, duty 100.8 X 10^6 Btu/hr. area/unit 5200 sq ft	1	49,500	49,500	40
Low-Pressure Steam Water Preheater	E-802	Low-pressure steam feedwater from 218° to 338°F, 100 psig, methanation effluent from 363° to 280°F, 1020 psig, duty 177.0 X 10^6 Btu/hr. area/unit = 6000 sq ft	12	30,400	364,800	40
Low-Pressure Steam Water Preheater	E-803	Low-pressure steam feedwater from 87° to 218°F, methanation effluent from 280° to 200°F, 1015 psig, duty 189.588 X 10^6 Btu/hr, area/unit = 8000 sq ft	2	27,940	55,900	40
Methanation Effluent Cooler	E-804	Methanation effluent 200° to 100°F, 1010 psig, cooling water 85° to 115° F, 50 psig, total duty 213.311 X 10^6 Btu/hr, area/unit = 9400 sq ft	4	31,500	126,000	40
Dryer	D-801	Dries gas to 7 lb/10^6 CF, 1000 psig package unit	1		450,000	40
				Total	$4,117,500	

* Catalyst Costs Included in Above: Stage 1, $135,000, Stage 2, $258,000; Stage 3, $490,000; and Stage 4, $928,000 } See Sector 27

Source: [42] , p. 41

The dollar flows thus generated were inflated by 1.09 to be on a comparable basis with the electric generation part of the plant. Next the construction costs associated with building the gas part of the plant (essentially the sum of the differences between the equipment costs and the base installed costs in Figure C.1 ($55,667,600)) was multiplied by 1.09 and allocated to Sector 11. Because the escalated cost of equipment comes out to less than their stated total for gas plant equipment the amount allocated to the electric utility portion of the plant was increased accordingly to $127.68 million. From this was deducted the estimated $15.93 million additional for a larger boiler to provide process steam for the gas plant. This figure ($15.93) was obtained by subtracting the purchased electric gas plant cost from the on-site gas plant cost, since the additional amount represents the cost of a process steam boiler. The result of this subtraction ($111.75 million) was allocated to the electric plant. This is a mere $155/Kw since the gas plant required 755 MW. This number may be on the low side.

Figure C.12 aggregates the coal fired electric generation plant capital cost breakdown from the Bechtel report, (Bechtel-1) prepared for the Harvard Economic Research Project, into a single, capital vector. No trade or transportation margins are included yet. These will be removed when the final capital dollar flows for Hygas are obtained. This capital vector for coal fired plants was used to disaggregate the $111.75 million into sectual flows. The $15.93 million for additional boiler facilities was disaggregated according to the breakdown of account 312 - Boiler Plant Equipment in the Bechtel report. These two dollar flows then were added to the previously calculated flows.

F I G U R E C.12

COAL-FIRED STEAM ELECTRIC GENERATION

PLANT CAPITAL VECTOR
(BEFORE REMOVAL OF MARGINS)

BEA Sector Number	Industry	Fraction[1]
11	New Construction	.39139
40	Heating, Plumbing & Structural Metal Products	.26730
42	Other Fabricated Metal Products	.07107
43	Engines and Turbines	.09474
46	Materials Handling Machinery	.00741
47	Metal Working Machinery	.00200
49	General Industrial Machinery	.07030
53	Electric Industrial Equipment	.08607
55	Electric Lighting Equipment	.00572
71	Real Estate and Rental	.00050
73	Business Services	.00350
	Total	1.00000

1 Fraction calculated with labor margins assigned to 11.

Source: [5].

Pollution control costs were a major uncertainty. Informal conversations with IGT personnel indicated the total costs for pollution control on a 250 billion BTU/day could be as high as $25 million. Doubling this for a 500 billion BTU/day plant gives $50 million. To check out this number, some rules of thumb applicable to electric utilities were used. For example, Reference 26 quotes figures of $1759/MW for precipitator costs and $11/Kw for natural draft wet cooling towers. If one assumes that the small amount of residual sulfur contained in the lignite char (or worse yet that the plant burns high sulfur bituminous coal) constitutes a potential air emission problem when burned in the electric generation plant, then one is forced to install scrubbers. Estimates of limestone scrubbing costs go as high as $40/KW for capital equipment, but $25/KW was used. This leaves $21.6 million to handle the water pollution associated with the gas process plant itself. To illustrate that this is a reasonable number, Figure C.13 lists the capital expenditures for air and water pollution for different industries. Electric utilities are predominantly air polluters, while refineries are predominantly water polluters. From these figures, it is clear that $21.6 million for water pollution abatement equipment is quite reasonable.

To disaggregate these dollars amount, Figure C.14 lists the air and water pollution equipment purchase breakdowns found in the most recent Bureau of Labor Statistics bulletin [53]. These fractions were used to disaggregate the air and water pollution dollar figures. It should be mentioned that there is still no provision in these figures for the removal and recovery of H_2S from the raw gasified coal. The IGT report makes the glib statement that the cost of sulfur recovery is covered by the funds received from

FIGURE C.13

1970 CAPITAL EXPENDITURES FOR POLLUTION CONTROL EQUIPMENT

Industry	Water Pollution	Air Pollution	Water % of Total
Petroleum Refining	185	59	.75819
Chemicals Manufacturing	90	79	.53254
Electric Utilities	149	331	.31041

Source: *Environmental Quality 1971*, Tables A-2, A-4 [12]

FIGURE C.14

PERCENTAGE OF POLLUTION CONTROL EQUIPMENT BY PRODUCING INDUSTRY

Industry	Water (%)	Air (%)
11 New Construction	---	6.9 (7.709)[1]
13 Stone & Clay Products	.4 (0.447)[1]	---
40 Heating, Plumbing & Fabricated Structural Metal Products	36.0 (40.323)	10.7 (11.955)
48 Special Industry Machine & Equipment	.6 (0.677)	---
49 General Industrial Machinery & Equip.	28.2 (31.678)	71.9 (80.336)
52 Service Industry Machines	14.5 (16.237)	---
62 Professional, scientific, & cont. instruments & supplies	9.5 (10.638)	---
65 Transportation & Warehousing	1.7	3.6
69 Wholesale & retail trade	9.0	6.9
TOTAL	100.0% (100.0%)	100.0% (100.0%)

[1] Numbers in parentheses are fractions before trade and transportation margins.

Source: [53]

sulfur sales. This is a highly dubious statement on many grounds: (1) sulfur prices are quite volatile to begin with, (2) if sulfur were recovered from all stack gas, it would more than satisfy the current U.S. sulfur requirements, (3) if low sulfur lignite is converted, the H_2S concentrations are low enough to present difficulty to a recovery process, (4) if a high sulfur coal is used, the residual sulfur in the char will be costly to remove from the stack gases of the electric plant. All of which says, these are conservative figures. Figure C.15 provides the disaggregation scheme for precipitator and cooling towers.

Contractors overhead and profit was recalculated on the basis of the new capital cost of the gas plant by scaling the old profit and overhead figure to the new total. The difference between a 10% profit and the actual figure was allocated to 73 for consultants fees, design, supervision, etc. Interest was then assessed at 7.5% (this assumes a two year construction time with an average of half the money outstanding).

Working capital was then recalculated by using 12¢/lb. lignite rather than the original 8¢/lb., inflating other materials by the average price change of 13.6% (6.6% compounded), and accounts receivable by the roughly doubled price of gas. Figure C.16 lists these changes and their sectoral allocations.

The final IGT high BTU coal gasification vector was calculated by summing all the previously described flows removing trade and transportation margins and dividing by the total cost of the plant ($354.8 million). Thus what we have is a capital cost per plant breakdown, not a capital/output vector. For our purposes where the actual cost of the plant and selling price of the gas are not determined,

F I G U R E C.15

COST ALLOCATION FOR VARIOUS EQUIPMENT

Item	BEA Sector No.	Sector Name	Fraction
Precipitators	49	General Industrial Equipment	1.0
Natural Draft	11	New Construction	.81818
Wet Cooling	42	Other Fab Met Prods	.090911
Towers	49	Gen Ind. Equip.	.090911

Source: [27], Appendix D

FIGURE C.16

REVISED INVESTMENT SUMMARY

Item	Process Equipment, $	Bare Cost Installed, $	BGA Sector Number
Gas Plant	65,221,700	125,910,000	D[1]
Pollution Control	--	50,000,000	D
Electric Plant	--	127,680,000	d
Subtotal, Bare Cost		303,590,000	
Contractor's Overhead and Profit (on gas plant only)		9,732,000	11,73
Subtotal		313,322,800	
Interest During Construction		23,499,200	VA[2]
Total Fixed Investment		336,822,000	
Working Capital			
Raw Materials	2,983,500		7
Other Materials	101,400		27
Accounts Receivable	10,031,000	13,115,900	VA
Total Capital Investment		349,937,900	

[1] D stands for distributed among various sectors. This breakdown is given elsewhere.

[2] VA stands for Value Added sector.

the capital cost per plant is a more useful vector. Figure C.17 lists the non-zero components of the final percentage capital vector.[27]

27 The percentage capital vector must be multiplied by the capital/output ratio before it becomes the standard capital vector. However, it is easier to manipulate before such multiplication.

FIGURE C.17

Non-Zero
HYGAS CAPITAL EXPENDITURE COEFFICIENTS[1]
(Percentage)

104 Order Sector Number	Industry	Coefficient
7	Coal Mining	0.005310
11	New Construction	0.342777
29	Industrial Chemicals	0.007110
44	Stone and Clay Products	0.001087
51	Plumbing & Structural Meta	0.253008
54	Other Fab Metal Prods	0.024998
55	Engines & Turbines	0.026814
57	Construction & Mining Equipment	0.015146
58	Material Handling Machinery	0.007270
59	Metal Working Machinery	0.000580
60	Special Industry Machinery	0.000379
61	General Industry Machinery	0.090903
64	Service Industry Machinery	0.016520
66	Electrical Industry	0.027165
68	Elec. Lighting Equipment	0.001587
75	Scientific & Control Ins.	0.005595
78	Railroad Transportation	0.000119
80	Truck Transportation	0.004351
81	Water Transportation	0.006045
82	Air Transportation	0.000250
89	Wholesale Trade	0.027106
90	Retail Trade	0.009035
91	Finance and Insurance	0.010000
92	Real Estate & Rental	0.000154
94	Business Services	0.017595

1 See footnote 27 for definition of percentage capital coefficients

Appendix D Derivation of Hygas Technical Coefficients

The same sources were used in deriving the technical coefficients as in deriving the capital coefficients [42,43]. Figure D.1 lists the escalated operating costs for the 500 billion BTU/day plant, together with my modifications to it. Most of these modifications came about as a result of the changes in capital costs described in Appendix C. Limestone costs were added on the basis of scaled up demonstration plant costs. $350,000 was added to labor costs to reflect limestone handling costs. Here the same proportion of labor to raw material was used as for coal. Figure D.2 lists the estimated labor requirements.

By-product credits were not subtracted from the total revenue requirement because, by definition, a technical coefficient is calculated by using the total output for an industry, which includes the sale of by-products. Figure D.3 lists these by-products. Annual material requirements are further broken down in [43]. Figure D.4 reproduces this breakdown. Note that the costs of these materials are not escalated by any inflation factor from the original 1968 study. This is probably an error, however the additional $130,000 does not make a very large difference. Figure D.5 lists the process and feedwater requirements for the plant. Figure D.6 lists the cooling water requirements. Only process and feedwater is assumed to be purchased. The original study, [42] includes $2.3 million for a water purification plant as part of the off-site costs that includes the MHD plant. Whether this purification plant is included in the new costs was not certain but since process water typically costs 30¢/thousand gallons and since the plant uses 7.3 billion gallons per year, the estimated $2.2 million water cost could scarcely be served by a $2.3 million water plant. The demonstration plant is expected to use considerably less water than is projected here, but since the demonstration plant study was not available, the figures in [42] were used.

ANNUAL OPERATING EXPENSE AND REVENUE REQUIREMENTS:
PIPELINE GAS FROM LIGNITE BY HYGAS PROCESS

	Modified	Original	BEA Sector Number
Raw Material = Coal (at 12¢/MMBTU)	33,651,200	33,651,200	7
Limestone	4,400,000	---	9
Other Materials	1,007,000	1,007,000	27,45
Direct Labor	2,956,100	2,606,100	VA
Maintenance (3% of bare cost)	5,790,000	4,082,200	12,VA
Supplies (15% of Main.)	869,400	612,300	D
Supervision (10% of labor)	295,600	260,000	VA
Payroll Overhead (10% of labor and supervision)	325,200	286,600	D
General Overhead (50% of labor, supervision, maintenance, supplies)	4,963,000	3,780,600	D
Power Generation (Oper. & Main.)	4,985,000	4,985,000	D
Depreciation (5% straight line)	20,620,300	14,684,500	VA
Taxes (Local & State = 2% of invest.)	7,096,000	8,810,700	VA
Insurance (1% of investment)	3,548,000		70
Total operating Expense	90,507,800	74,766,800	
By-Product Credit	---	(9,789,100)	
Contingencies (2% at Operating)	1,816,200	1,495,200	VA
Gross Return (9% of rate base, 20 year average)	18,965,800	13,554,900	VA
Federal Income Tax (48%, 20 year average)	7,413,600	5,298,500	VA
Total Revenue Requirement	118,703,400	85,326,300	
Average Gas Price	72.6¢/MMBTU (no by-product credit)	52.0¢/MMBTU	

AGA Conventions Used: 20 year straight line depreciation: 65/35 debt/equity:
7.5% interest on debt; 9% return on rate base.

Source: [42] p, 72.

FIGURE D.1

FIGURE D.2

ESTIMATED OPERATING LABOR FOR PIPELINE GAS SECTION
(Exclusion of MHD Unit*)

	Men Per Shift
Lignite Storage, Reclaiming	3
Lignite Grinding and Drying	4
Slurry Feed Preparation	4
Hydrogasification, Electrogasification, Char Combustor	16
Quench System and Light Oil Recovery	4
Prepurification I and II	21
CO Shift	3
Methanation, Drying	5
Offsites	10
	70

At $3.75 per man-hour 70 x $3.75 x 24 = $6300/day

Annual Cost = $2,299,500

*Labor and maintenance calculated from unit cost per MW. For the MHD steam cycle with producer gas feed annual costs for operating, maintenance and seed amount to $2,673,000

Source: [42], p. 70.

FIGURE D.3

BY-PRODUCTS OF HYGAS PROCESS

By-product	Amount/Year	Unit Value	Annual Value, $	¢/10^6 Btu Pipeline Gas
Benzene	30,712,800 gal	15¢/gal	4,607,000	2.84
Oil	20,727,800 million Btu	25¢/10^6 Btu	5,181,900	3.18
Electric Power	998.1144 x 10^6 Kwhr	3 mils/kwhr	2,994,500	1.84
			12,783,400	7.86

Source: [42], p. 69

FIGURE D.4

SUMMARY OF ANNUAL MATERIAL REQUIREMENTS 90 PERCENT PLANT OPERATING FACTOR

Item	Annual Cost, $
Lignite at 8¢/10^6 Btu ($1.17/ton)	21,478,500
Catalysts and Chemicals	
Potassium Carbonate System Losses	171,000
Activated Carbon	27,000
Zinc Oxide	182,700
CO Conversion Catalyst	54,000
Methanation Catalyst	407,700
Hammers and Grinding Rolls	99,000
Water Treatment Chemicals	65,700
Subtotal	1,007,100
Total Annual Material Cost	22,485,600

Source: [42], p. 71

FIGURE D.5

PROCESS AND FEEDWATER REQUIREMENTS

Total process and boiler feed rate requirements give a total plant makeup of 15,562 gpm. This is summarized as follows:

	gpm	
Reaction Steam Feedwater	3,117	
Hot Carbonate Regeneration Steam	890	
Hydrogasifier CTR Quench	235	
Quench Tower Makeup	3,640	
Cooling Water Makeup	7,680	
Total	15,562	= 7361 10^6 gal/yr.

Source: [42], p. 61

FIGURE D.6

COOLING WATER SUMMARY

Process Cooling Water 85° - 115°F

Service	gpm
Cooling Recycle Light Oil from 250°-115°F	4,746
Condenser for Hot Carbonate I	57,800
Condenser for Hot Carbonate II	39,146
Cooling Methanation Feed From 240°-100°F	7,162
Cooling Methanation Effluent from 200°-100°F	14,220
Cooling CO Shift Effluent 256°-240°F	3,152
Condenser for Activated Carbon Regeneration	4,420
Cooling Activated Carbon Recycle Compressor	335
Total Gas Plant	130,981
MHD Turbine Steam Condensation	88,400
Total Combined Requirements	219,381

Source: [42], p. 59

With these data sources, all well defined numbers were assigned to BEA categories as illustrated in Figure D.1. The residual 9.5% was distributed on the basis of comparison with the electrical utility, chemicals, and petroleum refining industries. In general an average of coefficients for BEA sectors 27,28,31, and 68 was used, supplemented by the author's judgements. Figure D.7 summarizes the non-zero technical coefficients for Hygas process.

Trade and transportation were removed from all commodities except coal, since the plant was assumed to be at mine-mouth. This is contrary to the standard BEA practice of removing a uniform margin for all commodities but it is probably more correct.

FIGURE D.7

HYGAS TECHNICAL COEFFICIENTS ($1.017/MCF)

(NON-ZERO)

104 Order Sector Number	Industry	Coefficient
7	Coal Mining	0.202000
9	Stone & Clay Mining	0.017429
12	Maint. & Repair Construction	0.017357
19	Apparel	0.000071
28	Printing and Publishing	0.000050
29	Industrial Chemicals	0.006521
33	Drugs, Clng, Toilet Prep.	0.000071
38	Rubber & Plastic Products	0.000143
39	Leather Tanning Products	0.000071
44	Stone and Clay Products	0.000729
51	Plumbing & Structural Metals	0.000007
54	Other Fabricated Metal Products	0.000286
57	Construction & Mining Equipment	0.000643
58	Material Handling Machinery	0.000057
62	Machine Shop Products	0.000007
68	Elec. Lighting Equipment	0.000007
71	Elec. Mach. Equipment & Supplies	0.000021
72	Motor Vehicles & Equipment	0.000057
76	Optical and Photo Equipment	0.000021
77	Misc. Manufacturing	0.000007
78	Railroad Transportation	0.006214
80	Truck Transportation	0.002071
88	Water & Sanitary Services	0.013529
90	Retail Trade	0.004000
91	Finance and Insurance	0.021929
92	Real Estate & Rental	0.004371
94	Business Services	0.015357
96	Auto Repair & Service	0.000571
98	Medical & Education Services	0.000214
102	Business Travel, Gifts	0.003286
103	Office Supplies	0.000357

Appendix E Derivation of Capital Coefficients for Second Generation Texaco Low BTU Coal Gasification Process

The United Aircraft report [39] which served as the reference work for both low BTU coal gasification and the gas turbine topping cycle, was not nearly as well done as the IGT report [42,43]. This may be caused by the fact that the United Aircraft report was a joint production of three different organizations: United Aircraft, (gas-turbines): FMC (fuel desulfurization processes); and Burns and Roe (steam systems and power systems economics). FMC, who prepared the gasification parts of the report, did not appear to do as detailed a job as United Aircraft did on the gas turbine section of the report.

Figure E.1 illustrates the add-on procedure used to go from purchased equipment cost to total installed cost. Sector assignments are also provided there. Figure E.2 reproduces the purchased equipment list for the second generation Texaco process using hot carbonate scrubbing. Sector numbers (at 83 order) are also included here. Figure E.3 compares the Texaco process to the first generation Lurgi technology.

The costs of general process equipment (e.g. pumps or heat exchangers) were taken from standard lists. Costs of towers and other cylindrical vessels were estimated at 45¢/lb. for fabricated steel. The costs of any linings were added to derive the final estimated cost.

Because of the unusual way of presenting this cost information, we resorted to an unusual method of deriving capital coefficients. All items of equipment plus interest (@ 7.5% per year), engineering (6% of plant cost), instruments (one half of the figure shown in Figure E.1), insurance

FIGURE E.1

"ADD-ON" ESTIMATION TECHNIQUE ILLUSTRATION

Item		Amount
Equipment Purchased (Initial Estimate)		$1000
Commodities		
Excavation @ 6.4% equipment	$ 64	
Concrete @ 14.5% equipment	145	
Structural Steel @ 13.1% equip.	131	
Buildings @ 5% equipment	50	
Piping @ 40% equipment	400	
Electrical @ 32% equipment	320	
Instruments @ 25% equipment	250	
Insulation @ 6% equipment	60	
Painting @ 2% equipment	20	
Subtotal		1440
Total Direct Cost		1440
Indirect Costs @ 35% of Total Direct Cost		854
Engineering, supervision = 6% of total		
Interest = 7.5% of total		
Insurance = 1% of total		
Subtotal		3294
Contingency @ 10% of Total Direct-plus-Indirect Costs		329
Total Installed Costs (Final Estimates)		$3623

Source: [39], p. 458

FIGURE E.2

SECOND-GENERATION PARTIAL-OXIDATION HOT-CARBONATE PROCESS

Equipment List

No. Req'd.	Description	Equipment Purchased Cost-Dollars	BEA Sector Number
2	Underfeed Conveyors 115 TPH, w SS Hopper and Vibrating Feeders	35,000	45
1	Raw Coal Conveyor-Belt, 30 in. x 2000 ft long - 400 ft/min, 310 TPH	175,000	46
4	Belt Conveyor, 80 TPH, 220 ft long CS-24 in.	20,000	46
4	Primary Coal Crusher, 180 TPH, 70 hp	20,000	45
4	Hammer Mill, 80 TPH, 150 hp	105,000	45
4	Crushed Coal Elevators, 80 TPH	130,000	46
4	Surge Hopper, 100 T, 20 ft x 20 ft x 10 ft	50,000	40
4	Distributing Conveyor - Piggy Back Belt Type, 18 in. x 50 ft, 70 TPH	30,000	46
4	Slurry Tank, 14,000 gal, SS clad, 2/agitation	98,000	40
4	Slurry Pump, centrifugal, 450 gph, 85 hp	35,000	49
4	Vaporizer, 117 million Btu/hr, SS/CS, 7600 ft^2	171,000	40
4	Coal-Steam Separator, 47,000 acfm	14,000	40
4	Texaco Partial Oxidation Gasifiers, 14.75 ft D x 35.5 ft H, 18 in. refractory lining	700,000	36+40
4	Steam Coal Preheater, 64 million Btu/hr, SS/SS 21,000 ft^2	310,000	40
4	Pebble Elevator, 140 TPH, 80 ft H	51,000	46
4	Air Preheater, 17.75 ft D x 55 ft H, 13 in. refractor lining, 140 million Btu/hr pebble bed	1,300,000	40+36
4	Waste Heat Boiler, CS/CS, 60 million Btu/hr, 7300 ft^2	165,000	40
2	Air Compressor, 3-stage, intercooled, 280,000 scfm @ 256 psia, 34,000 hp	1,800,000	49
4	Multiclone Banks, 20,000 acfm	130,000	40
4	Venturi Scrubbers, 14,000 acfm	36,000	40
4	Water Scrubbing Towers, 12.3 ft D x 24 ft H, 1450 ft^3 drip-grind packing	228,000	40+36
4	Ash Separator Tanks, CS, 13,000 gal	11,000	40
8	Water Circulation Pumps	40,000	49
4	Hot-Carbonate Absorption Towers, 67 ft D x 27 ft H, CS, 15 turbogrid trays	90,000	40
4	Hot-Carbonate Stripping Towers, 6.7 ft D x 52 ft H, CS 28 turbogrid trays	160,000	40
4	Condensers, air cooled, 22,000 ft^2 of fin tube	58,000	40
4	Separators 6 ft D x 20 ft L, CS Horizontal	25,000	40
4	Demisters 6 ft D, CS	10,000	40
4	Liquor Pumps, 2000 gph, 200 psi head, SS internals	200,000	49
1	Waste Water Stripping Tower, 10.5 ft D x 30 ft H, 20 trays	54,000	40
1	Air Blower for Waste Water Stripping, 200,000 cfm @ 5 ft H_2O	75,000	49
1	Cooling Tower System, forced draft, 500,000 gph, 25 F range, 10 F approach	150,000*	11*
1	Process Water Treatment Plant, 60,000 gph	200,000*	11*
		6,676,000	

* Total installed cost including commodities, indirect costs, and contingency.

Source: [39], p. 485

FIGURE E.3

COMPARISON OF FIRST AND SECOND GENERATION LOW BTU COAL GASIFICATION PROCESSES

1000-Mw Nominal Size

	Second Generation Texaco Process	First Generation Lurgi Dry Ash
	(Thousand Dollars)	
Coal Handling	2,000	4,700
Coal Feeding	1,200	20,000
Gasification	1,800	
Air Compression	6,900	8,900
Heat Recovery	6,300	2,500
Dust Removal	1,200	--
Acid Gas Removal	3,300	2,500
Sulfur Recovery	1,800	1,900
	14,500	40,500
General Facilities	1,900	4,000
Total Fixed Capital	26,400	44,500
$/kw	28.3	46.1
Working Capital	1,100	1,800
Total Investment	27,500	46,300
$/kw	29.5	48.0

Source: [39], p. 87, 118

(1% of total direct cost) were allocated directly to sectors. These allocations amounted to $\frac{1778}{3294}$ of the plant cost before contingencies. The remaining $\frac{1513}{3294}$ of the plant cost was allocated to 11.03. The 11.03 coefficient vector was modified to exclude all boiler purchases (40.06), all 43.01, all 49.01, and all 73.03. These sectors had been allocated under the direct equipment purchases. The 11.03 vector was then rescaled to sum to 1.0 and used to allocate the construction component of the plant cost.

The capital equipment purchases had trade and transportation margins removed before they were combined with the construction components. To disaggregate the total transportation margin into rail, truck, water, etc. components, the breakdown for the electrical utility capital purchases was used. The source for this information was Battelle Institute's Ex Ante Capital Matrix [21]. Figure E.4 reproduces the actual transportation margins and the relative percentages for each. Trade and transportation margins themselves were obtained from the Survey of Current Business November 1969 article "The Input Output Structure of the U.S. Economy 1963." [48].

The result of this tortuous procedure is an estimated second generation low BTU coal gasification capital vector. It is set up like the Hygas capital vector to sum to 1.0 (when value added is included). When multiplied by the cost of the gas plant it will disaggregate the investment into purchases from individual sectors of the economy. Figure E.5 contains the final percentage capital vector. (See footnote 27).

FIGURE E.4

MODAL ALLOCATION OF TOTAL TRANSPORTATION COSTS FOR ELECTRIC UTILITIES

Mode	Fraction
Rail (65.01)	0.011
Motor Freight (65.03)	0.401
Water Transport (65.04)	0.557
Air Transport (65.05)	0.023
Misc. Transport (65.07) (Pipeline and Services)	0.008
Total	1.000

Source: [21], p. 92

FIGURE E.5

LOW BTU GAS (TEXACO PROCESS) CAPITAL EXPENDITURE COEFFICIENTS [1]

(PERCENTAGES)

		COEFFICIENT
1	LIVESTOCK & PRODUCTS	0.0
2	OTHER FARM PRODUCTS	0.000145
3	FORESTRY & FISHERY PROD	0.0
4	FARM, FOREST, FISH SERV	0.0
5	FERROUS METAL MINING	0.0
6	NONFERROUS METAL MINING	0.0
7	COAL MINING	0.0
8	CRUDE OIL AND NATURAL GA	0.0
9	STONE & CLAY MINING	0.002236
10	MINERAL MINING	0.0
11	NEW CONSTRUCTION	0.0
12	MAINT & REPAIR CONST	0.000088
13	ORDNANCE, ACCESSORIES	0.0
14	FOOD & KINDRED PRODUCTS	0.0
15	GRAIN MILLING	0.0
16	TOBACCO MANUFACTURES	0.0
17	FABRIC,YARN,THRD MILLS	0.000005
18	MISC. TEXTILE GOODS	0.000073
19	APPAREL	0.000187
20	MISC FAB TEXTILE PRODUCT	0.000005
21	LUMBER & WOOD PRODS	0.018639
22	WOODEN CONTAINERS	0.0
23	HOUSEHOLD FURNITURE	0.0
24	OTHER FURN & FIXTURES	0.000436
25	PULP MILLS	0.0
26	PAPER & ALLIED PRODS	0.000462
27	PAPER CONTAINERS, BOXES	0.0
28	PRINTING & PUBLISHING	0.000010
29	INDUSTRIAL CHEMICALS	0.000363
30	FERTILIZERS	0.000036
31	AGR & MISC CHEMICALS	0.000560
32	PLASTICS & SYNTH MTRL	0.0
33	DRUGS, CLNG, TOILET PREP	0.0
34	PAINTS & PRODUCTS	0.000374
35	PETROLEUM REFINING	0.005416
36	PAVING MIXTURES	0.002231
37	ASPHALT FELTS, COATINGS	0.000239
38	RUBBER & PLASTIC PRODS	0.001670
39	LEATHER TANNING PROD	0.0
40	FOOTWEAR & LEATHER PROD	0.000005
41	GLASS & GLASS PRODS	0.000067
42	CEMENT, HYDRAULIC	0.000835
43	LIME	0.000125
44	STONE & CLAY PRODS	0.044964
45	PRIMARY STEEL	0.027859
46	IRON & STEEL FOUNDRIES	0.014847
47	IRON & STEEL FORGINGS	0.000565
48	PRIMARY NON-FER METAL	0.0
49	MISC NON-FER METALS	0.035727
50	METAL CONTAINERS	0.0
51	PLUMBING&STRUCTURAL META	0.166970
52	HEATING EQUIP EXC ELEC	0.000503
53	SCREWS & METAL STAMPINGS	0.001447

		COEFFICIENT
54	OTHER FAB METAL PRODS	0.009052
55	ENGINES & TURBINES	0.0
56	FARM MACHINERY & EQUIP	0.000026
57	CONSTRUCTION&MINING EQUI	0.008622
58	MATERIAL HNDLG MACH	0.015642
59	METALWORKING MACH	0.000005
60	SPECIAL INDUSTRY MACH	0.0
61	GENERAL INDUSTRY MACH	0.082274
62	MACHINE SHOP PRODUCTS	0.000073
63	OFFICE COMP MACH	0.0
64	SERVICE INDUSTRY MACH	0.007789
65	REFRIG MACHINERY	0.0
66	ELECTRICAL INDUSTRY	0.039711
67	HOUSEHOLD APPLIANCES	0.0
68	ELEC LIGHTING EQUIP	0.006832
69	RADIO,TV & COMM EQUIP	0.003777
70	ELEC COMP & ACCESS	0.000021
71	ELEC MACH EQP & SUPPLIES	0.000327
72	MOTOR VEHICLES & EQUIP	0.000550
73	AIRCRAFT & PARTS	0.0
74	OTHER TRANSPORT EQUIP	0.000016
75	SCIENTIFIC & CONTROL INS	0.000187
76	OPTICAL & PHOTO EQUIP	0.000067
77	MISC MANUFACTURING	0.000192
78	RAILROAD TRANSPORTATION	0.005041
79	LOCAL PASSENGER TRANSPOR	0.0
80	TRUCK TRANSPORTATION	0.010484
81	WATER TRANSPORTATION	0.003973
82	AIR TRANSPORTATION	0.000200
83	MISC TRANSPORTATION	0.000093
84	COMMUNICATIONS EXC RAD&T	0.000908
85	RADIO & TV BROADCASTING	0.0
86	ELECTRIC UTILITIES	0.000680
87	GAS UTILITIES	0.000135
88	WATER & SANITARY SERV	0.000223
89	WHOLESALE TRADE	0.032367
90	RETAIL TRADE	0.012632
91	FINANCE AND INSURANCE	0.010253
92	REAL ESTATE & RENTAL	0.001484
93	HOTEL, PERS & REPAIR SER	0.0
94	BUSINESS SERVICES	0.063699
95	RESEARCH AND DEVELOPMENT	0.0
96	AUTO REPAIR & SERVICE	0.001183
97	AMUSEMENTS	0.0
98	MEDICAL & EDUCATION SERV	0.000285
99	FED GOVT ENTERPRISES	0.000093
100	STATE&LOCAL GOVT ENTERPR	0.000368
101	IMPORTS	0.0
102	BUSINESS TRAVEL, GIFTS	0.001800
103	OFFICE SUPPLIES	0.0
104	SCRAP, SECONDHAND GOODS	0.0

[1] See footnote 27 for definitions of percentage capital coefficients.

Appendix F Derivation of Second Generation Low BTU Coal Gasification Technical Coefficients

The data source for this derivation was, once again, Reference 39, the United Aircraft report on advanced power cycles. Figure F.1 reproduces the operating data on the second generation Texaco process. In the calculations to follow the sulfur credit was ignored, so that the net incremental use is $2.998 million, and the total cost is $14,525 million. This results in a gas price of 37.1¢/MMBTU. Figure F.1 also compares the second generation process to the current process using Lurgi technology. Figure F.2 provides a similar comparison with the material requirements. Both of these plants are sized to run a 1000 MW gas turbine topping cycle generator (first generation topping cycle efficiency = 47%; second generation efficiency = 54%; overall first generation efficiency = 36.1%, second generation = 47.6%).

With this small amount of information to go on, the standard procedure was followed of allocating the major identifiable items first. These are listed in the appropriate column of Figure F.1. The labor component listed there consists of direct labor, supervision, and overhead. Assuming that the same proportions hold for these labor figures as held for those of the Hygas process, Figure F.3 breaks up labor into its components. Capital related items are all allocated to value added except for 1% of fixed capital which is given to sector 70, (Insurance). 13% of maintenance is allocated to supplies to be distributed and half of the remainder (43.5%) is allocated to 12, with the remainder going to value added. Figure F.4 illustrates this procedure. This procedure assumes 15% of actual maintenance charges are for supplies and that half of all maintenance is contracted out. These are the same proportions that were used in the

FIGURE F.1

ANNUAL OWNING AND OPERATING COSTS FOR PARTIAL OXIDATION-HOT CARBONATE PROCESS

1000 MW Nominal Size	COGAS plant Thousand Dollar	COGAS plant Mills/Kwhr[1]	First Generation Lurgi Dry Ash Thousand Dollars	First Generation Lurgi Dry Ash Mills/kwhr[2]
Maintenance @ 5% Fixed Capital	1,320	0.23	2,225	0.40
Labor @ $60,000/man/shift	1,200	0.21	2,280	0.40
Utilities:				
Cooling Water @ 2¢/thousand gal.	159	0.03	294	0.05
Process Water @ 30¢/thousand gal.	196	0.03	103	0.02
Steam @ 50¢/thousand lb/hr	123	0.02	358	0.06
Sulfur Credit @ $25/long ton	(1,174) 2,998*[3]	(0.21)	(1,301)	(0.23)
Net Increment Cost	1,824	0.31	3,959	0.70
Coal @ 20¢/million Btu	7,831[4]	1.37	12,217[5]	2.17
Subtotal	9,655	1.68	16,176	2.87
Capital Related @ 14% of Fixed Capital	3,696	0.65	6,230	1.11
Total	13,351 14,525*[3]	2.33[6] 2.54	22,406	3.98[7]

[1] 5,721 x 10^9 kwhr/hr

[2] 5.64 x 10^9 kwhr/yr

[3] Starred figures do not include sulfur credit

[4] 0.619 lb coal/kwhr

[5] 0.85 lb/kwhr

[6] 34.1 ¢/million Btu

[7] 42.1 ¢/million Btu

Source: [39], p. 119, 87

FIGURE F.2

PARTIAL OXIDATION-HOT CARBONATE PROCESS MATERIAL BALANCE
1000-Mw Nominal Size

IN:

Coal -
- 1.772 million tons/yr
- 9632 lb/min
- 106.4 million Btu/min

Electricity - 67 Mw

OUT:

Gas -
- Temp. - 230 F
- Press - 325 psia
- Flow: 556,643 ft^3/min
  31,497 lb/min
- HHV - 173.9 Btu/ft^3
- Sensible Heat - 3.2 Btu/ft^3
- Sulfur - 6.5 g/million/Btu

Composition	Vol. %
H_2O	5.5
H_2	25.0
CO	27.2
CO_2	3.8
CH_4	0.5
H_2S	0.003
N_2	38.0

Sulfur: 46,976 long tons/day

FIRST GENERATION LURGI GASIFICATION PROCESS MATERIAL BALANCE

1000-Mw Nominal Size

IN:

Coal -
- 2.405 million ton/year
- 13,075 lb/min (as rec.)
- 144.5 million Btu/min

Electricity - 82 Mw

OUT:

Gas -
- Temp. - 230 F
- Press. - 315 psia
- Flow rate - 686,622 ft^3/min
  41,943 lb/min
- HHV - 172.7 Btu/ft^3
- Sensible Heat - 3.3 Btu/ft^3(1)(1)
- Sulfur - 221 g/million Btu

Composition, Vol %	
H_2O	6.6
H_2	20.9
CO	14.1
CO_2	12.5
CH_4	5.8
H_2S	0.1
COS	0.0
N_2	40.0

Sulfur - 52,067 long tons/year

Source: [39], p. 86, 117

FIGURE F.3

DISTRIBUTION OF LABOR CHARGES

	%	Dollars (100's)	Sector Number
Direct Labor	55.1	661	VA
Supervision	5.5	66	VA
Payroll Overhead	6.1	73	D[1]
General Overhead	33.3	400	D
Total Labor	100.0%	$1200	

1 D stands for distributed among various sectors, and described elsewhere.

FIGURE F.4

BREAKDOWN OF TOTAL MAINTENANCE COSTS

	%	Dollars (100's)	Sector Number
Maintenance	87.0	1148	
Contracted	43.5	574	12
Self-supplied	43.5	574	VA
Supplies	13.0	172	D
Total Maintenance	100.0%	1320	

Hygas operating cost calculations. The residual $768,000 (5.3% of the total) was distributed according to industry 31 (petroleum refining) and the author's judgment. An additional 1.2% was removed from value-added and allocated to real estate and rental (sector 71) to bring this sector up to a more reasonable level.

Finally trade and transportation margins were removed from all purchases except coal. Again it was assumed that the plant operated at mine-mouth. The final vector is displayed in Figure F.5.

FIGURE F.5

LOW BTU COAL GASIFICATION NON-ZERO TECHNOLOGICAL COEFFICIENTS

104 Order Sector Number	Industry	Coefficient
7	Coal Mining	.53913
8	Crude Oil & Natural Gas	.00026
9	Stone & Clay Mining	.00003
12	Maintenance & Repair Construction	.04543
19	Apparel	.00014
21	Lumber & Wood Products	.00024
29	Industrial Chemicals	.01090
31	Agriculture & Miscellaneous Chemicals	.00338
33	Drugs, Cleaning, Toilet Preparations	.00297
35	Petroleum Refining	.00100
49	Misc. Non-ferrous Metals	.00223
51	Plumbing & Structural Metals	.00006
54	Other Fabricated Metal Products	.00029
58	Material Handling Machinery	.00020
72	Motor Vehicles & Equipment	.00003
75	Scientific & Control Insurance	.00003
84	Communications except Radio & TV	.00108
88	Water & Sanitary Services	.01349
89	Wholesale Trade	.01381
90	Retail Trade	.00161
91	Finance & Insurance	.00964
92	Real Estate & Rental	.01982
94	Business Services	.02260
96	Auto Repair & Service	.00036
98	Medical & Education Service	.00063

Appendix G Derivation of Capital Coefficients for the Second Generation Gas Turbine Topping Cycle

The data source for this derivation was the United Aircraft report, [39], United Aircraft and Burns and Roe collaborated on the section of this report that describes the costs of the combined gas-turbine steam cycle generating plant. The particular system chosen for study is a second generation waste heat boiler combined cycle. A very detailed breakdown of installed equipment costs was provided by FPC account number. These lists are reproduced in Figures G.1-G.8. In addition these lists assign equipment to 86 order sectors.

Figure G.9 summarizes these costs and details the interest, escalation, design fees, etc. Since these numbers all represent installed costs, labor, transportation, and trade margins must be removed from them. Figure G.10 lists the labor margins that were removed from all equipment prices in each account before they were allocated to I/O sectors. These labor margins were taken from Reference 5. Once labor margins were removed, the equipment was assigned to I/O categories and the trade and transportation margins were removed. In the case of equipment falling into two categories, weights were assigned according to Reference 5.

Because of the detail provided in this section of the United Aircraft report, the derivation of capital coefficients was quite straightforward. The major questions that arose had to deal with the classification of piping (it was assigned to sector 42), the classification of instruments and controls (assigned to 53), the treatments of interest, insurance, and construction supervision fees, and, of course, whether the

FIGURE G.1

SECOND GENERATION COGAS PLANT

BREAKDOWN OF FPC ACCOUNT 341 - STRUCTURES AND IMPROVEMENTS

FPC Account Number 341 Structure & Improvements	Sector Number	Cost
Site Improvements		
Site Grading Building Excavation Borings Landscaping Fresh Water Supply Fire Protection Drainage & Sewage Disposal Flagpole Guard House Railroad Roads & Parking Lots Fencing Switchyard **Structures** Administration Building Turbine Generator Building Tank Farm Fuel Oil Pump House Gas Meter Area Circulating Water System Stack	11	$7,748,500
Total Amount 341		$7,748,500

Source: [39], p. 279

FIGURE G.2

SECOND GENERATION COGAS PLANT

BREAKDOWN OF FPC ACCOUNT 343 - PRIME MOVERS

FPC Account Number 343 Prime Movers (Gas Turbines)	Sector Number	Cost
Gas Turbines	43 or 60	$12,700,000
Start-up Motors	53	15,000
Torque Converter	49	150,000
Lube Oil Purification & Storage	49	60,000
Lube Oil Fire Protection	49	60,000
Turbine Air Precoolers	40	64,000
Air Compressors, Service & Installation	49	100,000
Breeching Including Lining, Silencers & Insulation	11	720,000
Expansion Joints	42	100,000
Inlet Filer Screens	42	60,000
Turbine Enclosure Air Cooler	40	40,000
Emergency Cooling Water Tank, Pump & Piping	40	8,000
Fuel Oil Heaters and Pumps	49	22.000
Miscellaneous Pumps and Tanks	49	10,000
Control Boards Instruments & Controls	53	100,000
Computer	51	200,000
Piping	42	800,000
Insulation	36	120,000
Total Account 343		$15,329,000

Source: [39], p. 280

F I G U R E G.3

SECOND GENERATION COGAS PLANT

BREAKDOWN OF FPC ACCOUNT 344 - ELECTRIC GENERATORS

FPC Account Number 344 Electric Generators	Sector Number	Cost
Electric Generators (for Gas Turbines)	53	$5,940,000
H_2 Seal Oil Coolers	40	20,000
Total Account 344		$5,960,000

Source: [39], p. 281

FIGURE G.4

SECOND GENERATION COGAS PLANT

BREAKDOWN OF FPC ACCOUNT 312 - BOILER PLANT EQUIPMENT

FPC Account Number 312 Boiler Plant Equipment	Sector Number	Cost
Waste Heat Boiler	40	$9,800,000
Boiler Feed Pumps	49	474,000
Boiler Feed Tank and Deaerator	49	40,000
Water Treatment	40,49	240,000
Condensate Storage Tank	40	25.700
Stack	(Included in Account 341)	
Process Steam Heat Exchanger		--
Miscellaneous Pumps	49	100,000
Piping	42	2,900,000
Insulation	36	270,000
Controls (Boiler & Turbine Generator)	53	300,000
Computer (Additive to Gas Turbine)	51	50,000
Total Account 312		$14,199,700

Source: [39], p. 282

FIGURE G.5

SECOND GENERATION COGAS PLANT

BREAKDOWN OF FPC ACCOUNT 314 - STEAM TURBINE GENERATOR UNITS

FPC Account Number 314 Steam Turbine Generator Units	Sector Number	Cost
Turbogenerators	43	$8,942,000
Pedastal	(Included in Acct. 341)	
Condenser & Tubes	40	805,000
Condenser Vacuum Pumps with Motor	49	90,000
Condensate Pumps with Motors	49	61,200
Cooling Towers	11	4,000,000
Circulating Water Piping	(Included in Acct. 341)	
Circulating Water Valves & Expansion Joints	42	90,000
Circulating Water Pumps	49	310,000
Make-up structure Screen & Pumps	49	250,000
Chlorination Equipment	40, 49	20,000
Lube Oil Purification	(Included in Turbogenerator Price)	
Total Account 314		$14,568,200

Source: [39], p. 283

F I G U R E G.6

SECOND GENERATION COGAS PLANT

BREAKDOWN OF FPC ACCOUNT 345 - ACCESSORY ELECTRICAL EQUIPMENT

FPC Account Number 345 Accessory Electrical Equipment	Sector Number	Cost
Auxiliary Transformers		$ 39,000
Start-up Transformers		297,300
8000 A Isolated Phase Bus		432,600
1200 A Isolated Phase Bus		82,800
Potential Transformer		39,000
Surge Protection		19,200
480 Vole Power Switchgear		124,300
480 Volt Motor Control Centers		58,530
Remote Motor Controls		5,250
Duplex Relay Switchboard		68,000
Annunciator Panel		16,500
Control Console		34,500
Turbine Control Panel	53	6,000
Temperature Detection Panel		15,000
Equipment Connections		1,800,000
Testing		378,300
250 V DC Switchboard		27,500
250 DC Panelboard		3,600
Station Battery & Rack		53,000
Battery Chargers		56,500
Cable Tray		82,000
600 V Instrument Cable		117,660
600 V Control Cable		236,900
Grounding Systems		370,500
480 V Valve Control Center		25,600
Conduit-fittings		150,000
600 V Power Cable		76,355
1000 V Power Cable		39,580
16000 A Isolated Phase Bus		426,100
2000 A Segregated Phase Bus		348,000
5 KV Switchgear		161,300
5 KV Power Cable		35,379
Total		$5,626,254

Source: [39], p. 284

F I G U R E G.7

SECOND GENERATION COGAS PLANT

BREAKDOWN OF FPC ACCOUNT 346 - MISCELLANEOUS POWERPLANT EQUIPMENT

FPC Account Number 346 Miscellaneous Powerplant Equipment	Sector Number	Cost
Laboratory and Sampling Equipment	53,62	$ 20,000
Tools, Shop, Stores & Work Equipment	42,47	125,000
Lockers	23	3,000
Emergency Equipment	49	10,000
Miscellaneous Cranes & Hoists	46	30,000
Portable Fire Extinguishers	64	20,000
Communication Equipment	56	50,000
Lunch Room Equipment	23	20,000
Office Furniture & Machines	23,51	15,000
Total Account 346		$293,000

Source: [39], p. 285

FIGURE G.8

SECOND GENERATION COGAS PLANT

BREAKDOWN OF FPC ACCOUNT 353 - MISCELLANEOUS STATION EQUIPMENT

FPC Account Number 353 Miscellaneous Station Equipment	Sector Number	Cost
346 KV Main Oil C/B		$ --
132 KV Outdoor Switchgear		--
705 MVA Auto-Transformers		--
370 MVA Transformer		--
410 MVA Transformer	53	--
400 MVA Transformer		990,000
450 MVA Transformer		619,000
228 MVA Transformer		--
506 MVA Transformer		--
Total Account 353		$1,609,000

Source: [39], p. 285

FIGURE G.9

CAPITAL COST SUMMARY FOR SECOND GENERATION ADVANCED COGAS POWER SYSTEMS

Federal Power Commission Acct. No.		Sector Number	Cost
340	Land & Land Rights	VA	$ 225,000
341	Structures & Improvements	*	7,742,500
343	Prime Movers (Gas Turbines)	*	15,329,000
344	Electric Generators (for Gas Turbines)	*	5,960,000
312	Boiler Plant Equipment	*	14,199,700
314	Steam Turbine-Generator Units	*	14,568,200
345	Accessory Electrical Equipment	*	5,626,300
346	Miscellaneous Powerplant Equipment	*	293,000
353	Miscellaneous Station Equipment	*	1,609,000
	Sub-total		$65,552,700
	Other Expenses	VA	1,250,000
	Total Direct Cost		66,802,700
	Engineering, Design, Construction, Supervision, and Contingency	70,73	10,590,300
	Sub-total		77,393,000
	Escalation		7,449,000
	Sub-total		84,842,000
	Interest During Construction	VA	9,163,000
	Total Estimated Cost		$94,005,000

*See previous tables for breakdown

Source: [39], p. 287

FIGURE G.10

LABOR MARGINS ON VARIOUS FPC CAPITAL ACCOUNTS

FPC Account	Name	Labor Margins[1]
311, 341	Structures & Improvements	25%
312	Boiler Plant Equipment	25%
343	Prime Movers (Gas Turbines)	7.5%
344	Electric Generators	6.5%
314	Steam Turbine Generator Units	5.5%
345	Accessory Electrical Equipment (Turbine plants)	25%
346	Miscellaneous Power Plant Equipment (Turbine Plants)	30%
353	Miscellaneous Station Equipment	25%
315	Accessory Electric Equipment (Steam plants)	32.5%
316	Miscellaneous Power Plant Equipment (Steam Plants)	17.5%

1 This amount of the total cost shown in each account is typically labor cost, while the rest is material cost.

Source: [5]

cost data presented was even close to being accurate. This latter question is impossible to answer, but the installed capacity figure of $100/KW seems amazingly low.

Figure G.11 lists the non-zero components of the final percentage capital vector (see footnote 27).

FIGURE G.11

COMBINED GAS AND STEAM CYCLE CAPITAL EXPENDITURE COEFFICIENTS
(NON-ZERO PERCENTAGES)[1]

104 Order Sector Number	Industry	Coefficient
11	New Construction	0.203699
24	Other Furniture and Fixtures	0.000188
44	Stone and Clay Products	0.002821
51	Plumbing and Structural Metals	0.084038
54	Other Fabricated Metal Products	0.027497
55	Engines & Turbines	0.198016
58	Material Handling Machinery	0.000439
61	General Industry Machinery	0.015191
63	Office Comp Machinery	0.001989
66	Electrical Industry	0.111873
69	Radio, TV and Comm. Equipment	0.000355
75	Scientific & Control Ins.	0.000064
77	Miscellaneous Manufacturing	0.000103
78	Railroad Transportation	0.000079
80	Truck Transportation	0.002890
81	Water Transportation	0.004015
82	Air Transportation	0.000166
89	Wholesale Trade	0.024417
90	Retail Trade	0.008139
91	Finance and Insurance	0.007106
94	Business Services	0.034487

1 See footnote 27 for definition of percentage capital coefficient

Appendix H Derivation of Technical Coefficients for the Second Generation Gas Turbine Topping Cycle

The data source for this derivation was again the United Aircraft report [39]. In contrast to the other nicely executed capital cost estimates provided in this report, there is no detailed summary anywhere in the book of what operating costs will be. Instead they are estimated simply as: .2 mills/Kwh and .5 mills/Kwhr for operation and maintenance of the steam and gas portions of the plant respectively; 0.2 mills for supplies and materials; and 2.35 mills for low BTU gas fuel. Using a 14% capital charge and a 70% load factor results in a 5.3 mills/Kwhr busbar cost for electricity. This compares to 7.3 mills/Kwhr for a first generation plant and 6.3 mills for a current steam plant (with no stack gas cleaning or cooling tower).

Faced with a problem like this, we allocated the capital charges to value added and the fuel costs to 68.02 which served as the temporary home for low BTU gas. When this derivation is finished, the low BTU gas technical coefficients will be combined with these technical coefficients to form one set of coefficients for a new coal-using electric generation process vector that will be combined with the four others described in Reference 26 to form an augmented I/O matrix.

After these two allocations, the residual was .11845. This residual was allocated according to the gas turbine generation vector described in the Istvan reports [26,27] after the fuel and value added components were removed. The results of this simple scaling procedure was illustrated in Figure H.1 where non-zero technical coefficients for the COGAS plant are displayed. These coefficients are based on a unit Kwhr cost. They must be divided by the average consumers cost per Kwhr before they can be used in the input-output model. This is explained more fully in Reference 27.

FIGURE H.1

TECHNOLOGICAL COEFFICIENTS FOR COGAS CYCLE (Non-Zero)

104 Order Sector Number	Industry	Coefficient[1]
8	Crude Oil & Natural Gas	.462659[2]
12	Maintenance & Repair Service	.072820
33	Drugs, Cleaning, Toilet Preparations	.004074
54	Other Fabricated Metal Products	.001631
64	Service Industry Machinery	.000726
75	Scientific & Control Ins.	.000408
78	Railroad Transportation	.007878
80	Truck Transportation	
81	Water Transportation	
82	Air Transportation	
84	Communications except Radio & TV	.002040
88	Water & Sanitary Services	.003632
89	Wholesale Trade	.016008
90	Retail Trade	.005000
92	Real Estate & Rental	.000115
102	Business Travel & Gifts	.003265
103	Office Supplies	.000816

1 Residual (.11845) after removal of fuel and value-added was prorated on the basis of "Other power" technological coefficients from [26].

2 This entry represents purchases of low BTU gas.

Figure H.2 combines the low BTU gas and COGAS technological coefficients into one process vector. This is done in the following way:

Let $\underline{A}_e$ = low BTU gas technological coefficient vector

$\underline{A}_c$ = COGAS technological coefficient vector

h = COGAS technological coefficient representing low BTU gas purchases (.462659 in sector 8 of Figure H.1)

$\underline{A}_c'$ = Modified COGAS technological coefficient vector with low BTU gas purchase coefficient set to zero (sector 8 of Figure H.1)

$\underline{A}_{lc}$ = combined low BTU gas and COGAS technological coefficient vector.

Then $\underline{A}_{lc} = h\,\underline{A}_e + \underline{A}_c'$

FIGURE H.2

NON-ZERO TECHNOLOGICAL COEFFICIENTS FOR COGAS PLANT COMBINED WITH LOW BTU COAL GASIFICATION

104 Order Sector Number	Industry	Coefficient
11	New Construction	.203699
24	Other Furniture & Fixtures	.000188
44	Stone & Clay Products	.002821
51	Plumbing & Structural Metals	.084038
54	Other Fabricated Metal Products	.027497
55	Engines and Turbines	.198016
58	Material Handling Machinery	.000199
59	Metal Working Machinery	.000439
61	General Industry Machinery	.015191
63	Office Comp Machinery	.001989
66	Electrical Industry	.111873
69	Radio, TV & Communication Equipment	.000355
75	Scientific & Control Insurance	.000064
77	Misc. Manufacturing	.000103
78	Railroad Transportation	.000079
80	Truck Transportation	.002890
81	Water Transportation	.004015
82	Air Transportation	.000166
89	Wholesale Trade	.024417
90	Retail Trade	.008139
91	Finance and Insurance	.007106
94	Business Services	.034487

Appendix I Analytical Convergence Procedure for 1985 Projections

I.1 Iso-Income Elastic Case

The problem is: given the system structure defined in Chapter 2

$$\underline{X}_1 = (\underline{I}-\underline{A}-\underline{C})^{-1} (\underline{Y} - \underline{C}\ \underline{X}_0) \qquad (I.1)$$

(where $\underline{Y}$ equals the $\underline{Y}^F$ of Chapter 2) and

$$\underline{Z} = \underline{C}\ (\underline{X}_1 - \underline{X}_0) \qquad (I.2)$$

(where $\underline{Z}$ equals $\underline{Y}^I$ of Chapter 2)

and given an initial projection of final demand ($\underline{Y} + \underline{Z}$), find a new final demand ($\underline{Y}' + \underline{Z}'$) such that $| \underline{Y}' + \underline{Z}' | = GNP_0$ and $\underline{Y}' = (1 + \delta)\ \underline{Y}$. This last constraint assumes all non-investment components of final demand (y_i) have the same income elasticity, i.e. as GNP changes, all non-investment final demand purchases change by the same percentage.

This is easily solved.

$$\text{Let} \quad \underline{B} = (\underline{I} - \underline{A} - \underline{C})^{-1} \qquad (I.3)$$

$$\text{and} \quad \underline{M} = (\underline{C}\ \underline{B}\ \underline{C} + \underline{C})\ \underline{X}_0 \qquad (I.4)$$

$$\text{Then} \quad \underline{Z} = \underline{C}(\underline{X}_1 - \underline{X}_0) = \underline{C}\ \underline{B}\ \underline{Y} - \underline{M} \qquad (I.5)$$

$$\text{Also} \quad \underline{Y}' = (1 + \delta)\ \underline{Y} \rightarrow \underline{Z}' = \underline{C}\ \underline{B}\ \underline{Y}' - \underline{M}$$

$$\text{and} \quad GNP_0 = \Sigma\ y_i' + \Sigma\ z_i'$$

$$= (1 + \delta)\ \Sigma\ y_i + \Sigma\ (1 + \delta)(\underline{CBY})_i - \Sigma\ m_i$$

Since $\underline{CBY} = \underline{Z} + \underline{M}$,

$$GNP_o = (1+\delta) \sum_i y_i + (1+\delta) \sum_i z_i + \delta \sum_i m_i$$

$$= GNP + \delta(GNP + \sum_i m_i) \qquad (1.6)$$

Thus $$\delta = \frac{GNP_o - GNP}{GNP + \Sigma m_i} \qquad (1.7)$$

or $$\lambda = (1+\delta) = \frac{GNP_o + \Sigma m_i}{GNP + \Sigma m_i} \qquad (1.8)$$

Thus by calculating the initial projection $\underline{Y}$ and $\underline{Z}$ and any multiple of these, $\alpha\underline{Y}$ and Z_α we can find $\underline{M}$ by subtracting Z_α and $^\alpha\underline{Z}$ or

$$Z_\alpha - \alpha\underline{Z} = \underline{CB}\ (\alpha\underline{Y}) - M - \alpha\underline{C}\ \underline{B}\ \underline{Y} + \underline{M} = (\alpha-1)\ M$$

or $$\underline{M} = \frac{1}{\alpha-1}\ (\underline{Z} - \underline{Z}) \qquad (1.9)$$

and $$|\underline{M}| = \Sigma\ m_i = \frac{1}{\alpha-1}\ [\Sigma\ (Z_\alpha) - \Sigma(Z)_i] \qquad (1.10)$$

Since $GNP = \Sigma y_i + \Sigma z_i$

from the initial projection and since GNP_o is given, λ is easily calculated from 1.8

Then $\underline{Y}' = \lambda\underline{Y}$

1.2 Income Elastic Case

Now if the income elasticities are different, C_i for the ith sector, and if we assume the change in income is equal to the change to GNP, then

$$y_i' - y_i = e_i\ y_i\ (\Delta I) = e_i\ y_i\ (\Delta\ GNP)$$

For our model we take

$$\underline{Y}' - \underline{Y} = \delta \, \underline{D} \, \underline{Y} \qquad (1.11)$$

where $\underline{D}$ = diag (d_i) and d_i is proportional to e_i

Thus our actual assumption is that the change in income is proportional (not equal) to the change in GNP.

Then $\underline{Y}' = (\underline{I} + \delta \, \underline{D}) \, \underline{Y}$ (1.12)

$$\underline{Z}' = \underline{C} \, \underline{B} \, \underline{Y}' - \underline{M} \qquad (1.13)$$

Solve for δ such that $\Sigma \, y_i' + \Sigma \, z_i = GNP_o$

$$GNP_o = \Sigma \, y_i + \delta \, \Sigma \, d_i y_i + \Sigma \, (\underline{CBY})_i + \Sigma \, \delta \, (\underline{CBDY})_i - \Sigma \, m_i$$

$$= \Sigma \, y_i + \delta \, \Sigma \, d_i y_i + \Sigma \, (z_i + m_i) + \delta \, \Sigma (\underline{CBDY})_i - \Sigma \, m_i$$

$$+ \, GNP + \delta \, \Sigma \, [(\underline{CB} + \underline{I}) \, \underline{DY}]_i$$

Thus

$$\delta = \frac{GNP_o - GNP}{\Sigma[(CB+I) \, \underline{DY}]_i} \qquad (1.14)$$

or

$$= \frac{GNP_o - GNP \, (\underline{Y})}{GNP(\underline{DY}) + \Sigma \, m_i} \qquad (1.15)$$

where GNP $(\underline{DY})$ is interpreted as the GNP of the product $\underline{DY}$.

The procedure is basically the same as it was for the iso-elastic case except that these separate final demands must be calculated. These are $\underline{Y}$, $\alpha\underline{Y}$, and $\underline{DY}$. Then $\underline{Y}' = (\underline{I} + \delta\underline{D}) \, \underline{Y}$ where δ can be calculated from 1.15.

Appendix J Detailed Figures

This appendix contains detailed figures that compare both the 1985 unscaled and balanced projections of final demand and total output (Figures J.1 through J.4) for the Low, Medium, High, High plus Hygas, and High plus Hygas plus Gas Turbine cases. Notice how close the unscaled and balanced final demands are.

It also contains in Figures J.5 and J.6 comparisons of the 1980 projected gross private domestic investment (GPDI), GPDI impacts (i.e. total sales caused by GPDI purchases), and total outputs. These comparisons illustrate the dependence (both direct and indirect) of various sectors on capital investment.

F I G U R E J.1

COMPARISON OF UNSCALED 1985 TOTAL FINAL DEMANDS

	1 LOW	2 MEDIUM	3 HIG	4 HIGH+HYGAS	5 HIGH+HYGAS+GT
1 LIVESTOCK & PRODUCTS	3169.9	3169.9	3169.9	3169.9	3169.9
2 OTHER FARM PRODUCTS	12716.5	12716.5	12716.5	12716.5	12715.5
3 FORESTRY & FISHERY PROD	266.8	266.8	266.8	266.8	266.8
4 FARM, FOREST, FISH SERV	-582.7	-582.7	-582.7	-582.7	-582.7
5 FERROUS METAL MINING	500.0	500.0	500.0	500.0	500.0
6 NONFERROUS METAL MINING	496.7	496.7	496.7	496.7	496.7
7 COAL MINING	980.6	980.6	980.6	990.5	986.8
8 CRUDE OIL AND NATURAL GA	86.7	86.7	86.7	86.7	86.7
9 STONE & CLAY MINING	265.8	265.8	265.8	265.8	250.7
10 MINERAL MINING	279.8	279.8	279.8	279.8	279.8
11 NEW CONSTRUCTION	121547.3	129127.4	154903.6	162479.1	156839.3
12 MAINT & REPAIR CONST	13458.0	13458.0	13458.0	13458.0	13458.1
13 ORDNANCE, ACCESSORIES	9729.8	9729.8	9729.8	9729.8	9729.8
14 FOOD & KINDRED PRODUCTS	98234.7	98234.7	98234.7	98234.7	98234.7
15 GRAIN MILLING	5404.7	5404.7	5404.7	5404.7	5404.7
16 TOBACCO MANUFACTURES	8357.0	8357.0	8357.0	8357.0	8357.0
17 FABRIC,YARN,THRD MILLS	2568.3	2568.3	2568.3	2568.3	2568.3
18 MISC. TEXTILE GOODS	3701.4	3707.1	3726.0	3731.9	3727.8
19 APPAREL	31701.3	31701.3	31701.3	31701.3	31700.1
20 MISC FAB TEXTILE PRODUCT	4091.2	4091.2	4091.2	4091.2	4091.2
21 LUMBER & WOOD PRODS	1589.4	1652.7	1864.1	1914.3	1883.6
22 WOODEN CONTAINERS	59.5	59.5	59.5	59.5	59.5
23 HOUSEHOLD FURNITURE	9189.6	9198.9	9230.0	9239.9	9233.1
24 OTHER FURN & FIXTURES	4055.3	4208.3	4721.0	4885.5	4773.6
25 PULP MILLS	1237.2	1237.2	1237.2	1237.2	1237.2
26 PAPER & ALLIED PRODS	5408.6	5410.2	5414.6	5415.3	5415.0
27 PAPER CONTAINERS, BOXES	405.3	405.3	405.3	405.3	405.3
28 PRINTING & PUBLISHING	10228.7	10228.7	10228.7	10228.7	10228.6
29 INDUSTRIAL CHEMICALS	6080.4	6080.8	6082.4	6103.3	6100.9
30 FERTILIZERS	817.8	817.8	817.8	817.8	817.6
31 AGR & MISC CHEMICALS	2248.9	2248.9	2248.9	2248.9	2245.1
32 PLASTICS & SYNTH MTRL	2944.7	2944.8	2945.0	2945.0	2945.0
33 DRUGS, CLNG, TOILET PREP	21080.7	21080.7	21080.7	21080.7	21080.7
34 PAINTS & PRODUCTS	199.3	199.3	199.3	199.3	196.8
35 PETROLEUM REFINING	20830.2	21868.0	22742.8	22742.8	22706.2
36 PAVING MIXTURES	7.9	7.9	7.9	7.9	2.8
37 ASPHALT FELTS, COATINGS	11.6	11.6	11.6	11.6	10.0
38 RUBBER & PLASTIC PRODS	6916.3	6929.5	6972.3	6985.9	6976.0
39 LEATHER TANNING PROD	74.2	74.2	74.2	74.2	74.2
40 FOOTWEAR & LEATHER PROD	4006.6	4007.8	4011.5	4012.8	4011.9
41 GLASS & GLASS PRODS	903.5	903.5	903.5	903.5	903.0
42 CEMENT, HYDRAULIC	10.7	10.7	10.7	10.7	10.9
43 LIME	3.5	3.5	3.5	3.5	2.9
44 STONE & CLAY PRODS	1371.0	1386.1	1434.2	1449.8	1449.9
45 PRIMARY STEEL	1384.7	1390.7	1408.6	1411.2	1414.4
46 IRON & STEEL FOUNDRIES	122.5	122.7	123.1	123.3	97.7
47 IRON & STEEL FORGINGS	40.7	40.9	41.4	41.5	41.5
48 PRIMARY NON-FER METAL	792.8	792.8	792.8	792.8	792.8
49 MISC NON-FER METALS	800.3	848.6	990.1	1010.4	1004.0
50 METAL CONTAINERS	56.9	57.6	60.0	60.7	60.1
51 PLUMBING&STRUCTURAL META	2595.7	3405.2	4658.3	5730.5	5300.1
52 HEATING EQUIP EXC ELEC	303.9	303.9	303.9	303.9	300.5
53 SCREWS & METAL STAMPINGS	2023.7	2023.7	2023.7	2023.7	2014.0

F I G U R E J.1 (continued)

	1 LOW	2 MEDIUM	3 HIG	4 HIGH+HYGAS	5 HIGH+HYGAS+GT
54 OTHER FAB METAL PRODS	3469.8	3581.9	3960.1	4122.3	4007.0
55 ENGINES & TURBINES	4358.4	4567.3	5207.6	5414.4	5359.1
56 FARM MACHINERY & EQUIP	3842.6	3894.5	4026.7	4070.1	4039.3
57 CONSTRUCTION&MINING EQUI	5166.4	7061.3	13433.8	15488.1	14082.9
58 MATERIAL HNDLG MACH	3091.0	3455.1	4744.6	5154.2	4877.5
59 METALWORKING MACH	3249.3	3862.7	5973.0	6660.5	6195.6
60 SPECIAL INDUSTRY MACH	8005.8	8550.4	10690.5	11239.3	10943.3
61 GENERAL INDUSTRY MACH	3885.1	4267.3	5584.3	6217.0	5893.4
62 MACHINE SHOP PRODUCTS	424.6	424.7	424.9	424.9	424.4
63 OFFICE COMP MACH	20530.1	21968.1	26780.0	28250.2	27189.6
64 SERVICE INDUSTRY MACH	2927.2	3051.3	3464.2	3641.0	3542.9
65 REFRIC MACHINERY	3951.6	4073.9	4481.8	4610.2	4516.3
66 ELECTRICAL INDUSTRY	6507.1	7255.9	9744.5	10429.2	9930.4
67 HOUSEHOLD APPLIANCES	11407.5	11421.2	11467.2	11481.8	11471.9
68 ELEC LIGHTING EQUIP	1845.4	1888.5	2017.3	2042.2	2023.9
69 RADIO,TV & COMM EQUIP	32576.8	33206.5	35311.3	35547.1	35490.6
70 ELEC COMP & ACCESS	3913.2	3914.1	3917.1	3918.0	3917.1
71 ELEC MACH EQP & SUPPLIES	2661.0	2675.8	2727.0	2739.8	2728.3
72 MOTOR VEHICLES & EQUIP	61236.5	63457.6	70911.0	73218.2	71553.3
73 AIRCRAFT & PARTS	16119.8	16509.6	17804.3	18194.1	17896.4
74 OTHER TRANSPORT EQUIP	8185.3	8482.4	9481.0	9826.2	9513.4
75 SCIENTIFIC & CONTROL INS	6972.4	7084.2	7460.8	7573.7	7489.8
76 OPTICAL & PHOTO EQUIP	10364.4	11039.8	13299.7	13785.6	13490.2
77 MISC MANUFACTURING	15850.2	15905.6	16085.9	16143.6	16100.9
78 RAILROAD TRANSPORTATION	9768.5	9899.5	10344.6	10472.0	10371.3
79 LOCAL PASSENGER TRANSPOR	8303.4	8303.4	8303.4	8303.4	8303.4
80 TRUCK TRANSPORTATION	11654.1	11816.8	12387.9	12559.2	12436.6
81 WATER TRANSPORTATION	7050.6	7060.2	7090.5	7115.1	7107.7
82 AIR TRANSPORTATION	6557.3	6564.1	6585.6	6590.9	6584.7
83 MISC TRANSPORTATION	1237.5	1248.8	1287.2	1298.3	1289.4
84 COMMUNICATIONS EXC RAD&T	27318.8	27498.0	28097.3	28278.5	28147.4
85 RADIO & TV BROADCASTING	194.9	194.9	194.9	194.9	194.9
86 ELECTRIC UTILITIES	17903.4	18977.6	19736.7	19736.7	19736.8
87 GAS UTILITIES	8874.3	9406.7	9783.0	9783.0	9783.0
88 WATER & SANITARY SERV	3230.1	3230.1	3230.1	3230.1	3230.1
89 WHOLESALE TRADE	70408.5	71210.4	73913.9	74925.3	74230.0
90 RETAIL TRADE	144316.0	145120.3	147830.8	148691.2	148087.1
91 FINANCE AND INSURANCE	40701.0	40706.7	40723.6	40754.8	40755.9
92 REAL ESTATE & RENTAL	183230.3	183769.8	185573.3	186118.4	185724.1
93 HOTEL, PERS & REPAIR SER	31909.3	31909.4	31909.6	31909.6	31909.6
94 BUSINESS SERVICES	11161.6	11197.6	11303.0	11368.8	11381.1
95 RESEARCH AND DEVELOPMENT	931.0	931.0	931.0	931.0	931.0
96 AUTO REPAIR & SERVICE	12139.4	12139.4	12139.4	12139.4	12139.6
97 AMUSEMENTS	8678.1	8678.1	8678.1	8678.1	8678.1
98 MEDICAL & EDUCATION SERV	88089.6	88089.6	88089.6	88095.6	88089.6
99 FED GOVT ENTERPRISES	3543.1	3543.1	3543.1	3543.1	3543.1
100 STATE&LOCAL GOVT ENTERPR	2590.3	2590.3	2590.3	2590.3	2590.4
101 IMPORTS	-73498.9	-73498.9	-73498.9	-73498.9	-73498.9
102 BUSINESS TRAVEL, GIFTS	0.0	0.0	0.0	0.0	0.3
103 OFFICE SUPPLIES	1683.7	1683.7	1683.7	1683.7	1683.7
104 SCRAP, SECONDHAND GOODS	2797.6	2797.6	-30.0	2797.6	2797.6
105 TOTAL	1290286.0	1321172.0	1394916.0	1421395.0	1404875.0

F I G U R E J.2

COMPARISON OF BALANCED 1985 TOTAL FINAL DEMANDS

	1 LOW	2 MEDIUM	3 HIGH	4 HIGH+HYGAS	5 HIGH+HYGAS+GT
1 LIVESTOCK & PRODUCTS	3191.1	3180.2	3145.0	3134.7	3141.7
2 OTHER FARM PRODUCTS	12801.3	12757.8	12616.4	12575.1	12602.2
3 FORESTRY & FISHERY PROD	269.6	267.7	264.7	263.8	264.4
4 FARM, FOREST, FISH SERV	-586.6	-584.6	-578.1	-576.2	-577.5
5 FERROUS METAL MINING	503.3	501.6	496.1	494.5	495.6
6 NONFERROUS METAL MINING	500.0	498.3	492.8	491.2	492.3
7 COAL MINING	987.2	983.8	972.9	977.5	978.5
8 CRUDE OIL AND NATURAL GA	87.2	86.9	86.0	85.7	85.9
9 STONE & CLAY MINING	267.6	266.7	263.7	262.9	248.3
10 MINERAL MINING	281.6	280.7	277.6	276.7	277.3
11 NEW CONSTRUCTION	134027.8	135240.2	139072.9	139600.1	138700.5
12 MAINT & REPAIR CONST	13547.8	13501.8	13352.1	13308.4	13338.2
13 ORDNANCE, ACCESSORIES	9794.7	9761.5	9653.2	9621.6	9643.2
14 FOOD & KINDRED PRODUCTS	98890.3	98554.3	97461.6	97142.4	97359.9
15 GRAIN MILLING	5440.8	5422.3	5362.2	5344.6	5356.6
16 TOBACCO MANUFACTURES	8412.7	8384.2	8291.2	8264.0	8282.6
17 FABRIC,YARN,THRD MILLS	2585.4	2576.7	2548.1	2539.8	2545.4
18 MISC. TEXTILE GOODS	3737.4	3724.7	3682.7	3670.4	3678.7
19 APPAREL	31912.9	31804.5	31451.8	31348.9	31417.8
20 MISC FAB TEXTILE PRODUCT	4118.5	4104.5	4059.0	4045.7	4054.7
21 LUMBER & WOOD PRODS	1684.3	1699.2	1742.9	1740.6	1745.2
22 WOODEN CONTAINERS	59.9	59.7	59.0	58.8	58.9
23 HOUSEHOLD FURNITURE	9272.7	9239.5	9130.6	9098.9	9120.3
24 OTHER FURN & FIXTURES	4379.1	4366.8	4316.6	4304.0	4311.5
25 PULP MILLS	1245.5	1241.3	1227.5	1223.5	1226.2
26 PAPER & ALLIED PRODS	5445.8	5428.3	5370.7	5353.1	5365.2
27 PAPER CONTAINERS, BOXES	408.0	406.6	402.1	400.8	401.7
28 PRINTING & PUBLISHING	10296.9	10261.9	10148.2	10114.9	10137.5
29 INDUSTRIAL CHEMICALS	6121.6	6100.8	6033.7	6031.6	6043.5
30 FERTILIZERS	823.3	820.5	811.4	808.7	810.3
31 AGR & MISC CHEMICALS	2263.9	2256.2	2231.2	2223.8	2225.0
32 PLASTICS & SYNTH MTRL	2964.6	2954.5	2917.9	2912.0	2918.5
33 DRUGS, CLNG, TOILET PREP	21221.3	21149.2	20914.7	20846.3	20892.9
34 PAINTS & PRODUCTS	200.6	200.0	197.7	197.1	195.0
35 PETROLEUM REFINING	20767.9	21939.2	22563.8	22489.9	22503.5
36 PAVING MIXTURES	7.9	7.9	7.8	7.8	2.7
37 ASPHALT FELTS, COATINGS	11.7	11.7	11.5	11.5	9.9
38 RUBBER & PLASTIC PRODS	6981.5	6961.3	6893.6	6874.0	6886.7
39 LEATHER TANNING PROD	74.7	74.4	73.6	73.3	73.5
40 FOOTWEAR & LEATHER PROD	4035.6	4021.9	3977.2	3964.2	3973.0
41 GLASS & GLASS PRODS	909.5	906.4	896.4	893.4	895.0
42 CEMENT, HYDRAULIC	10.8	10.8	10.6	10.6	10.8
43 LIME	3.5	3.5	3.5	3.5	2.9
44 STONE & CLAY PRODS	1400.0	1400.3	1397.9	1397.3	1406.7
45 PRIMARY STEEL	1398.1	1397.3	1392.0	1387.6	1394.8
46 IRON & STEEL FOUNDRIES	123.8	123.3	115.9	121.2	96.1
47 IRON & STEEL FORGINGS	41.3	41.1	40.7	40.6	40.8
48 PRIMARY NON-FER METAL	793.1	795.4	786.6	784.0	785.7
49 MISC NON-FER METALS	833.2	867.3	939.9	938.3	945.7
50 METAL CONTAINERS	58.5	58.4	57.9	57.7	57.8
51 PLUMBING&STRUCTURAL META	3474.7	3640.3	4080.9	4736.6	4534.4
52 HEATING EQUIP EXC ELEC	305.9	304.9	301.5	300.5	297.8
53 SCREWS & METAL STAMPINGS	2037.3	2030.3	2007.8	2001.2	1995.9

F I G U R E J.2 (continued)

	1 LOW	2 MEDIUM	3 HIGH	4 HIGH+HYGAS	5 HIGH+HYGAS+GT
54 OTHER FAB METAL PRODS	3641.9	3666.2	3741.0	3797.6	3755.2
55 ENGINES & TURBINES	4591.8	4681.8	4907.0	4971.0	4999.8
56 FARM MACHINERY & EQUIP	4010.9	3966.7	3821.9	3778.2	3806.5
57 CONSTRUCTION&MINING EQUI	8253.0	8572.2	9521.8	9823.8	9592.2
58 MATERIAL HNDLG MACH	3735.7	3770.3	3925.6	3973.5	3941.3
59 METALWORKING MACH	4328.2	4391.0	4606.6	4685.6	4630.1
60 SPECIAL INDUSTRY MACH	9037.6	9055.4	9377.2	9356.5	9348.2
61 GENERAL INDUSTRY MACH	4500.9	4568.9	4800.4	5051.7	4973.7
62 MACHINE SHOP PRODUCTS	427.6	426.1	418.4	419.9	420.4
63 OFFICE COMP MACH	23215.5	23282.6	23401.1	23388.6	23330.7
64 SERVICE INDUSTRY MACH	3192.3	3181.0	3133.6	3159.5	3160.1
65 REFRIG MACHINERY	4222.4	4206.4	4144.6	4126.3	4131.8
66 ELECTRICAL INDUSTRY	7569.4	7776.5	8386.3	8464.6	8372.5
67 HOUSEHOLD APPLIANCES	11516.1	11474.2	11337.0	11297.0	11324.2
68 ELEC LIGHTING EQUIP	1891.0	1910.9	1958.5	1957.3	1956.9
69 RADIO,TV & COMM EQUIP	33936.9	33871.9	33614.6	33512.0	33555.3
70 ELEC COMP & ACCESS	3945.5	3929.9	3753.7	3864.0	3873.8
71 ELEC MACH EQP & SUPPLIES	2703.1	2696.3	2675.2	2665.8	2669.5
72 MOTOR VEHICLES & EQUIP	65526.3	65557.1	65526.4	65466.9	65400.0
73 AIRCRAFT & PARTS	16897.5	16890.2	16830.0	16794.5	16785.4
74 OTHER TRANSPORT EQUIP	8761.6	8764.5	8757.8	8783.6	8689.0
75 SCIENTIFIC & CONTROL INS	7200.9	7196.0	7175.2	7162.5	7163.2
76 OPTICAL & PHOTO EQUIP	11607.6	11648.5	11733.9	11732.6	11702.1
77 MISC MANUFACTURING	16041.0	15998.8	15853.5	15811.8	15836.5
78 RAILROAD TRANSPORTATION	10046.5	10035.5	9997.3	9973.8	9976.8
79 LOCAL PASSENGER TRANSPOR	8358.8	8330.4	8238.1	8211.1	8229.5
80 TRUCK TRANSPORTATION	11998.2	11985.1	11956.9	11939.5	11945.1
81 WATER TRANSPORTATION	7110.1	7089.1	7019.2	7011.4	7024.9
82 AIR TRANSPORTATION	6608.6	6589.1	6524.1	6503.7	6515.5
83 MISC TRANSPORTATION	1263.7	1261.6	1254.6	1251.6	1252.5
84 COMMUNICATIONS EXC RAD&T	27809.8	27738.0	27491.8	27412.4	27458.0
85 RADIO & TV BROADCASTING	196.2	195.5	193.3	192.7	193.1
86 ELECTRIC UTILITIES	18022.9	19039.4	19581.4	19517.3	19561.1
87 GAS UTILITIES	8933.5	9437.3	9706.0	9674.2	9695.9
88 WATER & SANITARY SERV	3251.6	3240.6	3204.6	3194.1	3201.3
89 WHOLESALE TRADE	72326.7	72148.5	71534.6	71400.3	71504.1
90 RETAIL TRADE	146729.0	146299.6	144867.8	144448.6	144708.5
91 FINANCE AND INSURANCE	40976.5	40841.0	40398.0	40290.6	40383.4
92 REAL ESTATE & RENTAL	185380.3	184819.9	182958.0	182391.1	182752.1
93 HOTEL, PERS & REPAIR SER	32122.3	32013.2	31658.4	31554.7	31625.4
94 BUSINESS SERVICES	11260.4	11245.9	11182.4	11190.4	11234.4
95 RESEARCH AND DEVELOPMENT	937.2	934.0	923.7	920.6	922.7
96 AUTO REPAIR & SERVICE	12220.4	12178.9	12043.9	12004.4	12031.5
97 AMUSEMENTS	8736.0	8706.3	8609.8	8581.6	8600.8
98 MEDICAL & EDUCATION SERV	88677.4	88376.1	87396.3	87110.1	87305.1
99 FED GOVT ENTERPRISES	3566.7	3554.6	3515.2	3503.7	3511.5
100 STATE&LOCAL GOVT ENTERPR	2607.6	2598.7	2569.9	2561.5	2567.3
101 IMPORTS	-73989.4	-73737.9	-72920.4	-72681.7	-72844.4
102 BUSINESS TRAVEL, GIFTS	0.0	0.0	0.0	0.0	0.3
103 OFFICE SUPPLIES	1695.0	1689.2	1670.5	1665.0	1668.8
104 SCRAP, SECONDHAND GOODS	2816.2	2806.7	-29.8	2766.5	2772.7
105 TOTAL	1340845.0	1342986.0	1338973.0	1340905.0	1340959.0

FIGURE J.3

COMPARISON OF UNSCALED 1985 TOTAL OUTPUTS

	1 LOW	2 MEDIUM	3 HIGH	4 HIGH+HYGAS	5 HIGH+HYGAS+GT
1 LIVESTOCK & PRODUCTS	52823.297	52923.887	53265.035	53371.191	53297.410
2 OTHER FARM PRODUCTS	48729.555	48890.680	49437.918	49603.773	49484.430
3 FORESTRY & FISHERY PROD	2848.828	2907.715	3109.537	3169.202	3125.708
4 FARM, FOREST, FISH SERV	2287.006	2303.986	2361.705	2379.329	2367.461
5 FERROUS METAL MINING	3263.226	3375.354	3759.240	3886.951	3801.647
6 NONFERROUS METAL MINING	3600.808	3700.464	4043.854	4153.387	4080.324
7 COAL MINING	4834.766	5026.574	5395.922	6847.578	6827.359
8 CRUDE OIL AND NATURAL GA	25864.680	26942.492	28309.453	28795.098	28100.598
9 STONE & CLAY MINING	4368.461	4547.859	5160.367	5449.473	5297.016
10 MINERAL MINING	2850.823	2882.011	3014.765	3047.553	3025.962
11 NEW CONSTRUCTION	121543.125	129128.500	154904.875	162481.563	155841.500
12 MAINT & REPAIR CONST	44863.723	45175.484	46202.473	46597.453	46292.406
13 ORDNANCE, ACCESSORIES	12019.754	12059.828	12194.723	12236.012	12206.461
14 FOOD & KINDRED PRODUCTS	130617.938	130810.188	131471.563	131681.125	131539.313
15 GRAIN MILLING	18083.191	18118.887	18243.566	18281.560	18255.473
16 TOBACCO MANUFACTURES	10295.234	10303.441	10331.453	10340.625	10334.598
17 FABRIC, YARN, THRD MILLS	32093.953	32209.723	32668.762	32795.672	32707.500
18 MISC. TEXTILE GOODS	9841.422	9923.297	10302.359	10392.387	10329.637
19 APPAREL	39668.285	39700.438	39815.254	39850.754	39825.453
20 MISC FAB TEXTILE PRODUCT	7196.242	7228.453	7338.281	7372.609	7348.281
21 LUMBER & WOOD PRODS	19955.359	20731.129	23371.203	24154.441	23595.297
22 WOODEN CONTAINERS	620.018	628.274	656.455	665.429	659.156
23 HOUSEHOLD FURNITURE	10846.949	10916.500	11151.547	11223.711	11171.566
24 OTHER FURN & FIXTURES	5056.316	5255.816	5926.273	6138.867	5991.836
25 PULP MILLS	4110.461	4146.410	4321.172	4360.188	4333.168
26 PAPER & ALLIED PRODS	33235.355	33665.563	35160.086	35617.922	35302.129
27 PAPER CONTAINERS, BOXES	12311.098	12462.223	12998.203	13159.391	13048.066
28 PRINTING & PUBLISHING	38964.816	39363.816	40699.785	41128.961	40844.941
29 INDUSTRIAL CHEMICALS	43955.078	44564.711	47302.035	47940.711	47530.816
30 FERTILIZERS	4553.063	4572.273	4642.574	4662.512	4648.316
31 AGR & MISC CHEMICALS	8931.680	9058.781	9516.512	9645.172	9553.242
32 PLASTICS & SYNTH MTRL	28825.148	29172.930	32145.266	32542.555	32264.086
33 DRUGS, CLNG, TOILET PREP	33053.504	33128.973	33410.000	33486.785	33446.406
34 PAINTS & PRODUCTS	5745.035	5867.223	6291.387	6423.699	6324.887
35 PETROLEUM REFINING	41910.898	43712.461	46009.711	46400.824	45388.285
36 PAVING MIXTURES	735.985	761.571	848.322	875.058	850.249
37 ASPHALT FELTS, COATINGS	833.761	860.271	950.305	977.713	955.708
38 RUBBER & PLASTIC PRODS	36516.172	37134.344	40916.617	41629.535	41143.203
39 LEATHER TANNING PROD	1111.629	1117.565	1139.151	1146.073	1141.538
40 FOOTWEAR & LEATHER PROD	4763.355	4770.297	4795.578	4803.141	4797.969
41 GLASS & GLASS PRODS	7348.617	7467.625	7893.805	8022.047	7931.711
42 CEMENT, HYDRAULIC	2895.633	3032.843	3499.525	3641.240	3539.770
43 LIME	576.453	597.291	669.492	693.055	676.717
44 STONE & CLAY PRODS	17290.398	18067.441	20711.660	21522.043	20950.898
45 PRIMARY STEEL	35318.668	36915.285	42323.430	44157.828	42933.660
46 IRON & STEEL FOUNDRIES	6011.336	6352.668	7513.680	7889.355	7607.398
47 IRON & STEEL FORGINGS	2558.989	2706.099	3202.924	3365.529	3256.417
48 PRIMARY NON-FER METAL	9605.723	9944.098	11094.648	11467.672	11219.125
49 MISC NON-FER METALS	27288.859	28407.484	32178.605	33383.422	32574.691
50 METAL CONTAINERS	4735.199	4758.922	4842.223	4866.117	4848.855
51 PLUMBING&STRUCTURAL META	16508.141	17554.484	21452.016	23246.859	22259.723
52 HEATING EQUIP EXC ELEC	2713.904	2811.615	3142.669	3247.445	3168.305
53 SCREWS & METAL STAMPINGS	11018.254	11315.348	12323.938	12651.367	12420.516

F I G U R E J.3 (continued)

	1 LOW	2 MEDIUM	3 HIGH	4 HIGH+HYGAS	5 HIGH+HYGAS+GT
54 OTHER FAB METAL PRODS	20856.617	21591.305	24057.313	24883.410	24302.512
55 ENGINES & TURBINES	6994.305	7346.535	8462.449	8825.730	8668.422
56 FARM MACHINERY & EQUIP	5190.629	5287.242	5613.816	5717.992	5647.148
57 CONSTRUCTION&MINING EQUI	7670.266	9776.379	16857.078	19191.078	17632.375
58 MATERIAL HNDLG MACH	4890.367	5370.578	7056.980	7601.773	7238.066
59 METALWORKING MACH	9216.598	10107.223	13162.723	14158.723	13486.672
60 SPECIAL INDUSTRY MACH	10646.055	11279.816	13755.000	14399.098	13937.379
61 GENERAL INDUSTRY MACH	12004.273	12936.324	16129.398	17375.055	16638.641
62 MACHINE SHOP PRODUCTS	6109.234	6301.879	6960.930	7170.348	7027.898
63 OFFICE COMP MACH	31104.461	32877.219	38809.066	40626.984	39322.910
64 SERVICE INDUSTRY MACH	4015.872	4160.918	4644.078	4844.305	4732.516
65 REFRIG MACHINERY	8934.285	9281.941	10455.836	10817.305	10553.484
66 ELECTRICAL INDUSTRY	19259.391	20624.813	25211.141	26571.816	25612.316
67 HOUSEHOLD APPLIANCES	15222.066	15370.785	15876.422	16030.973	15917.637
68 ELEC LIGHTING EQUIP	7898.773	8188.078	9151.867	9431.223	9230.672
69 RADIO,TV & COMM EQUIP	43960.660	44850.387	47830.180	48733.379	48085.391
70 ELEC COMP & ACCESS	31192.535	31981.609	34627.316	35437.234	34857.313
71 ELEC MACH EQP & SUPPLIES	6763.609	6901.855	7367.172	7509.047	7406.566
72 MOTOR VEHICLES & EQUIP	95957.938	99310.875	110568.750	114073.500	111557.000
73 AIRCRAFT & PARTS	25632.297	26188.953	28048.723	28616.472	28189.387
74 OTHER TRANSPORT EQUIP	10349.512	10714.629	11940.598	12368.281	11995.668
75 SCIENTIFIC & CONTROL INS	13192.129	13465.023	14389.004	14671.723	14468.234
76 OPTICAL & PHOTO EQUIP	15979.117	16762.500	19390.191	20190.086	19616.230
77 MISC MANUFACTURING	24136.160	24315.504	24925.461	25119.055	24983.930
78 RAILROAD TRANSPORTATION	27843.668	28418.566	30399.805	31021.004	30397.348
79 LOCAL PASSENGER TRANSPOR	10688.348	10736.012	10898.504	10951.535	10915.844
80 TRUCK TRANSPORTATION	32754.410	33406.723	35641.098	36323.691	35637.516
81 WATER TRANSPORTATION	10747.563	10835.266	11096.203	11182.867	11043.211
82 AIR TRANSPORTATION	11134.629	11231.609	11557.344	11658.586	11525.563
83 MISC TRANSPORTATION	3906.926	3997.877	4200.168	4242.922	4157.492
84 COMMUNICATIONS EXC RAD&T	54219.617	54835.547	56910.629	57559.406	57102.281
85 RADIO & TV BROADCASTING	3349.664	3403.468	3580.773	3637.884	3600.419
86 ELECTRIC UTILITIES	47223.461	48831.586	53538.875	54212.098	53791.898
87 GAS UTILITIES	32441.816	33806.867	38814.543	39241.793	38084.379
88 WATER & SANITARY SERV	8274.828	8353.367	8621.453	8784.012	8725.504
89 WHOLESALE TRADE	136950.563	139327.875	147418.688	150026.500	148308.750
90 RETAIL TRADE	179204.438	180824.563	186281.188	188011.750	186816.063
91 FINANCE AND INSURANCE	86145.938	86702.563	88556.875	89325.313	88926.750
92 REAL ESTATE & RENTAL	241709.250	243057.063	247296.688	248571.313	247616.563
93 HOTEL, PERS & REPAIR SER	39613.125	39724.734	40105.828	40229.023	40146.930
94 BUSINESS SERVICES	105174.125	106989.688	112974.125	114902.625	113638.625
95 RESEARCH AND DEVELOPMENT	2531.434	2564.632	2677.258	2712.323	2687.613
96 AUTO REPAIR & SERVICE	24347.137	24561.930	25284.398	25512.574	25339.797
97 AMUSEMENTS	15551.098	15600.836	15765.375	15818.063	15781.953
98 MEDICAL & EDUCATION SERV	92994.625	93057.813	93270.500	93338.688	93292.375
99 FED GOVT ENTERPRISES	13073.992	13206.660	13653.762	13791.734	13695.816
100 STATE&LOCAL GOVT ENTERPR	12753.930	12872.992	13281.156	13434.379	13339.422
101 IMPORTS	-15874.203	-14423.918	-9578.984	-8297.867	-9382.984
102 BUSINESS TRAVEL, GIFTS	17332.480	17693.066	18922.328	19324.586	19060.316
103 OFFICE SUPPLIES	6775.484	6854.387	7119.766	7205.980	7148.293
104 SCRAP, SECONDHAND GOODS	2797.563	2797.563	-30.000	2797.563	2797.563
105 TOTAL OUTPUT	2698421.000	2754312.000	2938353.000	2997726.000	2956741.000

FIGURE J.4

COMPARISON OF BALANCED 1985 TOTAL OUTPUTS

	1 LOW	2 MEDIUM	3 HIGH	4 HIGH+HYGAS	5 HIGH+HYGAS+GT
1 LIVESTOCK & PRODUCTS	53329.628	53171.191	52652.441	52499.535	52601.742
2 OTHER FARM PRODUCTS	49300.293	49169.512	48740.680	48608.641	48691.285
3 FORESTRY & FISHERY PROD	2957.340	2960.836	2972.778	2972.196	2970.292
4 FARM, FOREST, FISH SERV	2329.298	2324.667	2309.273	2304.635	2307.635
5 FERROUS METAL MINING	3460.166	3471.784	3510.060	3526.213	3515.753
6 NONFERROUS METAL MINING	3775.811	3786.152	3822.200	3833.183	3826.426
7 COAL MINING	4974.203	5095.836	5214.254	6531.250	6574.781
8 CRUDE OIL AND NATURAL GA	26381.004	27198.438	28135.367	27837.609	27355.379
9 STONE & CLAY MINING	4673.180	4697.086	4774.359	4887.941	4851.629
10 MINERAL MINING	2913.360	2912.615	2935.233	2933.454	2935.285
11 NEW CONSTRUCTION	134028.625	135241.375	139074.250	139602.563	138702.875
12 MAINT & REPAIR CONST	45559.668	45515.918	45338.066	45355.137	45307.422
13 ORDNANCE, ACCESSORIES	12168.398	12132.441	12012.148	11977.430	12000.344
14 FOOD & KINDRED PRODUCTS	131787.688	131381.125	130062.438	129678.250	129939.875
15 GRAIN MILLING	18258.879	18204.660	18030.797	17978.879	18013.836
16 TOBACCO MANUFACTURES	10376.742	10343.203	10234.043	10202.504	10224.172
17 FABRIC,YARN,THRD MILLS	32497.605	32406.941	32172.172	32086.543	32142.453
18 MISC. TEXTILE GOODS	10043.516	10022.129	10047.086	10026.297	10038.492
19 APPAREL	39984.297	39854.609	39437.266	39314.793	39397.012
20 MISC FAB TEXTILE PRODUCT	7297.641	7278.004	7213.855	7194.691	7206.586
21 LUMBER & WOOD PRODS	21271.680	21375.754	21704.105	21748.855	21686.625
22 WOODEN CONTAINERS	637.307	636.733	634.821	634.285	634.424
23 HOUSEHOLD FURNITURE	11038.555	11010.168	10914.656	10885.262	10902.234
24 OTHER FURN & FIXTURES	5459.754	5453.242	5421.191	5411.918	5414.391
25 PULP MILLS	4194.086	4187.313	4214.984	4208.203	4212.328
26 PAPER & ALLIED PRODS	34127.891	34102.297	34039.555	34009.824	34024.453
27 PAPER CONTAINERS, BOXES	12630.984	12618.734	12596.285	12583.063	12590.160
28 PRINTING & PUBLISHING	39820.793	39762.609	39631.063	39593.344	39623.844
29 INDUSTRIAL CHEMICALS	45067.828	45109.473	45871.063	45887.535	45899.922
30 FERTILIZERS	4611.734	4600.949	4570.285	4559.234	4566.055
31 AGR & MISC CHEMICALS	9177.223	9178.961	9206.930	9199.930	9199.555
32 PLASTICS & SYNTH MTRL	29565.641	29535.230	31150.078	31121.117	31134.813
33 DRUGS, CLNG, TOILET PREP	33382.711	33289.734	33009.492	32916.512	32991.000
34 PAINTS & PRODUCTS	5972.223	5978.441	6004.969	6010.773	5997.379
35 PETROLEUM REFINING	42725.117	44116.535	44969.242	44907.281	44223.234
36 PAVING MIXTURES	779.606	782.933	793.138	795.345	787.035
37 ASPHALT FELTS, COATINGS	879.634	882.733	892.320	893.999	889.320
38 RUBBER & PLASTIC PRODS	37765.406	37745.691	39272.523	39264.938	39265.359
39 LEATHER TANNING PROD	1128.924	1126.019	1117.790	1115.488	1117.194
40 FOOTWEAR & LEATHER PROD	4806.691	4791.453	4743.328	4728.887	4738.668
41 GLASS & GLASS PRODS	7592.035	7586.742	7585.066	7581.723	7582.125
42 CEMENT, HYDRAULIC	3126.400	3145.859	3207.097	3218.737	3204.573
43 LIME	612.518	614.951	623.792	626.970	624.311
44 STONE & CLAY PRODS	18606.418	18711.930	19044.285	19113.336	19039.391
45 PRIMARY STEEL	38068.641	38261.922	38841.785	39112.223	38936.285
46 IRON & STEEL FOUNDRIES	6603.055	6642.422	6759.266	6806.848	6749.063
47 IRON & STEEL FORGINGS	2815.418	2831.666	2878.223	2896.874	2884.630
48 PRIMARY NON-FER METAL	10184.074	10227.313	10361.391	10407.355	10378.656
49 MISC NON-FER METALS	29171.805	29329.617	29789.262	29931.891	29838.004
50 METAL CONTAINERS	4800.398	4790.793	4761.691	4750.922	4757.172
51 PLUMBING&STRUCTURAL META	18216.141	18491.430	19276.918	20000.461	19708.543
52 HEATING EQUIP EXC ELEC	2884.037	2894.924	2927.669	2936.538	2921.870
53 SCREWS & METAL STAMPINGS	11577.898	11589.297	11617.203	11635.086	11613.992

F I G U R E J.4 (continued)

	1 LOW	2 MEDIUM	3 HIGH	4 HIGH+HYGAS	5 HIGH+HYGAS+GT
54 OTHER FAB METAL PRODS	22108.492	22204.367	22471.938	22587.035	22487.691
55 ENGINES & TURBINES	7463.004	7576.316	7863.723	7950.359	7966.094
56 FARM MACHINERY & EQUIP	5456.512	5417.219	5285.918	5248.098	5273.078
57 CONSTRUCTION&MINING EQUI	11099.129	11455.984	12508.285	12892.555	12638.691
58 MATERIAL HNDLG MACH	5730.605	5782.016	5989.992	6062.074	6017.180
59 METALWORKING MACH	10788.418	10876.855	11172.605	11283.910	11207.398
60 SPECIAL INDUSTRY MACH	11842.160	11865.305	12233.023	12215.875	12203.984
61 GENERAL INDUSTRY MACH	13558.762	13697.668	14156.055	14488.523	14354.359
62 MACHINE SHOP PRODUCTS	6461.191	6474.191	6512.973	6529.441	6519.012
63 OFFICE COMP MACH	34415.367	34497.992	34642.547	34632.566	34564.535
64 SERVICE INDUSTRY MACH	4320.828	4310.129	4263.348	4290.484	4292.422
65 REFRIG MACHINERY	9595.742	9605.723	9624.797	9619.953	9603.191
66 ELECTRICAL INDUSTRY	21399.398	21673.172	22484.969	22637.430	22492.180
67 HOUSEHOLD APPLIANCES	15568.324	15540.141	15445.930	15412.816	15426.297
68 ELEC LIGHTING EQUIP	8369.035	8418.410	8554.730	8570.867	8548.688
69 RADIO,TV & COMM EQUIP	45836.816	45768.367	45479.703	45367.773	45411.109
70 ELEC COMP & ACCESS	32761.773	32749.594	32520.785	32608.750	32611.031
71 ELEC MACH EQP & SUPPLIES	7034.703	7034.535	7027.086	7019.793	7018.000
72 MOTOR VEHICLES & EQUIP	102415.125	102471.438	102461.375	102399.875	102290.438
73 AIRCRAFT & PARTS	26752.379	26737.094	26645.355	26599.941	26588.629
74 OTHER TRANSPORT EQUIP	11046.109	11055.609	11065.617	11105.617	10997.180
75 SCIENTIFIC & CONTROL INS	13720.867	13723.816	13724.637	13715.387	13709.043
76 OPTICAL & PHOTO EQUIP	17435.688	17475.535	17556.461	17551.828	17522.172
77 MISC MANUFACTURING	24577.961	24531.555	24377.703	24333.797	24359.418
78 RAILROAD TRANSPORTATION	28900.086	28935.730	29067.148	29100.754	28881.137
79 LOCAL PASSENGER TRANSPOR	10833.754	10807.078	10719.609	10695.891	10712.273
80 TRUCK TRANSPORTATION	33973.672	34003.574	34104.828	34110.848	33888.531
81 WATER TRANSPORTATION	10917.109	10918.254	10885.293	10877.867	10803.523
82 AIR TRANSPORTATION	11351.418	11337.656	11287.074	11271.078	11219.891
83 MISC TRANSPORTATION	3997.395	4042.332	4085.502	4078.277	4028.507
84 COMMUNICATIONS EXC RAD&T	55556.918	55489.805	55241.680	55162.313	55197.344
85 RADIO & TV BROADCASTING	3450.907	3453.027	3453.538	3454.668	3454.808
86 ELECTRIC UTILITIES	48337.418	49380.180	52045.648	52062.984	52084.680
87 GAS UTILITIES	33183.734	34173.742	37766.211	37734.379	36914.336
88 WATER & SANITARY SERV	8446.168	8437.191	8407.563	8473.813	8478.992
89 WHOLESALE TRADE	141759.625	141681.313	141387.688	141343.188	141408.875
90 RETAIL TRADE	183084.688	182722.313	181466.750	181100.438	181319.125
91 FINANCE AND INSURANCE	87537.688	87383.125	86834.000	86845.250	86952.750
92 REAL ESTATE & RENTAL	245278.375	244802.063	242901.000	242287.125	242614.813
93 HOTEL, PERS & REPAIR SER	40053.910	39940.035	39568.617	39463.148	39536.262
94 BUSINESS SERVICES	108538.188	108636.500	108742.313	108807.125	108794.750
95 RESEARCH AND DEVELOPMENT	2599.109	2597.749	2592.484	2590.358	2590.763
96 AUTO REPAIR & SERVICE	24837.930	24802.004	24673.941	24635.617	24643.141
97 AMUSEMENTS	15729.074	15687.785	15548.180	15538.078	15534.816
98 MEDICAL & EDUCATION SERV	93709.563	93406.500	92417.750	92129.875	92325.813
99 FED GOVT ENTERPRISES	13357.410	13345.328	13299.609	13283.566	13291.887
100 STATE&LOCAL GOVT ENTERPR	12984.785	12985.992	12991.887	13017.492	13008.637
101 IMPORTS	-13892.305	-13452.180	-12226.734	-11978.617	-12294.922
102 BUSINESS TRAVEL, GIFTS	18009.563	18024.504	18067.773	18395.398	18084.543
103 OFFICE SUPPLIES	6940.031	6934.898	6913.855	6910.086	6913.172
104 SCRAP, SECONDHAND GOODS	2816.230	2806.663	-29.764	2766.457	2772.650
105 TOTAL OUTPUT	2797423.000	2802791.000	2813371.000	2817768.000	2813976.000

FIGURE J.5

COMPARISON OF GROSS INVESTMENT AND TOTAL OUTPUT (1980)

	1 GROSS INVESTMENT	2 TOTAL OUTPUT	3 PERCENTAGE
1 LIVESTOCK & PRODUCTS	258.0	44965.2	0.6
2 OTHER FARM PRODUCTS	729.0	40234.4	1.8
3 FORESTRY & FISHERY PROD	73.0	2558.5	2.9
4 FARM, FOREST, FISH SERV	13.0	2166.9	0.6
5 FERROUS METAL MINING	53.0	2628.4	2.0
6 NONFERROUS METAL MINING	32.0	3096.6	1.0
7 COAL MINING	9.0	4328.5	0.2
8 CRUDE OIL AND NATURAL GAS	53.0	22352.0	0.2
9 STONE & CLAY MINING	60.0	3939.5	1.6
10 MINERAL MINING	0.0	2204.7	0.0
11 NEW CONSTRUCTION	74246.0	117216.0	63.3
12 MAINT & REPAIR CONST	0.0	35136.7	0.0
13 ORDNANCE, ACCESSORIES	100.0	8330.1	1.2
14 FOOD & KINDRED PRODUCTS	0.0	112436.1	0.0
15 GRAIN MILLING	0.0	14706.3	0.0
16 TOBACCO MANUFACTURES	12.0	9666.1	0.1
17 FABRIC, YARN, THRD MILLS	171.0	26515.9	0.6
18 MISC. TEXTILE GOODS	336.0	8102.8	4.1
19 APPAREL	729.0	33288.6	2.2
20 MISC FAB TEXTILE PRODUCT	45.0	5626.7	0.8
21 LUMBER & WOOD PRODS	129.0	17272.4	0.7
22 WOODEN CONTAINERS	18.0	485.0	3.7
23 HOUSEHOLD FURNITURE	351.0	9046.0	3.9
24 OTHER FURN & FIXTURES	2565.0	4862.8	52.7
25 PULP MILLS	0.0	2798.5	0.0
26 PAPER & ALLIED PRODS	0.0	26938.6	0.0
27 PAPER CONTAINERS, BOXES	97.0	10082.6	1.0
28 PRINTING & PUBLISHING	126.0	31614.5	0.4
29 INDUSTRIAL CHEMICALS	0.0	34030.3	0.0
30 FERTILIZERS	0.0	3385.2	0.0
31 AGR & MISC CHEMICALS	0.0	7102.1	0.0
32 PLASTICS & SYNTH MTRL	277.0	23254.0	1.2
33 DRUGS, CLNG, TOILET PREP	405.0	25511.9	1.6
34 PAINTS & PRODUCTS	15.0	4758.5	0.3
35 PETROLEUM REFINING	0.0	36082.5	0.0
36 PAVING MIXTURES	0.0	647.8	0.0
37 ASPHALT FELTS, COATINGS	0.0	726.5	0.0
38 RUBBER & PLASTIC PRODS	262.0	30369.3	0.9
39 LEATHER TANNING PROD	12.0	982.6	1.2
40 FOOTWEAR & LEATHER PROD	115.0	4357.8	2.6
41 GLASS & GLASS PRODS	66.0	5966.8	1.1
42 CEMENT, HYDRAULIC	0.0	2657.4	0.0
43 LIME	0.0	496.7	0.0
44 STONE & CLAY PRODS	0.0	15424.9	0.0
45 PRIMARY STEEL	0.0	31440.6	0.0
46 IRON & STEEL FOUNDRIES	0.0	5321.5	0.0
47 IRON & STEEL FORGINGS	0.0	2223.3	0.0
48 PRIMARY NON-FER METAL	0.0	8155.5	0.0
49 MISC NON-FER METALS	479.0	23541.9	2.0
50 METAL CONTAINERS	175.0	4157.5	4.2
51 PLUMBING&STRUCTURAL META	1490.0	14752.0	10.1
52 HEATING EQUIP EXC ELEC	0.0	2411.8	0.0
53 SCREWS & METAL STAMPINGS	70.0	8770.9	0.8

F I G U R E J.5 (continued)

	1 GROSS INVESTMENT	2 TOTAL OUTPUT	3 PERCENTAGE
54 OTHER FAB METAL PRODS	649.0	17430.1	3.7
55 ENGINES & TURBINES	948.0	5457.1	17.4
56 FARM MACHINERY & EQUIP	3427.0	5645.0	60.7
57 CONSTRUCTION&MINING EQUI	3294.0	7798.5	42.2
58 MATERIAL HNDLG MACH	1126.0	3341.0	33.7
59 METALWORKING MACH	3169.0	9362.6	33.8
60 SPECIAL INDUSTRY MACH	3659.0	7507.0	48.7
61 GENERAL INDUSTRY MACH	2737.0	10922.9	25.1
62 MACHINE SHOP PRODUCTS	68.0	5036.2	1.4
63 OFFICE COMP MACH	12089.0	24347.7	49.7
64 SERVICE INDUSTRY MACH	1611.9	2762.9	58.3
65 REFRIG MACHINERY	1698.1	7592.9	22.4
66 ELECTRICAL INDUSTRY	4266.0	16691.2	25.6
67 HOUSEHOLD APPLIANCES	414.0	12585.1	3.3
68 ELEC LIGHTING EQUIP	298.0	6794.1	4.4
69 RADIO,TV & COMM EQUIP	7504.0	33266.0	22.6
70 ELEC COMP & ACCESS	748.0	24312.5	3.1
71 ELEC MACH EQP & SUPPLIES	363.0	5483.8	6.6
72 MOTOR VEHICLES & EQUIP	15423.0	82555.2	18.7
73 AIRCRAFT & PARTS	3207.0	22727.2	14.1
74 OTHER TRANSPORT EQUIP	4391.0	10649.7	41.2
75 SCIENTIFIC & CONTROL INS	2110.0	10984.3	19.2
76 OPTICAL & PHOTO EQUIP	3659.0	11096.2	33.0
77 MISC MANUFACTURING	843.0	18596.3	4.5
78 RAILROAD TRANSPORTATION	1147.4	23382.1	4.9
79 LOCAL PASSENGER TRANSPOR	0.0	8395.0	0.0
80 TRUCK TRANSPORTATION	1592.7	26935.8	5.9
81 WATER TRANSPORTATION	66.5	8963.4	0.7
82 AIR TRANSPORTATION	82.4	8948.1	0.9
83 MISC TRANSPORTATION	0.0	3174.2	0.0
84 COMMUNICATIONS EXC RADST	1449.0	42004.5	3.4
85 RADIO & TV BROADCASTING	0.0	2734.5	0.0
86 ELECTRIC UTILITIES	0.0	42955.7	0.0
87 GAS UTILITIES	0.0	28691.5	0.0
88 WATER & SANITARY SERV	0.0	6928.3	0.0
89 WHOLESALE TRADE	7265.6	107084.4	6.8
90 RETAIL TRADE	6959.3	153574.3	4.5
91 FINANCE AND INSURANCE	0.0	70030.1	0.0
92 REAL ESTATE & RENTAL	4063.0	185063.3	2.2
93 HOTEL, PERS & REPAIR SER	0.0	31238.1	0.0
94 BUSINESS SERVICES	0.0	97557.4	0.0
95 RESEARCH AND DEVELOPMENT	0.0	2249.5	0.0
96 AUTO REPAIR & SERVICE	0.0	20441.3	0.0
97 AMUSEMENTS	83.0	12698.4	0.7
98 MEDICAL & EDUCATION SERV	0.0	70478.8	0.0
99 FED GOVT ENTERPRISES	0.0	7925.8	0.0
100 STATE&LOCAL GOVT ENTERPR	0.0	10440.0	0.0
101 IMPORTS	50.0	-3653.5	-1.4
102 BUSINESS TRAVEL, GIFTS	0.0	14070.5	0.0
103 OFFICE SUPPLIES	0.0	5340.3	0.0
104 SCRAP, SECONDHAND GOODS	-990.0	1466.0	-67.5

FIGURE J.6

COMPARISON OF 1980 INVESTMENT (GPDI) IMPACTS WITH TOTAL OUTPUT (1980)

	1 INVESTMENT IMPACT	2 TOTAL OUTPUT	3 PERCENTAGE
1 LIVESTOCK & PRODUCTS	1245.1	44965.2	2.8
2 OTHER FARM PRODUCTS	2352.3	40234.4	5.8
3 FORESTRY & FISHERY PROD	596.8	2558.5	23.3
4 FARM, FOREST, FISH SERV	196.5	2166.8	9.1
5 FERROUS METAL MINING	908.5	2628.4	34.6
6 NONFERROUS METAL MINING	829.2	3096.6	26.8
7 COAL MINING	557.8	4328.6	12.9
8 CRUDE OIL AND NATURAL GA	1893.4	22352.0	8.5
9 STONE & CLAY MINING	1729.5	3839.5	45.0
10 MINERAL MINING	250.5	2204.7	11.4
11 NEW CONSTRUCTION	74246.0	117216.0	63.3
12 MAINT & REPAIR CONST	2018.5	35136.7	5.7
13 ORDNANCE, ACCESSORIES	514.2	8330.1	6.2
14 FOOD & KINDRED PRODUCTS	1596.4	112436.1	1.4
15 GRAIN MILLING	354.8	14706.3	2.4
16 TOBACCO MANUFACTURES	79.5	9666.1	0.8
17 FABRIC,YARN,THRD MILLS	1752.8	26515.9	6.6
18 MISC. TEXTILE GOODS	1055.1	8102.8	13.0
19 APPAREL	1123.3	33288.6	3.4
20 MISC FAB TEXTILE PRODUCT	301.1	5626.7	5.4
21 LUMBER & WOOD PRODS	6901.9	17272.4	40.0
22 WOODEN CONTAINERS	93.0	485.0	19.2
23 HOUSEHOLD FURNITURE	980.1	9046.0	10.8
24 OTHER FURN & FIXTURES	3031.1	4862.8	62.3
25 PULP MILLS	324.0	2798.5	11.6
26 PAPER & ALLIED PRODS	3679.3	26938.6	13.7
27 PAPER CONTAINERS, BOXES	1455.2	10082.6	14.4
28 PRINTING & PUBLISHING	3304.1	31614.5	10.5
29 INDUSTRIAL CHEMICALS	4525.9	34030.3	13.3
30 FERTILIZERS	215.5	3385.2	6.4
31 AGR & MISC CHEMICALS	1044.2	7102.1	14.7
32 PLASTICS & SYNTH MTRL	3524.7	23254.0	15.2
33 DRUGS, CLNG, TOILET PREP	1015.7	25511.9	4.0
34 PAINTS & PRODUCTS	1081.2	4758.5	22.7
35 PETROLEUM REFINING	2851.6	36082.5	7.9
36 PAVING MIXTURES	241.7	647.8	37.3
37 ASPHALT FELTS, COATINGS	243.7	726.5	33.6
38 RUBBER & PLASTIC PRODS	5232.5	30369.3	17.2
39 LEATHER TANNING PROD	85.0	982.6	8.7
40 FOOTWEAR & LEATHER PROD	174.5	4357.8	4.0
41 GLASS & GLASS PRODS	1156.9	5966.8	19.4
42 CEMENT, HYDRAULIC	1280.7	2657.4	48.2
43 LIME	174.3	496.7	35.1
44 STONE & CLAY PRODS	7045.8	15424.9	45.7
45 PRIMARY STEEL	12092.4	31440.6	38.5
46 IRON & STEEL FOUNDRIES	2197.9	5321.5	41.3
47 IRON & STEEL FORGINGS	809.6	2223.3	36.4
48 PRIMARY NON-FER METAL	2678.9	8155.5	32.8
49 MISC NON-FER METALS	9161.4	23541.9	38.9
50 METAL CONTAINERS	362.7	4157.5	8.7
51 PLUMBING&STRUCTURAL META	8246.8	14752.0	55.9
52 HEATING EQUIP EXC ELEC	931.8	2411.8	38.6
53 SCREWS & METAL STAMPINGS	2450.4	8770.9	27.9

F I G U R E J.6 (continued)

	1 INVESTMENT IMPACT	2 TOTAL OUTPUT	3 PERCENTAGE
54 OTHER FAB METAL PRODS	5416.9	17430.1	31.1
55 ENGINES & TURBINES	1844.1	5457.1	33.8
56 FARM MACHINERY & EQUIP	3800.3	5645.0	67.3
57 CONSTRUCTION&MINING EQUI	4242.6	7798.5	54.4
58 MATERIAL HNDLG MACH	1963.0	3341.0	58.8
59 METALWORKING MACH	4998.6	9362.6	53.4
60 SPECIAL INDUSTRY MACH	4295.9	7507.0	57.2
61 GENERAL INDUSTRY MACH	6040.7	10922.8	55.3
62 MACHINE SHOP PRODUCTS	1454.1	5036.2	28.9
63 OFFICE COMP MACH	14845.3	24347.7	61.0
64 SERVICE INDUSTRY MACH	1785.5	2762.9	64.6
65 REFRIG MACHINERY	3875.4	7592.9	51.0
66 ELECTRICAL INDUSTRY	8900.2	16691.2	53.3
67 HOUSEHOLD APPLIANCES	1729.2	12585.1	13.7
68 ELEC LIGHTING EQUIP	2489.5	6794.1	36.6
69 RADIO,TV & COMM EQUIP	9918.2	33266.0	29.8
70 ELEC COMP & ACCESS	8150.9	24312.5	33.5
71 ELEC MACH EQP & SUPPLIES	1283.9	5483.8	23.4
72 MOTOR VEHICLES & EQUIP	23308.4	82555.2	28.2
73 AIRCRAFT & PARTS	4635.5	22727.2	20.4
74 OTHER TRANSPORT EQUIP	4957.1	10649.7	46.5
75 SCIENTIFIC & CONTROL INS	3593.2	10984.3	32.7
76 OPTICAL & PHOTO EQUIP	4437.0	11096.2	40.0
77 MISC MANUFACTURING	1891.7	18596.3	10.2
78 RAILROAD TRANSPORTATION	4777.7	23382.1	20.4
79 LOCAL PASSENGER TRANSPOR	378.3	8395.0	4.5
80 TRUCK TRANSPORTATION	5657.6	26935.8	21.0
81 WATER TRANSPORTATION	524.2	8963.4	5.8
82 AIR TRANSPORTATION	763.5	8948.1	8.5
83 MISC TRANSPORTATION	248.8	3174.2	7.8
84 COMMUNICATIONS EXC RAD&T	4907.1	42004.5	11.7
85 RADIO & TV BROADCASTING	419.2	2734.5	15.3
86 ELECTRIC UTILITIES	4464.1	42955.7	10.4
87 GAS UTILITIES	2810.0	28691.5	9.8
88 WATER & SANITARY SERV	625.3	6928.3	9.0
89 WHOLESALE TRADE	23424.2	107084.4	19.1
90 RETAIL TRADE	14032.7	153574.3	9.1
91 FINANCE AND INSURANCE	4295.3	70030.1	6.1
92 REAL ESTATE & RENTAL	9513.4	185063.3	5.1
93 HOTEL, PERS & REPAIR SER	907.9	31238.1	2.9
94 BUSINESS SERVICES	14151.5	87557.4	16.2
95 RESEARCH AND DEVELOPMENT	246.1	2249.5	10.9
96 AUTO REPAIR & SERVICE	1824.0	20441.3	8.9
97 AMUSEMENTS	481.9	12698.4	3.8
98 MEDICAL & EDUCATION SERV	495.8	70478.8	0.7
99 FED GOVT ENTERPRISES	1024.7	7925.8	12.9
100 STATE&LOCAL GOVT ENTERPR	776.1	10440.0	7.4
101 IMPORTS	10506.2	-3653.5	-287.6
102 BUSINESS TRAVEL, GIFTS	2857.3	14070.5	20.3
103 OFFICE SUPPLIES	625.4	5340.3	11.7
104 SCRAP, SECONDHAND GOODS	-990.0	1466.0	-67.5

BIOGRAPHICAL NOTES

James Edward Just was born April 18, 1946 in Johnstown, Pennsylvania. He graduated from New Castle Senior High School in June, 1964 and entered Massachusetts Institute of Technology in the fall of that year. He received both the Masters and Bachelors degrees in Electrical Engineering in June, 1969, and the Electrical Engineer degree in June, 1970.

He received financial support from MIT, the Wolves Club of New Castle, Pennsylvania, the NDEA, and the War Orphans Education Act during his undergraduate years. From September, 1968 to September, 1970, he was supported by an NDEA traineeship and the Pennsylvania Higher Education Act loans. In June, 1969, he joined MITRE Corporation as a part-time employee and received a fellowship from them in September, 1970. A number of classified publications resulted from this association.

In September, 1970, he began work on energy-related research with Prof. David C. White and Prof. Fred C. Schweppe. This resulted in an Electrical Engineering Ph.D thesis and a Masters in Business Administration thesis.

He is a member of Sigma Xi, Eta Kappa Nu, and Tau Beta Pi.