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INDUSTRIAL SECTOR TECHNOLOGY USE
MODEL (ISTUM): INDUSTRIAL ENERGY
USE IN THE UNITED STATES, 1974-2000
VOLUME 1 - PRIMARY MODEL DOCUMENTATION
BOOK 2
CHAPTERS IV, V, VI, and VII

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PREFACE

This book is part of the documentation of the Industrial Sector Technology Use Model (ISTUM). It contains the last three chapters of Volume 1 (Primary Model Documentation). The breakdown is as follows:

Volume 1 Primary Model Documentation

Book 1:

Chapter I	Introduction
Chapter II	Technologies
Chapter III	Service and Fuel Demands

Book 2 (this book):

Chapter IV	Primary Model Logic
Chapter V	Environmental Factors in ISTUM
Chapter VI	Macroeconomic Background
Chapter VII	Glossary

Volume 2 Results of the Base Case

Volume 3 Appendix on Service and Fuel Demands

Volume 4 Appendix on Technologies

This report is subject to the usual caveats concerning draft reports. This book, in particular, assumes that the reader has already read at least Chapter I of Volume 1.

CHAPTER IV

PRIMARY MODEL LOGIC

A. Introduction

The Industrial Sector Technology Use Model encompasses many different elements. A variety of types and sources of data are needed. Certain assumptions about the future state of the world must be made in a consistent fashion, such as in the oil price and environmental areas. Most of these pieces require their own careful analysis. These fairly independent portions of data and analysis are the subject of Chapters II, III, V, and VI.

But overall, ISTUM was designed to provide a single framework for integrating all of the information and analysis into a set of predictions of industrial energy use. Given the volume of information which must be considered, this requires a set of computerized engineering-economic models. The design of these models is the subject of Chapter IV.

Specifically, this chapter describes how the market shares of various energy technologies are projected. This involves combining the technology cost information with the data on industrial demands for energy. Economic, financial, and behavioral analysis is used to provide the most accurate projections possible.

The layout of the rest of this chapter is as follows. The remainder of the introduction gives an overview of the

modeling approach used. Sections B, C, and D discuss in turn each of the three major portions of the analysis. These are loosely characterized as economic competitiveness, behavioral lag, and capital turnover, respectively.

1. Philosophy of the Approach Used

There are two essential elements to the approach used here for modeling the selection of energy technologies in the industrial sector. The first is that the key determinant of which technologies will be selected is their comparative costs. Those technologies which are cheapest in any particular application will be selected for that application. Estimating which technologies will be cheapest includes consideration of factors such as reliability, ability to meet environmental constraints, etc. That is, the costs of a particular technology may be more than its obvious direct capital, fuel, operating, and maintenance costs. But other issues, such as esthetics, are assumed not to be relevant unless they in some way might affect the cash flow of the firm using the technology.

This assumption would be too strong for modeling energy consumption in other cases, for example in the residential sector. There may be cases where it is slightly incorrect in the industrial sector. Nevertheless, it was adopted because 1) there is overwhelming evidence that it is correct in the majority of industrial decisions in both energy and non-energy fields, and 2) although theoretically it would be possible to do without this assumption, major data gathering would have to be done on non-cost issues in order to implement a more general model. The additional insights gained

from this data gathering might not be worth the effort, except for a few special topics^{1/}.

The second cornerstone of the approach used in ISTUM is that all choices should be modeled from the perspective of the person who will in fact be making those decisions. This leads to a "bottom up" type of modeling like those used in corporations for evaluating alternative investments. To the extent possible, uses of energy are disaggregated according to those characteristics which will have the most impact on the costs of alternative technologies: type of energy, size of combustor, load factor of the application, location, etc.^{2/} Naturally, when dealing with the entire industrial sector it is not possible to encompass the full richness of decision making at the individual plant or combustor level. Some aggregation above this level was necessary (this is the purpose of the cost frequency distributions). The distinction to draw here is with "top down" approaches such as econometric models. These models deal with aggregated data from the beginning. They capture the aggregated effects of many individual decisions, but do so without explicitly modeling any of those individual decisions.

1/ Note that assuming that all decisions are based on "costs" does not necessarily mean that all decisions are rationally made. Nor does it mean that all decision makers, when faced with the same data, would choose the same technology. It says only that when decisions are made, only cost issues will be considered.

2/ Some of this disaggregation is done explicitly and carried all the way through the model; other disaggregation is done only at one stage and then collapsed into other results.

2. Overview of Model Logic

An overview of the entire Industrial Sector Model is given in Figure IV-1. The areas inside the "Primary Model Logic" box are described in this chapter. Basically, the various portions of the ISTUM logic take the model inputs (described elsewhere), and analyze them to estimate how much of each technology (and each fuel) will be used by the industrial sector.

The first step in this analysis is to place the costs of each technology on a comparable basis. Capital costs, fuel costs, and operating and maintenance costs are added together using standard discounted cash flow techniques. Each of these inputs is given by a distribution, rather than a point estimate. (Fuel prices vary because of regional, microgeographic, and other factors.) These distributions are called "cost frequency distributions" because they give the frequency with which each possible cost would occur if the technology were used everywhere. They are combined to give a composite cost frequency distribution of the total cost per million Btu delivered by a technology. The same unit of measurement is used for each technology in a service sector, making the distributions directly comparable. For example, for technologies in the steam service sector, costs are measured in constant 1977 dollars per million Btu's of steam supplied. (In the case of conservation process changes, this is per million Btu's of steam displaced.)

The second step is to compete the technologies against each other. This is done by using the costs of each technology to determine the fraction of the market which that technology should capture. This is called the "nominal" (or theoretical)

FIGURE IV-1

SCHEMATIC OF INDUSTRIAL SECTOR TECHNOLOGY USE MODEL

market share for that technology. It is based on the assumptions that all decisions are made rationally, and that everyone has complete information about the costs and performance of all technologies. (Since there is perfect information, there is no subjective uncertainty about going ahead with any particular technology.)

The nominal market share of a technology in a particular market segment is that portion of the market segment where it has a lower cost per million Btu of service demand than any other technology. Because the cost of each technology varies from application to application no single technology will capture an entire market segment.^{1/} The definition, calculation, and implications of this concept of theoretical market shares are discussed further in section IV.B.

The third step of the methodology adjusts the nominal market shares for the effects of behavioral factors. Perfect information about a technology is in fact not available immediately when it comes on the market. Potential users may not know about it at all; if they know about it, they may not be sure how well it works. Therefore the adoption of new technologies is slower than would be suggested by their nominal market shares. Technologies which are already proven make up any gap. This phenomenon is referred to as "behavioral lag" or penetration lag. It is discussed in section IV.C. Nominal market shares adjusted for penetration lag are referred to as "actual market shares".

^{1/} To reiterate, the frequency distributions of technologies are not in any way due to present (1978) uncertainty about their technical performance or costs. These factors are considered to be deterministic, as discussed in Chapter II.B.

The fourth step of the methodology considers the fact that the stock of energy capital is relatively fixed over short time periods. Once a capital investment has been made in a piece of energy consuming or transforming equipment, it is a sunk cost. Therefore new technologies will be put into place only as rapidly as energy capital stock is "turned over". That is, old equipment is retired, which requires new equipment; also, new demands require new equipment. New demand plus retirement is referred to as "incremental demand". The amount of new demand for energy is given by the industrial output growth rates discussed in Chapter III. Calculating the rate at which old capital stock will be retired is difficult, and is discussed in section IV.D. and Chapter VI.

The result of these steps is a large amount of detailed information about the economic competitiveness and Btu's supplied by each technology. This information is broken down by year, industry (at the 2 digit SIC code level), service sector (some technologies are applicable in several service sectors) and technology. This information is summarized and displayed in a variety of ways. The most important are profiles of each service sector and profiles of each of the major new technologies. This is discussed in Volume II on results.

Conservation technologies are treated in the methodology like supply technologies which use no fuel or a free fuel. That is, they fill service demand just like any other technology. Conservation technologies include waste heat using technologies, industrial waste using technologies, and process changes. Final demand for goods and services is fixed: conservation in ISTUM does not imply any life style changes by consumers or industry.

B. Economic Competitiveness

A variety of methods have been used in recent years to estimate the market shares for technologies which are competing with each other to capture a fixed market. Standard economic models provides insight into this problem but are not powerful enough to answer it. Many different approaches have been developed in the energy area. This section discusses a technology competition method developed by EEA. As far as the authors know, this method is essentially new, although analagous mathematical formulations have been used at least once to deal with technical uncertainty. Therefore it is developed in some detail in what follows.

For readers who are not interested in the intricacies of the methodology, it is presented at several levels. The key elements of the methodology can be followed without any mathematics. Then in sections B.4 and B.6 the formal equations and how to solve them are given twice, at increasing levels of mathematical sophistication. This portion of the discussion can be skipped by readers who are not interested, although with some loss of insight into energy related issues.

1. Statement of the Problem

The goal of this portion of the ISTUM methodology is to estimate the theoretical economic competetiveness of each ISTUM technology, in all relevant market segments. "Theoretical economic competetiveness" refers to the market share which optimally should be captured by the technology, in the absence of any strictly behavioral factors.

The perspective is that of the private decision maker in an industrial firm. He must select from among alternative

ways of providing the energy needed by his plant. Different individuals at different plants will be faced with a different set of circumstances, and will make different decisions. As conditions change over time, so will decisions.

The following elements are keys to the problem of estimating the market shares of each technology.

a. Decisions will be based on the comparative economics of available alternatives. The justification for this assumption has already been discussed. Environmental issues are encompassed in this criterion, because energy technologies are costed out including the cost of environmental control technologies. See Chapter V for a discussion of environmental issues.

Further, the economic analysis of all technologies must be done on a comparable basis. Industrial decision makers do not apply one set of criteria to one class of technologies and another set of criteria to a different class.^{1/}

b. Decision makers will generally choose the lowest cost option available to them. That fraction of the market in which a technology will be the lowest in cost is called its nominal (or theoretical) market share. The calculation of nominal market shares is the subject of this section. In order to calculate which technology is the lowest in cost among a range of technologies, capital cost, operating cost, and fuel cost must be placed on a comparable basis. This is done using standard discounted cash flow techniques.

^{1/} Some relevant issues are studied in: "Investment Risk Evaluation Techniques: Use in Energy Intensive Industries and Implications for ERDA's Industrial Conservation Program," EEA, Inc., prepared for ERDA, July, 1977.

c. Behavioral issues, principally lack of information and confidence about the performance of new technologies, will reduce the penetration of new technologies to less than their nominal market share. This phenomena is discussed in section IV.C.

d. The industrial market is highly fragmented, and the comparative economics of different technologies will change depending on the characteristics of the particular submarket. Therefore no single estimate of the cost of a particular technology is correct.

ISTUM deals with this problem in two ways, both of them central to its methodology. First, the industrial market is explicitly segmented into major submarkets and all relevant technologies are competed separately in each submarket. The cost of each technology is explicitly recalculated in each submarket. (This was discussed in Chapter II, and is discussed further in section IV.B.2 below.)

The explicit submarkets used in the current version of ISTUM are:

- 1) Industry (26 SIC's, not all of which appear in every service sector).
- 2) Service sector, or form of energy. (23, of which 13 are used for active modeling of inter-technology competition.) (See Table IV-2 in section IV.D.3.)
- 3) Combustor size (1 or 2, depending on service sector.)
- 4) Combustor load factor (1 or 2, depending on load factor.)
- 5) Year (1980, 85, 90, 95, 2000.)

Thus there are about 1000 non-zero cells in which technologies compete. Of these, about 360 cells are unique, and are solved independently.

e. Second, even after explicitly subdividing the industrial market, there are many remaining sources of cost variability, which lead to a range of costs for any single technology in a single market cell. This range of costs is captured by a distribution, showing what fraction of the demand in a cell will experience each possible cost. Sources of this cost variability can be divided into application specific factors, such as the process temperature; site specific factors, such as fuel cost; and firm specific factors, such as the cost of capital. Each factor may affect different technologies in different ways. Many will be unimportant for certain technologies. (For example, variations in the cost of coal will not affect the price of oil consuming technologies.)

Estimating cost distributions for each technology is discussed in Chapter II, and the Technology Appendix (Volume IV).

f. In each submarket, there are many alternative technologies, each of which must be compared with all of the others to determine its market share. That is, there is no single "technology to beat", such that if a new technology is cheaper it will be adopted. Instead, each new technology must be compared with all alternatives, both new and conventional, to determine its market share.

g. As discussed in point e above, the costs of a technology will be different in each potential application. These cost variations from application to application will be interrelated for similar technologies. For example, site specific factors may influence the installed cost of coal handling equipment. All coal using technologies will therefore have interdependent cost distributions.

The problem is to estimate the nominal market share of each technology in each demand cell based on the above assumptions. The "nominal market share" corresponds to the theoretical economic competitiveness, under conditions when complete information about all technologies is available. Behavioral issues, having to do with the transfer of performance information and with risk aversion on the part of potential purchasers who do not have complete information, are modeled separately. This is discussed in section IV.C. Capital turnover is discussed in section IV.D.

The methodology adopted for calculating nominal market shares in ISTUM fits all of the criteria listed above. In addition, there are always practical issues in computer and mathematical models such as ISTUM. There are usually trade-offs among the following criteria:

- The model should be robust, i.e., small changes in input parameters should not significantly change the results. (Assuming that this is how the real world acts.)
- The computer formulation adopted should be inexpensive to use. More than 100,000 output numbers are created and manipulated in each full run of the present version of ISTUM. This is necessary because of the large number of demand cells which are analyzed separately.
- The mathematical model used should be precise. Variables should correspond to measurable quantities (even if realistic data is not always

available), so that there is no ambiguity in their interpretation or use, nor in the meaning of the results.

- Perhaps most important, the model should be accurate. Defining "accurate" is always difficult, and depends to some extent on the needs of the user.

The nominal market share formulation adopted for ISTUM contains all of the elements a through g listed above. In addition, it goes a long way towards satisfying all of the practical criteria.

Some difficulties were encountered in implementing the nominal market share model in the time available. As a result, the form of the model presently implemented on the computer leaves out some of the features of the theoretical model on which it is based. Most important, it does not consider interdependencies among technologies (element "g" above). The significance of this is discussed later.

2. Finding Total Costs of One Technology

The first stage in calculating nominal market shares for all technologies in a single market cell^{1/} is to determine

^{1/} A typical market cell would be: The demand for steam,

- in SIC 20 (food and kindred products),
- in 1990,
- in units sized to produce 50 MMBtu/hr of steam service demand,
- in units operating at a load factor of 7000 hours per year (equivalent to operating at full load 80 percent of the time, or an 80 percent load all the time, etc.).

the total cost of each technology in that cell. "Total cost" must include all costs which result from using that technology: capital costs (including indirect capital costs)

- maintenance costs
- fuel costs
- non-fuel operating costs.

Once a composite cost has been calculated for each technology, the costs of different technologies can be compared.

There are two issues involved in determining the total costs for a single technology. The first is that of adding a one-shot expenditure (capital cost) to recurrent expenditures (fuel, other operating, and maintenance expenses). This is done using the standard discounted cash flow analysis normally used by corporate planners. The second issue is that the costs of fuel, capital, and O&M for a technology are each described as frequency distributions, not point estimates. Summing quantities which must be described by distributions is not straightforward. Therefore, this section deals mainly with the deterministic (point estimate) case, leaving for later the intricacies of adding distributions.

The overview of the procedure is provided in Figure IV-1a and IV-1b. The first stage, extensively discussed in Chapter II, is to divide each technology into its natural "building blocks" -- basically self contained components. For example, for a coal using technology, these might be:

- site preparation and powerhouse
- combustor equipment and controls
- fuel handling and storage system
- environmental controls.

FIGURE IV-1a
DERIVING TOTAL COST DISTRIBUTION FOR TECHNOLOGY Y :
Adding Fuel, Operating, and Capital Costs for One Building Block

FIGURE IV-1b
DERIVING TOTAL COSTS COMBINING COST COMPONENTS

Then for each of these building blocks, the same procedure is followed. First, the basic capital cost of that building block is estimated, as discussed in section 2.c below. This is multiplied by a factor which accounts for indirect capital costs: engineering and design, contingency, and startup. This results in the total capital cost for that building block. This is then multiplied by the capital charge rate, which converts a one time capital expenditure into an equivalent annual amount. (Discussed in section B.2.a below.)

To the annual capital cost is added the annual non fuel operating and maintenance cost. The sum is then divided by the number of Btu's of service demand produced each year. This gives the cost of that building block in dollars per million Btu of service demand.

Figure IV-1b shows how the cost distributions for the four building blocks are summed. Their sum is then multiplied by a factor which reflects variability in capital and labor costs in different parts of the U.S., due to local unions and similar factors. (The mean value of this distribution is exactly 1.00, but it widens the composite distribution significantly.)

The penultimate stage is to figure out the cost of fuel for the technology. This is simply the local cost of fuel delivered to an industrial plant, divided by the efficiency with which the particular technology converts fuel into service demand. (For example, 82 percent for coal boilers.) Delivered fuel costs vary widely depending on region and microgeography, and are therefore also treated as a distribution.

Finally, the distribution showing the cost of fuel per million Btu of service demand is added to the distribution showing the cost of capital building blocks per MMBtu of service

demand. The result is the total cost of the technology per million Btu of service demand.

a. Calculating Total Cost - Deterministically

The method used to add fuel, capital, and operating costs of a piece of equipment (e.g., a boiler) is that used by industrial firms when evaluating investments, namely discounted cash flow analysis. There are two equivalent methods. One is to sum up the initial capital cost and all recurrent expenditures incurred during the life of the equipment, discounting expenditures in later years using the appropriate rate of discount. The result would be some number of millions of dollars; buying and operating the equipment over its lifetime has a cost equivalent to this value (called the Net Present Value). The alternative with the least negative net present value is the best. (Of course, all alternative pieces of equipment considered must have been sized so as to produce the same amount of service demand.)

In ISTUM the net present value is calculated, but it is then adjusted to a more natural unit of measurement. All costs are annualized; i.e., they are reduced to a value such that paying the same amount in each successive year would (after discounting) add up to the net present value. These annualized costs are then divided by the number of Btu's produced per year. The result is an annualized cost, in dollars per million Btu.

The details of this procedure, illustrated by example^{1/}, are as follows. Technology 8.31 is used for the example. It

^{1/} The logic used follows Figure IV-1a and IV-1b. However only point estimates (means) are used for each value. Technology cost data is taken from Volume 4.

is a natural gas boiler, producing 50 MMBtu/hr. (about 40,000 pounds of steam per hour), and operated at a load factor of 4000 hours per year.

Step 1: Calculate the capital cost of each component.

In this example, the mean cost of each distribution will be used. They are calculated in Volume 4, section I.B.2. The result is:

site preparation and powerhouse	\$276,000
boiler and controls	\$335,000
fuel handling	\$149,000
environmental control	0
utilities	<u>\$205,000</u>
TOTAL	\$965,000

Step 2: Add indirect capital costs (engineering, startup, and general contingency).

These are calculated as 41 percent of base cost, or \$396,000. So the total capital cost in 1977 is \$1.36 million.

Step 3: Escalate this to the year in which the equipment will be built.

For example, for equipment built in 1990, the composite facility deflator is 2.41. The GNP deflator^{1/} from 1977 to 1990 is 1.93. Their quotient is 1.25. Therefore the capital cost in 1990, measured in 1977 dollars, is:

$$1.25 \times \$1.36 \text{ million} = \$1.70 \text{ million}$$

^{1/} See Chapter VI section 5, page VI-39.

Step 4: Annualize this capital expenditure.

For a boiler with a life of 20 years, the appropriate annualization factor is about 0.11. (This is discussed in subsection b directly below.) That is, a firm is indifferent between making a capital expenditure now of \$1.00, and losing \$.11 after tax profit every year for 20 years. So the annualized capital cost is:

$$\begin{array}{rcl} \$1,700,000 & \times & \underline{.11} \\ & & \text{yr.} \quad \text{year} \end{array} = \underline{\$187,000}$$

Note that the capital charge rate of 0.11 depends on the tax laws in effect during the life of the boiler.

Step 5: Calculate operating and maintenance costs.

These are for a boiler operated 4000 hours a year.

Site preparation	8,270	(\$/year)
Boiler and controls	38,500	
Fuel Handling	17,880	
Environmental control	0	
Utilities	<u>14,310</u>	
TOTAL	\$78,960	\$/year

(Boilers with other load factors would have different operating costs).

Step 6: Add capital and operating costs. Convert to \$/MMBtu.

Total annualized costs, except for fuel, are:

Capital	187,000	\$/year
O&M	<u>79,000</u>	\$/year
TOTAL	\$266,000	\$/year.

Convert this to \$/per million Btu by dividing by the number of Btu's produced each year:

$$\frac{\$266,000}{\text{year}} \div (4000 \text{ hrs/year} \times 50 \text{ MMBtu/hr}) = \$1.33/\text{MMBtu}$$

Note the critical importance of load factor. If the same boiler were operated 6000 hours per year, the capital cost per million Btu of steam would drop by one third.

Step 7: Calculate fuel cost per unit of steam.

The delivered cost of natural gas in 1990 is projected to range from 2.49 to \$5.40, with a mean of \$3.26 \$/MMBtu. However, a boiler built in 1990 will be burning natural gas for 20 years. Over this period the cost of natural gas will increase. The equivalent constant price, called the "levelized fuel price", depends on the anticipated price trajectory and on the financial parameters of the firm. In the base case run of ISTUM, the levelized natural gas price in 1990 was \$3.77. To turn the fuel price into the cost of fuel per unit of service demand, just divide by efficiency. For natural gas boilers, the efficiency is 82 percent^{1/}.

Fuel cost per MMBtu of steam = Fuel cost/efficiency

$$\frac{\$4.60}{\text{MMBtu steam}} = \frac{\$3.77/\text{MMBtu fuel}}{.82 \frac{\text{Btu steam}}{\text{Btu fuel}}}$$

^{1/} Efficiencies in the ISTUM data base are assessed assuming standard conservation measures (air preheater, condensate return, and stack gas monitor) as part of the original equipment. See Chapter II, and Volume 4.

This is the cost for a boiler built in an area with the mean delivered price of natural gas.

Step 8: Add fuel, capital, and O&M costs

Capital + O&M	1.33	\$/MMBtu
Fuel	4.60	\$/MMBtu
TOTAL	5.93	\$/MMBtu

The result of these steps is the final levelized/annualized cost per unit of steam produced. It is \$5.93/MMBtu, measured in constant 1977 dollars. Of this cost, about one sixth is capital cost, one twelfth is operating and maintenance, and the rest is fuel cost. Thus natural gas boilers are a fuel intensive technology.

This example is only deterministic, hence cannot give the full flavor of the cost calculations. For example, most uses of natural gas boilers in 1990 would probably be in the areas where natural gas is cheapest, rather than at its mean. In such a region the total cost of natural gas would be closer to \$4.80. But the basic methods illustrated here still apply in the non-point estimate case; only the mathematics becomes more difficult.

b. Calculating the Capital Charge Rate

A major parameter in making choices between alternative capital investments is the decision maker's rate of time preference for money. Some investments require large capital expenditures "up front" and then low operating and fuel costs in later years; others are the opposite. The rate of time preference for money places one time capital expenditures on a basis comparable with recurrent annual expenditures.

There are standard methods for performing this time preference analysis for private corporations, and these methods were used in ISTUM. They are worth a brief discussion because they are very important to the comparison of technologies.

The final outcome of the calculations is called the "capital charge rate". It is a factor, which when multiplied by the size of a one time capital expenditure, gives an annual amount which is equivalent to the capital expenditure. The firm is indifferent between paying this amount (after taxes) each year for the life of the capital good, and paying the capital expenditure once. In the example calculation of section 2.a above, a capital charge rate of .11 was used. This rate varies from firm to firm, and as discussed below it is impossible to be certain what a firm's exact capital charge rate should be. Nevertheless the .11 value is approximately correct for most investments in the industrial sector of the U.S.

Four sets of parameters are needed to determine the capital charge rate which is correct for a particular investment by a particular firm.

- 1) The anticipated sources and cost of capital for the firm^{1/}.
- 2) The tax treatment they are subject to. These include:
 - Investment tax credit.
 - Income tax on profits.
 - Property taxes.

^{1/} ISTUM is a descriptive model - it simulates how firms will actually make decisions. It is not a normative model - it does not simulate how firms, ideally, should make their decisions. Therefore it is appropriate to use the private cost of capital rather than the social discount rate.

- Tax effects due to depreciation methods.
 - Any special taxes or credits, such as those proposed for the National Energy Act in 1977.
- 3) The physical life and construction period of the equipment.
 - 4) The inflation expectations assumed by the firm when calculating its capital charge rate. These may not be stated explicitly during the firm's calculation, yet they are quite important to the result. The reason is that the costs of debt and equity capital mentioned in item (1) above are usually stated in nominal (current dollar) terms. Models such as ISTUM are normally done in real (constant dollar) terms, because it gives results which are much easier to understand. The capital charge rate must be adjusted to convert from one to the other. The correct inflation rate to use during the adjustment is the inflation rate assumed by the firm at the time it calculates its capital charge^{2/}. Basically, if the firm expects inflation to be high during the life of the investment (e.g., 10 percent per year) then it considers a nominal interest rate of 12 percent as reflecting a mild trade off between current and future expenses. In contrast if it expects inflation to be only 3 percent, then a 12 percent nominal interest rate would say that current expenses are much less desirable than future expenses.

1/ There is no such thing as a single inflation rate. Which one to use (e.g., the GNP deflator, a wholesale price deflator, or one appropriate to the inputs or outputs of the firm in question,) is too complex an issue to discuss here. Ideally they will not be very different.

To calculate the capital charge rate, the first step is to calculate the cost of capital to the firm, also known as its discount rate. This is given by:

$$(Eq.IV.a) \quad r = (d)(D) + e(1-D)$$

where:

r = Cost of capital (nominal) sometimes called the "hurdle rate". (.1325).

d = Interest rate on debt for the firm. (.10)

D = Fraction debt in the firm's financial structure.^{1/} (.35)

e = Cost of equity for the firm. (.15)

The values shown in parentheses are those used in the base case run of ISTUM. The interest rate on debt is taken from relevant Data Resources, Inc. projections. The cost of equity

^{1/} If loan guarantees were in effect for a particular project then a different debt fraction might be appropriate for that particular project than for the firm as a whole.

varies from firm to firm, but .15 is a reasonable average.^{1,2/}

The next step is to calculate the equivalent real cost of capital, after adjusting for inflation. This is given by:

(Eq. IV.b)
$$R = \frac{r - \text{inf}}{1 + \text{inf}}$$

where:

R - Real cost of capital (.079)

r = Nominal cost of capital, from equation IV.a

inf = Anticipated inflation rate (.05).

Now adjustments must be made for all of the relevant financial and physical events. These include interest during construction, the investment tax credit, tax savings due to depreciation, and income tax rate (since an after tax capital

^{1/} Various surveys are available, although the investment decision criteria of many firms are confidential. For example, one study using a questionnaire found an average rate of return of cutoff of 12.8 percent. ("Effective Use of Capital Budgeting Tools", Glenn H. Petry, Business Horizons, October 1975, page 63, Table 8.) This is close to the 13.25 percent number in equation IV.a. See also "Investment Risk Evaluation Techniques: Use in Energy-Intensive Industries and Implications for ERDA's Industrial Conservation Program", EEA, Inc., July, 1977, NTIS acquisition number SAN/1225/T010-1. This study investigates financial parameters for a variety of industries; the 35 percent fraction debt used in ISTUM is taken from Table V-1, page 59.

^{2/} Since almost all of the investments in ISTUM are small relative to the total assets of the firm making the investment, it is not necessary to add risk premiums to the cost of capital. For new technologies subjective risk during the first years of introduction might retard acceptance; this is modeled using the penetration fractions discussed in chapter IV.C.

charge factor is being calculated). The precise equation is relegated to a footnote^{1/}, but the result is a capital charge rate of .115. This is based on the following parameters:

Income tax rate .50
Investment tax credit .10
Physical and tax life 25 years
Construction period 2 years
Double declining balance depreciation (with optimal switch to straight line)

For sensitivity runs involving special tax credits or other government incentives, the parameters above would be changed, giving a lower capital charge rate. Different capital charge rates were always calculated for technologies with other physical lives and construction periods.

^{1/} The source of the equation used was D. Nesbitt and S. Regulinski "A Format for Communicating Cost and Financial Estimates", Decision Focus, Inc. unpublished draft, September 1977.

This paper is excellent because the authors take the time to put in one place the results of all of the necessary algebra, and appropriate explanations. They have used formulas so that a hand calculator can be used without doing any summations over time periods. The result is:

(Eq. IV.c)

$$CCR = \frac{(1 + R)^{B/3} (1-i) \left[1 - f_{tax} \frac{\frac{2}{TL} - \frac{2}{TL} \left(\frac{1 - \frac{2}{TL}}{1 + r} \right)^{TL}}{r + \frac{2}{TL}} \right] \left[\frac{1 - (1 + R)^{-1}}{1 - (1 + R)^{-TL}} \right]}{(1 - f_{tax})}$$

footnote 1/ continued

where: CCR = capital charge rate (in constant dollars)
r = nominal discount rate (.1325)
R = actual discount rate (.079, from equation IV.b)
i = investment tax credit (.10)
 f_{tax} = income tax rate (.50)
B = Length of construction period. All money is
assumed to be expended 2/3 of the way through
the construction period.
TL = Tax life = physical life

This form is for double declining balance depreciation, without
a switch to straight line. Switching to straight line gives a
slightly lower CCR. Optimal switching was used in ISTUM.

c. Specifying Cost-Frequency Distributions

The previous section discussed how to calculate a single, annualized, cost for each technology. This is the procedure which would be followed by any one plant manager who is considering various options. He faces a point cost for each alternative technology. His point estimate of capital costs will be annualized and added to his point estimates of fuel costs, giving him a point estimate of total cost.^{1/}

However ISTUM must deal with many different plants. As discussed in Chapter II, there is considerable variation in the cost of the same technology from application to application, site to site. Even after a few key dimensions (size and load factor) have been explicitly allowed for, it is still necessary to specify the costs of a technology as a distribution rather than a point estimate. The reasons are listed in Table IV-1. This subsection shows how to represent distributions for the purposes of estimating nominal market share. The discussion is conceptual compared with the more practical discussion in Chapter II.

The cost typology discussed in Chapter II divides each technology into its major cost components, such as basic

^{1/} Of course no plant manager will know precisely the cost of a technology not yet installed. However for mature, commercially proven, technologies the estimating errors will be very small. For investments of only a few million dollars, such as these energy investments, no one will bother to consider their estimates as ranges rather than points. (For investments over \$100 million, formal risk evaluation might be performed. See "Integration of Uncertainty into Industrial Evaluations of Fossil Energy Technologies", EEA, Inc., Prepared for ERDA, Feb. 1977.)

TABLE IV-1

PARTIAL LIST OF SOURCES OF TECHNOLOGY COST VARIABILITY

A. Application Related Variability

1. Specific process requirements. These may vary within a service sector. For example some direct heat applications may require more uniform heat distribution, which is accomplished by increasing the number of burners resulting in higher costs. Another example is steam, where pressure and temperature requirements vary with application.
2. Turndown requirements. Batch processing or discontinuous shipments of raw materials may call for equipment that can respond to rapidly changing loads.
3. Reliability requirements. Some industries place a high premium on reliability. The value of lost output due to equipment failure may make it economic to have complete backup systems.

B. Site Related Variability

1. Available Space. A lack of available space can greatly increase the cost of certain technologies, particularly solar where collector space is needed, and coal where room for coal handling is required.
2. Local variables. Such as the cost of the land, costs of obtaining required permits and costs related to environmental restrictions.

TABLE IV-1 continued

3. Weather. Harsh weather increases coal handling costs, and amount of sunlight (insolation) is important for solar costs.
4. Terrain - Rugged, sloped or marshy land can increase construction costs.
5. Auxiliary costs. Some technologies require considerable water and/or electricity. Their cost and availability varies from site to site. Boiler feedwater and electricity for coal handling equipment are examples.
6. Labor wages and productivity variability. Wage rates and labor productivity vary from site to site.

C. Firm Related Variability

1. Cost of Capital. Different firms have different financial structures.
2. Operator and maintenance skill levels.
3. Familiarity with technology being installed. DO they have past experience with this type of system?
4. Planning Horizon and general organization.

Note: Technical uncertainty is not incorporated into the cost variability. It is a separate issue. ISTUM assumes for example, that any technical barriers preventing the use of an energy technology are overcome, and at reasonable cost.

equipment and controls, environmental controls, and fuel handling. Each of these will have its own range of costs, from case to case. For the moment consider only a single cost component for a single technology, such as the power house (the enclosure) for a coal fired boiler sized at 250 MMBtu/hr steam produced.

Suppose an exhaustive site survey were conducted which covered every location in the U.S. where steam will be demanded in the appropriate demand cell. (The demand cell specifies the SIC, year, size, load factor, and the fact that it is steam. For example, it might be "SIC 29, size 250, load factor 7000 hrs/yr.") At each site a careful cost estimate would be prepared for a coal fired boiler, with power house costs broken out separately. If there were 1000 locations surveyed, there would be 1000 pairs of costs: one capital cost, and one operating/maintenance cost for each location. As shown in Volume 4, there would be considerable variation in costs between locations.

The next step is to apply the annualization procedure discussed in subsection 2.a separately to each location's pair of data. This gives 1000 costs, each expressed in dollars per million Btu, for the power house portion of a hypothetical coal boiler if it were to be built at that site. Some of these 1000 costs may be infinite. This would be the case, for example, in applications where there was no space for a power house. There would also be an infinite cost if coal fired boilers were, for any reason, prohibited at that location.

Now sort these costs, and group them into categories. For example, suppose that ten out of the 1000 costs are as follows (in \$/MMBtu, using 1977 dollars):

0.13 0.20 0.24 0.17 100.00 0.12 0.11 100.00
0.36 0.15

(The \$100.00 costs are essentially infinite, i.e., correspond to locations where the technology can't be used.)

After sorting, these numbers are:

0.11 0.12 0.13 0.15 0.17 0.20 0.24 0.36
100.00 100.00

Then group the costs into ranges and get the following:

Range, \$/MMBtu	Number of costs in this range	Percent of costs in this range	Percent of costs in this range or below
0.11 to 0.15	4	40%	40%
0.16 to 0.20	2	20%	60%
0.21 to 0.25	1	10%	70%
0.25 to 0.50	1	10%	80%
infinite	2	20%	100%

The number of locations falling into each cost range may then be graphed. In this hypothetical example, the graph might look like this (using the full 1000 locations would give a smooth graph).

$f(x)$ = fraction
of all potential
users in the
demand cell
who would
experience
this cost

This curve then summarizes all of the information about the cost of powerhouses for coal boilers in the specified demand cell. It is called a cost frequency distribution. The fraction of potential users who would experience any particular cost can be read directly from the graph. Other useful values, such as the mean cost, modal (most likely) cost, and median cost can be calculated from the graph.

Note that the area under the curve shown is only 0.8, not 1.0 as is the case for most frequency distributions. The reason is that in 20 percent of the cases, coal boilers could not be used. (Symbolically, this could be represented by a spike with an integral of 0.2, at the \$100/MMBtu mark.)

The final stage, which is not theoretically necessary but is needed to make subsequent calculations practical, is to fit a standard probability distribution to the graph. Choosing which of a number of standard distributions to use is difficult.^{1/} Several weeks were spent on this issue during the development of ISTUM. Once a particular type of distribution is chosen, fitting different sets of data to it is fairly simple.

The above procedure is then repeated for each of the other components of a coal boiler, such as site preparation, feedwater treatment, and fuel storage/handling. That is, each cost component of a technology is described by its own cost distribution.^{2/} These distributions specify how much

^{1/} The standard reference on this subject is Maurice Kendall and Alan Stuart, The Advanced Theory of Statistics, Volume 1, 4th edition, MacMillan Publishing Co, Inc., New York, 1977.

^{2/} The procedure discussed here implies that the distributions for each cost component are independent, in the statistical sense of that word. This was discussed in Chapter II and Volume IV. It is a reasonable assumption once one adjustment is made.

of the universe of potential users would experience each possible cost for that cost component of that technology.

d. Cost Distributions Do Not Encompass Technical Uncertainty

The derivation procedure described above is hypothetical, since in practice no exhaustive site survey and cost estimating could be done. Instead, a procedure based more on analysis and less on empirical work is used to find the cost distributions used in ISTUM, as described in Chapter II.

However, the site survey approach described in section 2.c above is useful for discussion purposes, because it shows what issues are and are not included in the cost frequency distributions. Those issues which lead to the distributions were summarized in Table IV-2. (Not all of the factors in that table are significant enough to be worth modeling or measuring individually. Instead, once all of the major factors have been modeled and estimated as in Chapter II, a "residual variation" is added to each distribution in the "indirect capital cost" component.)

Not included in the cost frequency distributions is "technical uncertainty" -- the concept that the specifications and performance of the technologies in ISTUM are not always known today (1978). Some of the technologies have not even had pilot scale prototypes built; many others have not yet been tested under actual operating conditions. Therefore their cost and performance is not fully known, even if the site and application are fully described. (For example, an AFB unit is being built to supply heating to Georgetown University. The unit has been designed and is under construction; but no one is positive what its efficiency and

reliability will be, how much maintenance it will require, what air pollution standard it will meet, etc.)

Technical uncertainty is often modeled by mathematical methods very similar to that used in ISTUM for cost frequency distributions. It is very tempting to try to simply "fold in" technical uncertainty as yet another source of variation. However that would not be correct; the results (the nominal market shares calculated from such hybrid distributions) would be meaningless.

Instead, the following provisions for technical uncertainty have been made in ISTUM. The cost frequency distributions used are based on a single, realistic, estimate of the performance of new technologies. These estimates may subsequently turn out to have been incorrect. Technologies for which, in EEA's opinion, the performance or cost estimates are particularly speculative are coded with quality codes "C" or "D". Technologies for which this is not a problem receive quality codes "A" or "B". The entire ISTUM model may be run deleting technologies with a poor quality code.

A second provision is that there are special sensitivity analysis routines which show what would happen to the nominal market share of any particular technology if it performs either better or worse than expected in the basic estimates. The impact of its performance on other technologies can also be estimated at the same time. Sensitivity analysis of this kind can be done only on one technology at a time.

e. Adding Cost Components

The discussion up to this point has shown how to derive a cost frequency distribution for each cost component of

a given technology. This has been from a fairly theoretical perspective, while Chapter II.B discussed how to do this on a practical level. Volume IV gives detailed derivations of the costs actually used in the base case of ISTUM.

The ultimate objective is to compare technologies; therefore the individual cost components for each technology must be summed, to come up with a cost frequency distribution for the total technology. This was shown in Figure IV-1b. Sophisticated mathematics are required even if approximate methods are used. The equations used are discussed below in section II.B.6.

3. Determining the Appropriate Market for Each Technology

The ISTUM methodology matches technologies to markets, and determines how much each technology will be used in each market segment. In order to do this, the cost of each technology in each market segment must be determined. This was discussed in the preceeding section. In addition, the applicability of each technology to each market segment must be determined. Certain technologies are not appropriate for use in certain market segments. In addition, there may be constraints which make a technology applicable to only a portion of a market segment. Both of these factors become part of the ISTUM characterization of each technology. They are then used in calculating nominal market shares.

The industrial energy market in ISTUM is broken down along five dimensions. The result is several thousand non zero market segments. The definition of each segment, and the method used to determine the size of each were discussed in Chapter III. In this section each dimension is reiterated,

and the reasons for which technologies might be excluded due to that factor discussed. The specific applicability of each technology to each market segment is covered in Volume IV.

a. Service Sector

There are 23 service sectors in ISTUM (see table IV-2). Many technologies are specific to one service sector, such as boilers being appropriate only in steam. In other cases it is theoretically possible to use a technology in a service sector, but not practical and not worth costing out. Any technology which occurs in more than one service sector is costed out separately in each.

Of these 23 service sector, 11 have no technologies in them at all. These are feedstock and other special service sectors. They are maintained for energy accounting purposes.

b. Industry (SIC)

There are 26 SIC's in ISTUM. Most of the conventional technologies, such as natural gas boilers, are applicable in all SIC's. Certain conservation technologies are specifically designed for the process of only one SIC. For example, the paper pulp sludge drying process is a process change applicable only in the paper industry.

A more subtle factor is that some classes of technologies are suitable only in plants with particular geographic characteristics. For example, medium Btu gas is costed out on the basis of a single gasifier supplying several large near-by plants. There are only a few SIC's which have large, physically close plants; therefore MBG is restricted to these industries. (See Chapter II.E.2.c, page II-31 in volume I, book 1.) Similarly, solar concentrating collectors are

TABLE IV-2

SERVICE SECTORS USED IN THE ISTUM MODEL

1. Steam
2. Direct Heat - (Intermediate)
3. Direct Heat - (Dirty)
4. Indirect Heat - (coal capable)
5. Machine Drive
6. Electrolytic
7. Liquid Feedstock
8. Natural Gas Feedstock
9. LPG Feedstock
10. Metallurgical Coal
11. Miscellaneous Energy and Lubes
12. Space Heat
13. Indirect Heat - (not coal capable)
14. Calcining
15. Glass Melting
16. Brick and Clay Firing
17. Ironmaking
18. Steelmaking
19. Steel Reheating
20. Internal Generation
21. Captive Electricity
22. Captive Direct Heat
23. Coke Consumption

excluded from industries whose plants do not normally have enough land to collect a significant amount of sunlight.

c. Combustor Size

A few technologies are restricted in the range of demand sizes (million Btu per hour) they can meet. This may be by regulation, as with the use of oil and natural gas in boilers. Under the Energy Supply and Environmental Coordination Act of 1974 (ESECA), the Department of Energy can prohibit their use in boilers greater than 100 MMBtu/hour. (See Chapter V.) Occasionally there may be technical limitations involved.

One side issue worth noting is that in some cases the size of individual combustors is important; for others, it is the size of total demand at one site, regardless of how many combustors are used to satisfy it. For example, low Btu gasification systems might be built to supply the needs of an entire plant from one central gasifier facility. Analyzing such issues requires case by case models of a single plant, and was not undertaken as part of the present ISTUM effort.

d. Combustor Load Factor

Many of the comparative economics of different technologies depends on the load factor at which they will be operated. (The term "load factor" as used here covers both hours per year of operation, and percent of full output at which the equipment is operated when it is turned on.) Therefore each service sector is disaggregated into different load factor categories, and technologies are competed separately in each category. See Chapter III.C.6 for a discussion of the load factor categories and how demand was disaggregated into them.

In a few cases there are technical or regulatory restrictions on the range of load factors which a technology will supply. In these cases the technology is excluded from competing in the appropriate load factor market segment.

e. Year

The ISTUM model is dynamic; it traces the use of energy over time. Most of the technologies included in the model are still being developed, and are not yet commercially available. Each technology is given an estimated date of availability as part of its specification. This is the year in which the technology is assumed to be fully proven and able to come on stream. (See Chapter II.D.) Depending on Department of Energy actions, this year of availability may shift.

ISTUM technologies are competed against each other at five year intervals: 1980, 1985, 1990, 1995, 2000. Only those technologies which are available in a given year are allowed to compete. Thus in the 1980 market segments, mainly conventional technologies are competed.

Each market segment defined by the above dimensions is analyzed separately. Only the applicable technologies are competed in that segment. Also, the costs of each technology will change in each segment. Therefore a technology may do well in one segment, and get very little market in another segment.

A further factor is that the cost of each technology changes in each segment. This is discussed more fully in Chapter II. Briefly, the reasons for these changes are as follows:

- Service sector: Different cleanliness, temperature, and end characteristics will dictate different hardware configurations.
- SIC: Technology costs were not modeled as shifting by SIC. For a few of the more heterogeneous service sectors, such as dirty direct heat, there will be variation between SIC's. But no data was available on these changes in most cases. Where the cost variations are significant, service sectors were disaggregated. For example, the calcining, brick firing, and glass melting service sectors were originally all classed as dirty direct heat; they were broken out to give increased accuracy.

The nominal market share of a given technology still varies a lot from SIC to SIC. See section B.5.d for an example and explanation.

- Combustor load factor: Capital intensive technologies will be less expensive per unit energy delivered when they are operated at higher load factors. The effect is often dramatic.
- Year: Both capital costs and fuel prices change over time.

4. Calculating Theoretical Market Shares

The preceeding sections discussed the question of how to define the theoretical market share of a technology, and showed how the raw technology characterizations discussed in Chapter II are used to derive the key inputs needed to estimate these shares. The first is a matrix showing which technologies are applicable in which market segments. The second is a cost frequency distribution of each technology for each relevant market segment, showing how much of the total demand in that market segment could be met at each of

a range of prices. The third is the maximum fraction of each technology in each applicable market segment; this is a single number showing the theoretical maximum percentage of the demand segment which that technology could meet^{1/}.

With these three pieces of information for all technologies, it is now possible to calculate the nominal market shares for those technologies. Nominal market shares are calculated for each market segment in turn. All technologies within a market segment must be competed simultaneously. For example, there are seven technologies which compete for glass melting service demand installed in 1990 in combustors of size 67 MMBtu/hour which will be operated at a load factor of 7000 hours per year. All seven technologies are competed simultaneously, to give seven nominal market shares. Then the nominal market shares for these same technologies in other size and load factor market segments are calculated. The overall nominal market share of these technologies is the average of their nominal market shares in each market segment, weighting by the comparative size of each market segment.

The definition of nominal market share was explained in section IV.A.2. The nominal market share of a particular technology in a particular market segment is that fraction of the market segment in which that technology will be able to supply energy to the final process more cheaply than any competitor. (This is a dynamic equilibrium definition; ISTUM explicitly models non-equilibrium adjustments over time; these are discussed in sections IV.C and IV.D.) Thus for one end user, technology A may be cheapest, whereas for another end user, technology E may be the cheapest and technology A the most expensive. The nominal market share calculation

^{1/} The maximum fraction can actually be incorporated into the cost frequency diagram, and this is done later.

aggregates over all end users in that market segment, and determines how many of them will find each technology to be the cheapest^{1/}.

The remainder of this section discusses in detail how to actually calculate nominal market shares. Subsection B.4.a shows how to visually summarize a market segment, using a cost frequency diagram. Subsection B.4.b. shows how to use this diagram. Graphic and verbal explanations are given.

Section B.5 discusses what the implications of these nominal market share calculations are. For example, a technology whose best cost is quite favorable may not capture a very large fraction of the market, because in most applications it has a cost much greater than its lowest cost. Previously used energy models generally would not capture this type of effect. The issue of whether technology costs should be modeled as being variable, as is done in ISTUM, or can be modeled as simply "most likely" estimates as is commonly done is discussed. This has been a somewhat controversial issue in previous presentations of ISTUM.

Finally, section B.6 discusses what happens when cost interdependencies between technologies are considered. For most technologies in ISTUM the effect would not be large, but for coal using technologies the results can change significantly. This section also gives a mathematical treatment of nominal market shares.

a. Diagrammatic Representation of a Market Segment

The simplest possible case for determining nominal market shares is one with only two technologies competing

^{1/} From this definition it is apparent that the sum of all nominal shares must be exactly 1. Each end user will find one of the applicable technologies to be cheapest. Therefore the alternatives are a mutually exclusive and collectively exhaustive set. Hence the sum of their frequencies must be unity. See for example William Feller, An Introduction to Probability Theory and Its Applications, Volume I, 3rd edition John Wiley & Sons, 1968, page 22.

for a market. Suppose that both have maximum fractions of 1, i.e., both can supply the entire demand of that market segment. Suppose further that there are no "interdependencies" between the two technologies. Then the situation can be summarized by a diagram showing the cost frequency distributions of both technologies on the same graph.

FIGURE IV-3
EXAMPLE COST FREQUENCY DISTRIBUTIONS FOR
TWO COMPETING TECHNOLOGIES

Each of the curves in Figure IV-3 was derived by the procedure shown in Figure IV-1a and IV-1b, and discussed in section IV.B.2. The interpretation of the two curves is as follows. Any single potential user will have some cost for each technology. The cost for technology A will be between $a_{\min}$ and $a_{\max}$. For example, potential user 1 might have cost a_1 for technology A, and cost b_1 for technology B. Since a_1 is less than b_1 , this user will use technology A. However user 2 might have cost a_2 for technology A, and b_2 for technology B. User 1 will therefore select technology A at cost a_1 , while user 2 will select B at cost b_2 .

Overall, the fraction of all users who will have cost a_1 for technology A is given by the height of the technology A curve at cost a_1 , and similarly for other costs. However, the fraction of all users who will find technology A to be cheaper cannot be read directly from Figure IV-3. A series of subsequent calculations is necessary. These are discussed in subsection 4.b. below.

All of the market segments actually considered in ISTUM are more complicated than Figure IV-3. First, they have more than two technologies. Second, the maximum fractions of some of these technologies is less than one.

Figure IV-4 shows a cost frequency diagram for an actual market segment, using the current version of the ISTUM computer programs. There are six technologies competing in this market segment.^{1/} (The segment shown is dirty direct heat, size 50 MMBtu/hour, load factor 6500 hours per year (74 percent), in 1985. The costs shown are for a generalized SIC, rather than one specific industry.)

1/

They are:

- 1.23 Low Btu gas
- 2.13 Heater air fuel control
- 2.33 High temperature recuperator
- 5.13 Direct Coal
- 8.23 Conventional oil
- 8.33 Conventional natural gas

Two other technologies which actually compete in this service sector, medium Btu gas and paper pulp sludge treatment, are not shown here. Both compete only in a few industries. See Volume 4, and (Vol. 1) Chapter II.E. for explanations of these technologies. (Natural gas was actually run in 1985 with a maximum fraction of 50 percent. This was moved to 100 percent for Figure IV-4 and IV-5 for simplicity.)

FIGURE IV-4

COST-FREQUENCY DIAGRAM
(Dirty Direct Heat - See text for full explanation)

Figure IV-4 shows a typical pattern for many market segments. Several conservation technologies have low costs in all applications. But they have maximum fractions much less than 1, i.e., they would only conserve a small fraction of the energy in that market segment even if universally applied. This is shown in the diagram by the area under their curves, which is equal to their respective maximum fractions. Then, starting at \$9.00/million Btu^{2/} several fossil fuel burning technologies, both new and conventional, compete. Their cost frequency distributions overlap greatly. Although the cheapest applications for coal are cheaper than the cheapest applications for any of the other three, there are many applications for which conventional coal will be more expensive than low Btu gas, natural gas, or oil. Therefore all four of these technologies will get some of the market.

b. Verbal, and Graphic Explanation of Nominal Market Share Calculations

Given only the information in Figure IV-4, the nominal market share of each technology can be calculated. The diagram shows the likelihood that any potential user will experience a particular price for a given technology. Therefore the fraction of all users who will find that technology to be the cheapest can be determined.

^{2/} Remember that all costs are per million Btu of service demand. Efficiencies in the dirty direct heat market are very low, on the order of 30 percent; therefore fuel is quite expensive per unit of useful output (service demand). Thus the seemingly high price of \$9/MMBtu is very reasonable.

Conceptually, calculating nominal market shares from Figure IV-4 is easy. There are several enumeration procedures, for example, which would work in theory. A Monte Carlo procedure of some type could also be used. However, none of these are practical. It can easily be shown that for a market segment with more than about ten technologies competing, any of the brute force methods such as these would be far too slow, even for a computer. Therefore the calculation technique used in ISTUM is analytical rather than brute force. That is, it is possible to derive equations which permit quick and easy calculations of the nominal market shares. Unfortunately, the derivation of these equations appears complicated to nonmathematicians. (In effect, we are substituting preliminary labor with pencil and paper, in place of tremendous later effort with a computer doing numerical calculations.)

It is not essential for the reader to follow the procedure used to translate cost frequency diagrams such as Figure IV-4 into nominal market shares. Subsection IV.B.5 discusses the implications of the treatment of nominal market shares, and the reader may prefer to take on faith the way they are determined. Nevertheless, to really understand the behavior of ISTUM it is preferable to have a good understanding of nominal market shares. Therefore this subsection walks through the calculation of nominal market shares carefully, without using sophisticated mathematics. (Section IV.B.6 gives a mathematical derivation.)

Figure IV-5 shows the procedure. Figure IV-5a is identical to Figure IV-4. This cost frequency diagram is the starting point for subsequent calculation. Its height shows what fraction of all potential users would experience exactly the price shown. (This is also the probability that a single, randomly chosen, potential user would find that he experienced the

05-VI

0.07-

FIGURE IV-5a

CALCULATING NOMINAL MARKET SHARES (a):

INITIAL COST-FREQUENCY DIAGRAM

(same as Figure IV-4)

0.06-

Key

- * Boiler Air Fuel Control (ID 2.)
- o High Temperature Recuperator (ID 2.33)
- + Direct Coal (ID 5.31)
- Low Btu Gas (ID 1.32)
- x Oil (ID 8.23)
- o Natural Gas (ID 8.33)

0.05-

0.04-

0.03-

0.02-

0.01-

0.00

FREQUENCY

PRICE (\$/MMBTU)

0.00 1.50 3.00 4.50 6.00 7.50 9.00 10.50 12.00 13.50 15.00

0.00 1.50 3.00 4.50 6.00 7.50 9.00 10.50 12.00 13.50 15.00

given price. We prefer to avoid this terminology, even though it is more concise, because it often leads to confusing the cost-frequency distribution with a distribution of technical uncertainty.)

Figure IV-5b shows the fraction of all potential users who will experience a price greater than the price shown, for each technology in turn. For example, there is a vertical line drawn at the \$12/MMBtu point on the horizontal axis. Looking upwards until this line crosses the dotted line for low Btu gas, one sees that 63 percent of all potential users of low Btu gas in this market segment would have a price higher than \$12/MMBtu. About 67 percent of the market would find that natural gas costs them more than \$12. And almost all users of oil would find it more expensive than \$12. Figure IV-5b shows the corresponding fraction for an entire range of prices, from 0 to \$15/MMBtu.^{1/}

Calculating the lines in Figure IV-5b from those in Figure IV-5a is the second stage of the nominal market share calculation. Each line in IV-5b is simply 1 minus the integral of the corresponding line of IV-5a. In statistical terminology, Figure IV-5a is a collection of probability density functions;

^{1/} The alert reader will notice that for many of the technologies, notably air fuel control and high temperature recuperators, the curve flattens out while still at a high probability. The reason is the maximum fractions for these technologies. For example, recuperators (technology 2.33) have a maximum fraction of 18 percent. Its curve therefore flattens out at 82 percent, saying that 82 percent of this market segment would experience an infinitely high price for this technology. No matter how expensive the design, only 18 percent of the dirty direct heat demand could be met by this technology. Combining maximum fractions into the cost distribution in this way is shown later to be mathematically correct; it makes solving for nominal market shares easy.

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FIGURE IV-5b
 CALCULATING NOMINAL MARKET SHARES (b):
 Fraction of Market Segment Having a Higher Cost,
 For Each Technology

the lines in Figure IV5b are the complements of their cumulative distribution functions.

The third stage in arriving at the nominal market share is to single out one technology, for example direct combustion coal (I.D. 5.13). Then, for each possible price, determine the fraction of applications for which all of the other technologies will be more expensive than this price. This is shown in Figure IV-5c. For example, in 34 percent of the market all of the other technologies will be more expensive than \$12.00 per million Btu.

This is calculated as follows:

(Eq. IV.1) Fraction of market segment for which all technologies except 5.13 are more expensive than \$12/MMBtu

$$= (\text{Pr}(T_{1.23} > \$12)) \times (\text{Pr}(T_{2.13} > \$12)) \times (\text{Pr}(T_{2.33} > \$12)) \times (\text{Pr}(T_{8.23} > \$12))$$

Where $(\text{Pr}(T_i > \$12))$ means "the fraction of the market segment for which users of technology i would find that it cost more than \$12 per million Btu." Numerically, we get $.34 = (.63)(.67)(.82)(.98)(.99)$. This calculation is repeated for all possible costs from 0 to \$15 per million Btu. The result is Figure IV-5c.^{1/}

(Equation IV.1 is correct in the simple multiplicative form shown only because of the assumption that the costs of all technologies are independent. This assumption is unfortunately not correct, but it is useful for explanatory purposes. When it is dropped, there is an equation analagous to equation IV.1, but much more complicated. This is taken up in subsection B.6, below.)

^{1/} Note that the left hand side of equation IV.1 says nothing about whether the costs of technology 5.13 itself are higher or lower than \$12.00. It only concerns the other technologies in the market segment.

FIGURE IV-5c

CALCULATING NOMINAL MARKET SHARES (c):
FRACTION OF MARKET FOR WHICH ALL TECHNOLOGIES
OTHER THAN DIRECT COAL WILL BE MORE EXPENSIVE THAN PRICE SHOWN

The fourth and final step is to multiply the fraction of the market in which all technologies other than 5.13 are more expensive than a particular price z (from Figure IV-5c), times the fraction of the market in which technology 5.13 itself has exactly price z (shown by the line for technology 5.13 in Figure IV-5a). This gives the fraction of the market for which technology 5.13 has a particular price z and all other technologies are more expensive. It is shown in Figure IV-5d. For example, in 34 percent of the market all other technologies are more expensive than \$12/MMBtu, and in 1.9 percent of the market conventional coal has a price exactly equal^{1/} to \$12.00/MMBtu. The product^{2/} of these frequencies is .006. This is the value shown in Figure IV-5d at the 12.00 mark on the cost axis.

Figure IV-5d therefore shows, for all possible costs, the fraction of the market segment in which direct coal has a particular cost and all other technologies are more expensive than that particular cost. This is equivalent to saying that conventional coal has a particular cost and all other technologies are more expensive than conventional coal. Now sum over all possible costs that conventional coal can have, to get the fraction of the market in which conventional coal is the lowest cost technology. This is given by the integral under the curve in Figure IV-5d. That is, the nominal market

1/ Actually, this is: the probability of being in the interval $(12 - \frac{dx}{2}, 12 + \frac{dx}{2}) (1/dx)$. (A scale factor of .15 is used on the left axis of figures IV-5a and IV-5d due to the particular numerical method used. It does not affect the shapes of the graphs.)

2/ Again, this assumes independence, this time between technology 5.13 and the other technologies.

F
R
E
Q
U
E
N
C
Y

0.07-

0.06-

0.05-

0.04-

0.03-

0.02-

0.01-

0.00-

0.00

1.50

3.00

4.50

6.00

7.50

9.00

10.50

12.00

13.50

15.00

FIGURE IV-5d

CALCULATING NOMINAL MARKET SHARES (d):
FRACTION OF MARKET IN WHICH COAL HAS A PARTICULAR COST AND
ALL OTHER TECHNOLOGIES ARE MORE EXPENSIVE

PRICE (\$/MMBTU)

share for technology 5.13 (conventional coal) is equal to the area under Figure IV-5d. In the example shown, it is 38.1 percent^{1/}. So in 38.1 percent of the market segment under discussion (dirty direct heat, 1985, size 50 MMBtu/hour, load factor 6500 hours/year), conventional coal is cheaper than any alternative.

Other Sizes and Load Factors

The above calculations yielded nominal market shares for only a single technology, single combustor size, and single combustor load factor. Shares for the other technologies in the same market segment can be produced from the same graph, Figure IV-5a, by stages analagous to diagrams 5b,c, and d. (In fact there is a computational shortcut which permits the nominal market shares for all six technologies to be calculated at the same time, rather than in sequence.) But the entire nominal market share calculation must be repeated from start to finish for other sizes and load factors, starting with the cost calculations needed to get a new cost frequency diagram for that market segment.

The importance of size and load factor can be seen in Table IV-3, which shows the nominal market shares by size and load factor for a portion of the intermediate direct heat service sector. (Intermediate direct heat is shown rather than dirty direct heat because the latter has only one load factor.) In the larger size category, oil and gas drop from satisfying 75 percent of demand at 2000 hours a year (23 percent load factor), to satisfying 28 percent of demand at 6500 hours per year (74 percent load factor). The reason is that these technologies are fuel intensive, compared with coal and recuperators.

^{1/} After dividing by the scale factor on the left axis to re-normalize.

TABLE IV-3

NOMINAL MARKET SHARES IN DIFFERENT SIZE/LOAD
 FACTOR MARKET SEGMENTS
 (Intermediate Direct Heat - 1985 - SIC 331)

Technology ^{a/} ID Name	Size = 10 MMBtu/hr		Size = 50 MMBtu/hr	
	LF = 23%	LF = 74%	LF = 23%	LF = 74%
1.22 Low Btu Gas ^{b/}	0	0	0	0
2.32 High Temp Recup	18.3%	4.0%	7.6%	15.7%
5.12 Direct Coal ^{b/}	0	0	11.7%	51.3%
8.22 Oil	57.4%	53.4%	51.9%	19.1%
8.32 Natural Gas	32.4%	24.3%	22.8%	8.9%

a/ Not all technologies shown

b/ Not allowed to compete at 10 MMBtu/hr.

5. Implications of the Approach Taken to Nominal Market Shares

The approach ISTUM takes to calculating market shares for different technologies, based on the concept of overlapping cost frequency distributions is, as far as the authors know, unique^{1/}. It was used nevertheless because in the opinion of its developers it has important differences compared with previously used approaches which make it more useful for the purpose at hand. This section sketches a few of the key consequences of the approach taken. Rudimentary comparison is made with a few of the other methods used in energy modeling to simulate the choice among technologies. More work is needed to fully analyze the approach used here in terms of conventional economic concepts such as demand curves and elasticities. (For example, recalculating market shares at different fuel prices, the own and cross price elasticities of demand for fuels can be found.)

The postulates and criteria which led to the nominal market share model used were discussed in section IV.B.1 above. The most notable implications are as follows.

^{1/} See "A System for Projecting the Utilization of Renewable Resources - SPURR Methodology", K. Rebibo et. al., MITRE Draft, September 1977, NTIS number ERHQ/2322-77/4, page 20 for a related approach in the utility sector. Here also, overlapping cost distributions are used. But their derivation is entirely different; they refer to the technical uncertainty concerning the performance of new technologies and to "scenario uncertainty" about the future price of fuels. Therefore the market shares calculated also have a different meaning. They are the probability that the specified technology will capture the entire market segment. In the applications of this model, Monte Carlo rather than analytical methods were used for solution, which causes other differences.

a. Lack of Single Technology Dominance

No single technology dominates any market. The ISTUM model has this behavior for two reasons. First, the total industrial market is segmented into many smaller pieces, each with different costs for the competing technologies. For example industries which have plants operating at very different load factors, and combustors with different sizes, will generally be characterized by several different technologies in use to fill the same type of energy demand (such as steam). This is a direct consequence of the fact that some technologies show economies of scale, and some are capital intensive, while others have linear costs as size increases, or are fuel intensive. This much is captured by any energy model which segments the demand market in as much detail as ISTUM.

The second and often stronger reason that no technology dominates a market is that cost distributions are used for each technology, rather than point estimates. When this happens several technologies must get a share of the market. Our empirical investigation of the costs of different technologies (see Chapter II in this volume, and Volume IV), and the well known range of fuel prices from one location to another, mean that the cost ranges for different technologies will overlap. This is graphically visible in Figure IV4, for example.

Theoretically, it is still possible that interdependencies between the cost distributions of different technologies could lead to dominance by a single technology. The reasons for this are discussed in section IV.B. below. The current version of the ISTUM computer programs does not properly deal with interdependencies. However, the data base has been set up to show interdependencies. Careful examination of the intermediate outputs from existing ISTUM runs indicates that proper treatment of interdependencies will still not lead to

dominance by a single technology. Most of the sources of variance for a technology are uncorrelated with the sources of variance for technologies which use other fuels. Therefore each market segment will tend to have several fuels in use, hence several technologies.^{1/}

b. Robust Behavior: Lack of Knife Edge Solutions

A related consequence of the fact that cost frequency distributions tend to overlap is that model solutions change gradually as scenarios are changed, over time or between separate runs of the model. Looking at Figure IV-4, it is easy to see that as coal, oil, and gas prices evolve gradually over time, so will the nominal market shares of the corresponding technologies shift gradually. (In fact, the probability distributions used in the current version of ISTUM have infinitely long right hand tails. Therefore no technology can get 100 percent of a market cell unless it is the only one competing in that cell.)

This also tends to make the model somewhat robust against errors in data inputs, although of course this is only a question of degree. A slight cost change will never cause a drastic change in nominal market shares.

This is a major difference between the cost-frequency distribution approach of ISTUM, and the point estimates used in other models of technology choice. Usually the point estimates are somewhere between the low cost and the mean cost. Figure IV-4 demonstrates why exclusive reliance on either one can significantly misrank technologies.

^{1/} For example, the correlated cost components of oil and natural gas technologies are about 5 percent of their total cost.

In practice, drastic enough changes in scenarios will still drastically change nominal market shares. For example, passage of the National Energy Act in its originally proposed form would have given coal using technologies a credit of about 50 percent on their capital cost. This would be enough to push them into dominance of many market segments. In this case other sections of the ISTUM methodology come into play to cause energy use to shift more gradually. These are the behavioral lag and capital turnover portions of the model, discussed in sections IV.C and IV.D respectively.

c. Difficulties With Cross-Technology Constraints

Many energy-economic modeling approaches use the concept of linear constraints on possible activities. This is the hallmark of linear programming process models (see below), but is also found elsewhere. Although in many cases these constraints are not needed in non LP situations, there are still some features of the real world which are very naturally modeled by such constraints. An example is an EPA regulation which limited the amount of total coal burning permitted in a region. ISTUM handles constraints on the level of one technology at a time, through the use of maximum fractions. (For example, coal boilers can be constrained to 70 percent of each market segment in steam.) But it is awkward to set up ISTUM to handle cross-technology constraints such as one which jointly limits direct coal and low Btu gasification of coal.

Further mathematical work might lead to a solution to this problem. It may eventually be possible to use general linear constraints in an ISTUM solution.

d. Variation Among Industries

One interesting result is the great variation in the nominal market share of the same technologies in different industries. Table IV-4 shows the nominal market shares for some of the major steam raising technologies in 1985, by SIC. There are tremendous variations from industry to industry. For example, the largest nominal market share for conventional coal (technology 8.11) is 47.8 percent in SIC 29 (petroleum refining); the smallest is 0.4 percent in SIC's 31 and 02 (leather and livestock respectively). Conversely, conventional oil goes from a low of 3.3 percent in SIC 29, to a high of 68.3 percent in SIC's 31 and 02.

There are three reasons that nominal market shares should indeed vary by industry. ISTUM currently captures two and a half of these three reasons.

i) Special technologies applicable only to particular industries. The best example of this is wood waste and spent black liquor as a boiler fuel in the pulp and paper industry. It gets about 40 percent of the market in this industry, but is not available in any other industry (except possibly small amounts in the lumber and furniture industries). Other examples are many conservation process changes which are specific to the processes of a particular industry. The market captured by other technologies in that industry is correspondingly reduced.

ii) Different size and load factors in different industries. This is the source of much of the variation shown in Table IV-4 for steam. Nominal market shares vary tremendously depending on the size/load factor market segment they are competing in, as for example Table IV-3 (in another service

TABLE IV-4

VARIATION IN NOMINAL MARKET SHARES AMONG INDUSTRIES
(Steam Service Sector - Only Selected Technologies Shown)

BASE CASE 4/6 (DRI PRICES/NO INCENTIVES) NOMINAL MARKET SHARES (PCT)																YEAR: 1985
SERVICE SECTOR: STEAM																REPORT PRINTED: 12 JUN 1978 10.26.10
DATA STORED: 4/07/78 16:49:18:58																
INDUSTRY (SIC)	1.11	1.21	1.31	2.11	2.21	2.61	3.11	3.21	5.51	5.61	5.71	8.11	8.21	8.31	8.41	TOTAL
FOOD - 20	18.72	4.55		2.05	0.06						0.01	25.05	32.94	13.64		97.01a/
TOBACCO -21	13.12	3.19		1.97								17.65	44.38	18.35		98.66
TEXTILES -22	7.39	1.68		1.52	0.09						0.02	10.35	29.88	12.84		63.78
APPAREL -23	1.87	0.46		1.71								2.53	65.26	26.90		98.73
FURNITURE -24	3.83	0.93		1.86	0.14						0.02	5.60	60.94	25.30		98.62
PAPER(TOTAL) -25	1.94	0.48		1.80							0.02	3.00	64.64	26.77		98.65
PRINTING, PUBL -27	3.91	0.94		1.94		2.41					0.01	20.53	7.54	3.19	44.14	98.03
CHEMICALS-TOTAL	22.75	5.01		2.27	0.14						0.04	6.07	60.46	25.18		98.53
PETRO. REFINING	35.84	7.80		2.34							0.03	31.05	26.06	11.03		98.34
RUBBER/MISC. PR	19.02	4.20		2.25	0.17							47.76	3.26	1.38		98.38
LEATHER -31	0.05	0.02		1.73							0.04	26.29	32.59	13.79		98.36
S. C. G. CONCRE	18.91	4.34		2.13								0.38	68.27	28.22		98.68
STEEL-331	26.43	5.86		2.28								25.83	33.28	13.92		98.47
OTHER PRIM. MET	26.47	5.87		2.28							0.02	35.71	19.69	8.29		98.29
FABRIC METALS	9.48	2.25		1.99	0.14						0.02	35.76	19.70	8.29		98.40
MACHINERY-35	14.99	3.64		2.01	0.07							13.23	50.45	21.02		98.56
ELEC MACH -36	5.65	1.38		1.84	0.10						0.01	20.12	40.90	16.93		98.66
TRANSPORT EQUIP	7.56	1.82		1.92	0.12						0.01	7.77	57.94	23.98		98.67
MEASURING EQ-38	15.03	3.61		2.04							0.02	10.51	54.17	22.49		98.61
MISC MANUFAC -39	7.57	1.82		1.92							0.01	20.34	40.70	16.88		98.61
LIVESTOCK - 02	0.05	0.02		1.73							0.02	10.52	54.26	22.50		98.61
METAL MINING -10	6.30	0.11		2.05							0.01	0.37	68.26	28.22		98.68
NONMETAL MIN -14	0.30	0.11		2.05							0.07	2.02	66.10	27.74		98.39
Unweighted average ^{b/}	11.5	2.6	0	2.0	0.04	0.1	0	0	0	0	0	15.8	44.5	18.5	1.8	
Weighted average ^{c/}	19.4	4.3	0	2.0	.08	.6	0	0	0	0	.02	26.3	24.0	10.1	10.6	

a/ Total does not equal 100 percent because not all technologies shown.

b/ (Sum of nominal market shares) ÷ 24.

c/ weighted by 1985 steam service demand. Note the big difference between weighted and unweighted.

Key

1.11 Atmos. Fluid Bed
2.11 Boiler Air/Fuel Control
8.11 Conventional Coal
8.41 Wood Waste/Spent Liquor

1.21 Low Btu Gas
2.21 Heat Pump - Steam
4.21 Conventional Oil

1.31 Medium Btu Gas
5.71 Gas Turbine
8.31 Conventional Gas

sector). Each industry has some of this demand in each size/load factor segment; the industry's overall nominal market share for a particular technology is thus a weighted average of the nominal market shares for that technology in each size/load factor segment.

Table IV-5 shows the size and load factor shares for each industry in the steam service sector. A glance at SIC's 29, 31, and 02 confirms that the variation in nominal market shares is due to variation in their sizes and load factors. This confirms the importance of getting accurate field data on the sizes and load factors at which combustors are actually used. It also suggests that using an average value for the entire industrial sector, as some other energy projections have been forced to do, leads to significant aggregation error. See Chapter III.C.7, page (vol. 1) III-38 for a discussion of the data used in ISTUM.

iii) Different cost frequency distributions in particular industries. Some of the factors which determine the cost distributions for a technology will vary between industries. For example, some industries use mainly low pressure, low temperature steam; others require higher temperatures and pressures. The differences are particularly acute in the direct heat service sectors. This is the reason that the steel and stone clay and glass industries were broken down into a total of eight direct heat service sectors. Even so, several of these service sectors still contain disparate processes, each with different characteristics and therefore different costs.

Where adequate data and time are available, one solution is further disaggregation of service sectors. The authors feel that this is an area where ISTUM could profit from more

TABLE IV-5

ALLOCATION OF SERVICE DEMANDS TO EACH SIZE/LOAD FACTOR CATEGORY

STEAM SERVICE SECTOR					
(ISTUM Allocation of Service Demands to Each Size-Load Factor Category)					
SIC	Industry	50 MMbtu/Hr Load Factor (Hrs/Yr)		250 MMbtu/Hr Load Factor (Hrs/Yr)	
		4000	7000	4000	7000
20	Food	.45	.05	.45	.05
21	Tobacco	.58	.06	.31	.03
22	Textiles	.42	.29	.13	.12
23	Apparel	.35	.00	.05	.30
24	Lumber and Wood	.72	.13	.06	.02
25	Furniture	.31	.14	.04	.01
26	Paper and Allied Products	.06	.14	.24	.56
27	Printing and Publishing	.58	.31	.36	.03
28	Chemicals and Allied Products	.10	.30	.15	.45
29	Petroleum Refining and Related Products	.01	.04	.19	.76
30	Rubber and Miscellaneous Plastics	.13	.38	.13	.38
31	Leather Products	.30	.10	.00	.00
32	Stone, Clay, Glass, and Concrete Products	.25	.25	.25	.25
331	Steel	.09	.21	.21	.49
3334	Aluminum	.00	.00	.00	.00
334	Other Primary Metals	.09	.21	.21	.49
34	Fabricated Metals	.52	.22	.17	.07
35	Machinery (Except Electrical)	.54	.06	.36	.04
36	Electrical Machinery	.76	.08	.13	.01
37	Transportation Equipment	.54	.16	.16	.04
38	Measuring Equipment	.48	.12	.32	.08
39	Miscellaneous Manufacturing Industries	.64	.16	.16	.04
01	Crops	.00	.00	.00	.00
02	Livestock	.30	.10	.30	.00
10	Metal Mining	.40	.60	.00	.00
14	Nonmetal Mining	.40	.60	.00	.00
	All Industry Average (Weighted by 1974 Service Demands)	.13	.13	.21	.41

SOURCE: This table copied from (Vol. III) page 44. Tables for other service sectors are given there. The derivation of these tables is discussed in Chapter III.C.7.

work, especially in the service sector now called "intermediate direct heat".

e. Comparison with Other Approaches

Many different energy models have been developed, particularly in the last five years. For those familiar with some of these other models, this section very briefly suggests how ISTUM differs from them.

The most important distinction is the unit of analysis. Many of the better known energy models are general equilibrium models; they simultaneously consider energy production, distribution, and use.^{1/} Imbedded within such models are analyses of industrial demand for energy. Of necessity, since it is only a small part of the total effort and since assumptions must be made which permit consistency with the rest of the overall model, the analysis of the industrial sector is usually fairly simple. Service sectors and technologies are aggregated together. All models provide separate projections for coal, oil, and gas use in industry, but in many cases do not break demand down any farther.

In contrast, ISTUM is not a general equilibrium model. Fuel prices are taken as exogenous, rather than being forecast within ISTUM. Conceptually, ISTUM could serve to model demands in one sector in an iteratively solved general equi-

^{1/} A survey of some general equilibrium models is: "Large Scale Energy Planning Models: A Methodological Analysis", Horace W. Brock and Dale M. Nesbitt, prepared for the National Science Foundation, May 1977. This volume is oriented towards methodology rather than data or implementation, but references studies of the latter.

librium model. Because it does not make an extensive analysis of the entire energy system, ISTUM is able to make a much more intensive analysis of the industrial sector. No general equilibrium model has close to the 156 technologies and several thousand segments which ISTUM has for the industrial sector.

At the other end of the spectrum, there are various models of a single industry. These are usually linear programming models, based on LP characterizations of alternative processes for that industry. These models have more detail than ISTUM. For example, they can investigate the energy impacts of technological change whose primary motivation is unrelated to energy consumption. (For example, the use of lower grade ores in the primary metals refining industries.) Of course, this is a two edged sword: the modelers must have an intimate understanding of the particular industry, not just its energy consumption. They must have engineering/cost data for all stages of its production processes.

ISTUM has difficulties with this level of detail for two main reasons. One is that the fundamental data by which alternative technologies are competed, the cost frequency distributions, are robust only for energy. Although credits for non energy savings can be introduced, any error in the size of those credits could greatly affect the results. Second, some of the interesting process changes tend to cross several service sectors. Since in ISTUM each service sector is solved independently of the others, this is a problem. The ISTUM team developed the logic to have cogeneration cross three service sectors, but this required an extensive and special purpose effort. Many process changes are modeled in ISTUM, but these mainly affect one service sector.

A natural question is the consequences of treating the costs of alternative processes as point estimates, rather than distributions. All linear programming models do this.^{1/} In order to prevent a "corner solution" in which one or a few technologies dominate the results, a set of constraints is introduced, sometimes using rather artificial methods to guess where they should be set. In contrast, the empirical investigation documented in Chapter II and Volume 4 shows that the costs of any particular technology will vary considerably from application to application, even within the same industry. There is one case in which cost frequency distributions are clearly unnecessary, and a straight linear programming approach is without bias. This is the analysis of a single, known, plant. In this case actual cost estimates can be obtained for all alternatives.^{2/} In the more general case of analysing an entire industry, with many plants scattered around the country, there are obvious advantages to both approaches. A balanced comparison cannot be made without a specific situation in mind.

6. Mathematical Development of Nominal Market Shares

The preceeding sections have given an overview of nominal market shares, how they are calculated, and what they mean. Some of the subtler issues concerning nominal market shares remain. Continued prose discussion of these issues would be wordy and still ambiguous. Therefore this section switches to a more mathematical approach.

^{1/} "Stochastic linear programs" are possible, but quickly become complex and hard to work with. They are rarely used.

^{2/} There may be uncertainty and error in the estimates, but this falls under the heading of technical uncertainty. Considering it would prevent the use of a straight LP, but the ISTUM nominal market share would not be correct either.

Three often conflicting objectives led to the nominal market share model which follows:

- Realism. The goal is to accurately represent the behavior of the industrial sector in choosing energy technologies. This means concentrating on phenomena which empirical data and preliminary modeling indicate are most important.
- Solvability. It is easy to write a very general and very precise model which everyone will agree covers most conceivable circumstances and is theoretically correct. However it will usually:
 - a. Require empirical inputs which there is no way to estimate - because there is no way to measure the quantities, or because it is not practical to do so with finite resources.
 - b. Not be mathematically solvable at reasonable costs. For example, all of the equations below could be solved by some brute force enumeration techniques; but the cost would limit the model to one or two market segments.
- Development Time
 - a. Preliminary Notation

All that follows is for one market segment at a time. All variables and functions should be subscripted by:

size
load factor
SIC
year
IV-70

These subscripts are left out to simplify notation. All of the equations that follow are repeated for each market segment.

- x_α The random cost of building block α , $\alpha=1, \dots, n$
In \$/MMBtu of service demand.
- $g_\alpha (x_\alpha)$ The density function of x_α , i.e., the cost frequency distribution of building block α . Building blocks are chosen so as to be independently distributed. Finding $g_\alpha (x)$ for the ISTUM technologies was the subject of Chapter II.
- n The number of independent building blocks needed to make up all the technologies in the market segment. Some of these building blocks are fuels; most are capital components.
- α Dummy variable for building blocks. $\alpha = 1, \dots, n$.
- β Dummy variable for technologies. $\beta = 1, \dots, m$.
- m The number of technologies in the market segment.
- a_β The random total cost of technology β , $\beta=1, \dots, m$.
In \$/MMBtu.
- $f(a_1, \dots, a_m)$ The joint density function of technologies, i.e., the probability that technology 1 has cost a_1 , technology 2 has cost a_2 , $\dots$, technology m has cost a_m .
- M_A The $m \times n$ matrix of technology composition.
See equation IV.2.
- S_k Nominal market share of technology k .

b. Assumptions

a) Building blocks are independently distributed. This is not a restrictive assumption, as building blocks may be broken down as far as necessary. In practice a breakdown only to the level discussed in Chapter II was necessary.

b) Technologies are linear sums of building blocks:

(Eq. IV.2) $\underline{a}_A = \underline{M}_A \underline{x}$

where $\underline{a}_A = (a_1, \dots, a_m)$ technology costs
 $\underline{x} = (x_1, \dots, x_n)$ building block costs

This assumption is the key to the treatment of interdependencies between technologies. It says that two technologies will have independent cost frequency distributions if and only if they have no building blocks in common. The more building blocks they share, the greater the interdependency between them.

An example will clarify the significance of the $\underline{M}_A$ matrix. Table IV-6 shows part of an actual $\underline{M}$ matrix. Four technologies are built up from seven building blocks. For example, conventional coal boilers are composed of:

.276 x fuel handling building block
+ .232 x environmental control building block
+ .165 x site preparation building block
+ .244 x boiler equipment building block
+ (1/.82) x the price of coal.

Atmospheric fluid bed boilers are almost the same, but fuel handling is more expensive, and environmental controls are cheaper. (see Volume 4 for explanations.)

In this example, the conservation technology is independent of the other three technologies. The coal and AFB technologies are very heavily interdependent. The oil technology

TABLE IV-6

SAMPLE M MATRIX, SHOWING INTERDEPENDENCIES
 (Size = 250, Load = 7000 hrs/yr, Year = 1985)
 (see text for explanation)

	Fuel Handling	Environ- mental	Site Pre- paration	Boiler Equipment	Conservation Equipment	Coal	Oil
Coal Boiler	.276	.232	.165	.244	0	1/.82	0
AFB Boiler	.356	.081	.147	.289	0	1/.82	0
Oil Boiler	.144	.011	.089	.104	0	0	1/.82
Conservation process change	0	0	0	0	1.438	0	0

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has an intermediate amount of interdependence. (The degree of interdependence cannot be quantified until one knows the exact cost frequency distributions of the individual building blocks.)

c) There are at least as many building blocks as technologies. This is for convenience. If it is not the case, slightly more elaborate algebra is necessary.

$$(Eq. IV.3) \quad m \leq n$$

d) Only non-negative costs are allowed.

$$x_{\beta} \geq 0 \quad \beta = 1, \dots, n$$

c. Deriving the General Form of the Equation for Nominal Market Shares

$$(Eq. IV.4) S_k \equiv \Pr (\text{Technology } k \text{ is cheaper than any other})$$

$$= \int_{\Omega_k} \Pr \{ \text{technology } k \text{ has cost } w \text{ and all other technologies have cost } \geq w \} dw$$

where Ω_k = set of all possible costs which technology k can have, for example $[0, \infty]$.

Using the definition of $f(a_1, \dots, a_m)$ gives:

$$\begin{aligned}
 (\text{Eq. IV.5}) \quad & \Pr \left\{ \text{Technology } k \text{ has cost } w \text{ and all other technologies} \right. \\
 & \quad \left. \text{have cost } \geq w \right\} \\
 &= \Pr \left\{ (\tilde{a}_k = w), (\tilde{a}_1 \geq w), (\tilde{a}_2 \geq w), \dots, (\tilde{a}_{k-1} \geq w), \right. \\
 & \quad \left. (\tilde{a}_{k+1} \geq w), \dots, (\tilde{a}_m \geq w) \right\} \\
 &= \int_w^{\infty} da_1 \underbrace{\int_w^{\infty} da_2 \dots \int_w^{\infty} da_m}_{a_k \text{ deleted}} f(a_1, a_2, \dots, a_k, a_{k+1}, \dots, a_m)
 \end{aligned}$$

So (IV.4) becomes:

$$\begin{aligned}
 (\text{Eq. IV.6}) \quad S_k &= \int_{\Omega_k} dw \underbrace{\int_w^{\infty} da_1 \dots \int_w^{\infty} da_m}_{a_k \text{ deleted}} f(a_1, \dots, a_m)
 \end{aligned}$$

Solving this equation in turn for $S_1, \dots, S_m$, gives the answer.

The multiple integral in equation IV.6 cannot be evaluated directly, unless $f(\underline{a})$ happens to be of exceptionally simple form. But equation IV.2 combined with the fact that the $\tilde{x}_\alpha$ are independently distributed, gives what is needed. A transformation of variables from $\underline{a}$ to $\underline{x}$ in equation IV.6 will give what we need.

We cannot transform variables immediately since $\underline{a}$ and $\underline{x}$ are of different dimension. Digress to augment $\underline{a}$ by adding dummy variables:

$$(eq. IV.7) \quad \underline{\hat{a}} = (\hat{a}_1, \dots, \hat{a}_m, \hat{a}_{m+1}, \dots, \hat{a}_n)$$

$$(Eq. IV.8) \quad \hat{a}_\beta = \hat{x}_\beta \quad \text{for} \quad \beta = m+1, \dots, n \text{ for convenience}$$

$$(Eq. IV.9) \quad \text{Define}$$

$$\underline{\underline{M}} = \left[\begin{array}{c|c} \underline{\underline{M}}_A & \\ \hline 0 & \underline{\underline{I}} \end{array} \right] \begin{matrix} \left. \vphantom{\begin{matrix} \underline{\underline{M}}_A \\ \hline 0 \end{matrix}} \right\} m \\ \left. \vphantom{\begin{matrix} \underline{\underline{I}} \end{matrix}} \right\} n-m \end{matrix}$$

$\underbrace{\hspace{10em}}_n$

where $\underline{\underline{I}}$ is the identity matrix. So $\underline{\underline{M}}$ is an augmented version of $\underline{\underline{M}}_A$.

Then

$$(Eq IV.10) \quad \underline{\hat{x}} = \underline{\underline{M}} \underline{\hat{x}}$$

$$(Eq IV.11) \quad \underline{\hat{x}} = \underline{\underline{N}} \underline{\hat{a}} \quad \text{(If } \underline{\underline{M}} \text{ is not invertible the size of the problem can be shrunk until it is)}$$

where $\underline{\underline{N}} = \underline{\underline{M}}^{-1}$

In equation IV.6 just integrate out the dummy variables to get:

$$(Eq. IV.12)$$

$$S_k = \int_{\Omega_k} dw \underbrace{\int_w^\infty da_1 \dots \int_w^\infty da_m}_{a_k \text{ deleted}} \int_0^\infty da_{m+1} \dots \int_0^\infty da_n f(a_1, \dots, a_n)$$

Equation IV.11 and the fact that the $\tilde{x}_\alpha$ are independent gives:

$$f(a_1, \dots, a_n) = g_1(x_1) \cdot g_2(x_2) \cdot \dots \cdot g_n(x_n)$$

$$\text{Since } x_\alpha = \sum_{\beta=1}^n N_{\alpha\beta} a_\beta \quad (\text{from equation IV.11})$$

this becomes:

$$\begin{aligned} (\text{Eq. IV.13}) \quad S_k = & \int_{\Omega_k} dw \int_w^\infty da_1 \dots \int_w^\infty da_{k-1} \int_w^\infty da_{k+1} \dots \int_w^\infty da_m \dots \int_0^\infty da_n \\ & \left\{ \left\{ \prod_{\alpha=1}^m g_\alpha \left(\sum_{\beta} N_{\alpha\beta} a_\beta \right) \right\} \prod_{\alpha=m+1}^n g_\alpha(a_\alpha) \right\} \end{aligned}$$

This is the key equation for nominal market shares. Its interpretation was discussed in section IV.B.4.

The simplified form of the factors involving $a_{m+1} \dots a_n$ stems from the partitioned inverse form of $\underline{N}$:

$$(\text{Eq. IV.14}) \quad \underline{N} = \underline{M}^{-1} = \begin{bmatrix} \underline{M}_B^{-1} & -\underline{M}_B^{-1} \underline{M}_C \\ \underline{0} & \underline{I} \end{bmatrix}$$

$$\text{where } \underline{M}_A = [\underline{M}_B, \underline{M}_C]$$

The actual evaluation of the nominal market share equation IV.13 of course depends on the functional form of the building block density functions, $g_{\alpha} (x_{\alpha})$. In addition, there will often be special structure to the matrix $\underline{M}_A$. This matrix says how technologies are build up from building blocks. It may have, for example, block structure, which in turn leads to block structure in the matrix $\underline{N}$.

In practice, equation IV.13 is difficult to evaluate unless the $g_{\alpha}(x_{\alpha})$ are chosen from a set of analytically tractable distributions. Various alternatives were considered, such as normals, lognormals, triangular, and piecewise uniform distributions. Ultimately a three parameter gamma distribution was selected as the best choice. It is a sufficiently flexible distribution to fit almost any reasonable cost distribution. It positively skewed. And it is defined in terms of elementary functions which are analytically tractable.

Unfortunately the algebra required to evaluate equation IV.13, when n , m , $\underline{M}$, and the parameters of the individual gamma distributions are not known in advance, is horrendous. There was not time to develop it.

Therefore three other examples are presented below. The actual method used in the present ISTUM computer programs is a modified version of example 2.

1. The case where technology costs are independent. This leads to a much simpler version of equation IV.13, which permits easy numerical solutions for a broad range of functional forms for the building block densities, g_{α} .
2. The case where technology costs are independent, and composed of the sums of exponentially distributed building blocks, limited by maximum fractions.
3. The case where the building block densities are exponentially distributed.

d. Special Case 1: Technologies Independent

In order for technology costs to be independently distributed, each technology must be built up from its own distinct set of building blocks. For example, technology 1 may be composed of building blocks 1, 2 and, technology 2 of building blocks 3 and 4, etc. (Usually each technology will have at least two building blocks, one for capital and the other for fuel. Conservation technologies might have only one building block.)

This leads to an $\underline{M}$ matrix which is diagonal or block diagonal. Non diagonal entries are 0. For example:

$$(Eq. IV.15) \quad \begin{array}{c} \underline{a} \\ \left[\begin{array}{c} a_1 \\ a_{d1} \\ a_2 \\ a_{d2} \\ a_3 \\ a_4 \end{array} \right] \end{array} = \begin{array}{c} \underline{M} \\ \left[\begin{array}{cccccc} 1 & 1 & 0 & 0 & 0 & 0 \\ 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 1 & .5 & 0 & 0 \\ 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 \end{array} \right] \end{array} \begin{array}{c} \underline{x} \\ \left[\begin{array}{c} x_1 \\ x_2 \\ x_3 \\ x_4 \\ x_5 \\ x_6 \end{array} \right] \end{array}$$

(Here technologies 1 and 2 have more than one building block, so dummy technologies a_{d1} and a_{d2} are introduced to make the $\underline{M}$ matrix square, analagous to equation IV.7.) In this case $\underline{N}$ is also block diagonal, and equation IV.13 can be factored into the product of a series of smaller integrals. Each integral can then be evaluated in turn.

This can also be seen directly from equation IV.6. Since the a_β are independent we can write:

$$(Eq. IV.16) \quad f(a_1, \dots, a_m) = f_1(a_1) \times f_2(a_2) \times \dots \times f_m(a_m)$$

Using this in equation IV.6 gives

(Eq. IV.17)

$$S_k = \int_{\Omega_k} f_k \left(\left\{ \left[\int_w^\infty f_1(a_1) da_1 \right] \left[\int_w^\infty f_2(a_2) da_2 \right] \dots \left[\int_w^\infty f_m(a_m) da_m \right] \right\} \right) dw$$

Now define

(Eq. IV.18)

$$G_\beta(w) \equiv \int_w^\infty f_\beta(a_\beta) da_\beta$$

= Probability that the price of technology β is higher than w .

and substitute in equation (IV.17) to get:

$$(Eq. IV.19) \quad S_k = \int_{\Omega_k} f_k(w) \prod_{\substack{\beta=1 \\ \beta \neq k}}^m [G_\beta(w)] dw$$

This expression can be easily evaluated if $f_k(a)$ and $G_\beta(w)$ can be evaluated. This will be the case for any of the commonly used probability distributions. More often, each technology will be the sum of several building blocks, each with its own distribution. In this case the family of distributions used to describe the building blocks should be a family which can be easily summed.^{1/}

In many cases the most appropriate way to evaluate IV.19 will be numerically. Examining Figure IV.5 will give clues as to how this is best done.

^{1/} See Maurice Kendall and Alan Stuart, The Advanced Theory of Statistics, Volume 1, "Distribution Theory", 4th edition, MacMillan Publishing Co., New York, 1977, page 2

e. Special case 2: Independent, Exponentially Distributed Technologies

One example of the case of independent distributions is similar to the case actually used in the current ISTUM computer programs. Model each technology as a two parameter exponential distribution with a maximum fraction.

(Eq. IV.20)

$$f_{\beta}(a) = \begin{cases} \frac{\tau_{\beta}}{\lambda_{\beta}} \exp[-(a-\rho_{\beta})/\lambda_{\beta}] & \rho_{\beta} \leq a < \infty \\ 0 & a < \rho_{\beta} \\ \tau_{\beta} & a = \infty \end{cases}$$

Here ρ_{β} is the lowest possible cost and λ_{β} is a shape parameter. The mode of the distribution is at ρ_{β} , where $f_{\beta}(\rho_{\beta}) = \tau_{\beta}/\lambda_{\beta}$. The mean is $\rho_{\beta} + \lambda_{\beta}$. The parameter τ_{β} is the maximum fraction. It is the probability of a less than infinite price. From IV.20 we get the complement of the cumulative distribution:

$$(Eq. IV.21) \quad G_{\beta}(a) = \begin{cases} 1 + \tau_{\beta} \{ \exp[-(a-\rho_{\beta})/\lambda_{\beta}] - 1 \} & \rho_{\beta} \leq a \\ 1 & \rho_{\beta} > a \end{cases}$$

Note that G_{β} never goes below the maximum fraction, τ_{β} . This was also the case in Figure IV-5b, which shows the effect graphically. (In Figure IV-5b each technology is the sum of several exponentially distributed building blocks.)

Formulas (IV.20) and (IV.21) can be plugged into equation IV.19 to give an analytically tractable expression. The only trick is to keep track of the region of integration, as the expressions for f_β and G_β depend on what region they are being evaluated in. A notational convenience is to order the technologies so that their lowest costs are in ascending order. That is,

$$(Eq. IV.22) \quad \rho_1 \leq \rho_2 \leq \rho_3 \leq \dots \leq \rho_m$$

Then equation IV.19 gives for the last technology (technology m):

$$(Eq. IV.23) \quad S_m = \int_{\rho_m}^{\infty} \frac{\tau_m}{\lambda_m} \exp[-(w-\rho_m)/\lambda_m] \left\{ \prod_{\beta=1}^{m-1} \left[1 + \tau_\beta \{ \exp[-(w-\rho_\beta)/\lambda_\beta] - 1 \} \right] \right\} dw$$

This can be tediously expanded to give something of the form:

$$(Eq. IV.24)$$

$$S_m = \frac{\tau_m}{\lambda_m} \left[\int_{\rho_m}^{\infty} T_1 e^{-(h_1+k_1 w)} dw \right] \left[\int_{\rho_m}^{\infty} T_2 e^{-(h_2+k_2 w)} dw \right] \dots \dots \dots \left[\int_{\rho_m}^{\infty} T_m e^{-(h_m+k_m w)} dw \right]$$

where the T_α are constants, defined in terms of the τ 's and λ 's, and the h_α 's and k_α 's are also constants, in terms of ρ 's and λ 's.

Note one immediately useful result, which generalizes to any independent technologies. The nominal market share of each technology is proportional to its maximum fraction, all other technologies' parameters being held constant.

To evaluate each of the separate integrals in IV.24, use the formula from elementary calculus:

$$(Eq. IV.25) \quad \int_c^{\infty} d e^{-(h+kw)} dw = \frac{d}{k} e^{-(h+kc)}$$

This gives for IV.24 :

(Eq. IV.26)

$$S_m = \frac{\tau_m}{\lambda_m} \left[\frac{T_1}{k_1} \cdot \frac{T_2}{k_2} \cdot \frac{T_3}{k_3} \dots \frac{T_m}{k_m} \right] \left[e^{-(h_1+h_2+h_3+\dots+h_m)} \right]$$

$$\left[e^{-(\rho_m[k_1+k_2+k_3+\dots+k_m])} \right]$$

This completes the problem, giving an analytic expression for the nominal market share of the m'th technology. The nominal market shares of other technologies turn out to involve almost identical parameters T_α , k_α , and h_α , so that little re-calculation is needed to get the nominal market shares of all technologies in the market segment.

The formulation actually used in current ISTUM computer programs is similar to this example. However, each technology is the sum of several exponentially distributed building blocks, rather than just one. Figure IV-4 showed a graph of several cost frequency distributions, the $f_\beta(a)$.

f. Special Case 3: Exponentially Distributed Building Blocks/
Technologies Interdependent

In this case technology interdependencies are fully treated. However the resulting nominal market share equation has not yet been solved. The specific assumptions are:

- 1) Building block cost frequency distributions can be described by two parameter exponential distributions. This is reasonable for most building blocks, although a few (especially fuel prices) are more symmetrically distributed than an exponential distribution. That is,

$$(Eq. IV.27) \quad g_{\alpha}(x_{\alpha}) = \begin{cases} \frac{1}{\lambda_{\alpha}} e^{-(x_{\alpha}-\rho_{\alpha})/\lambda_{\alpha}} & \text{if } x_{\alpha} \geq \rho_{\alpha} \\ 0 & \text{otherwise} \end{cases}$$

where x_{α} is the cost of building block α .

- 2) As in equation IV.2, technologies are the linear sums of building blocks. In a large service sector, there may be 20 technologies and 40 building blocks. ($m=20$, $n=40$).

Repeating the steps which led to the nominal market share equation IV.13, but sticking with matrix notation for conciseness, gives:

$$\begin{aligned} \underline{a} &= \underline{M} \underline{x} \\ \underline{x} &= \underline{N} \underline{a} \quad \underline{N} = \underline{M}^{-1} \end{aligned}$$

where $\underline{x}$ is the vector of building block costs, and $\underline{a}$ the (augmented) vector of resulting technology costs.

Then the matrix version of equation IV.13 is:

(Eq. IV.28)

$$S_k = \iiint_{\Phi_k} g(\underline{N} \underline{a}) \, d\underline{a}$$

where:

$$(Eq. IV.29) \quad g(\underline{x}) = \begin{cases} \prod_{\alpha=1}^n \left\{ \frac{1}{\lambda_{\alpha}} \exp \left[-(x_{\alpha} - \rho_{\alpha}) / \lambda_{\alpha} \right] \right\} & \text{if } x_{\alpha} \geq \rho_{\alpha} \\ 0 & \text{for all } \alpha=1, \dots, m \\ & \text{otherwise} \end{cases}$$

(Eq. IV.30)

$\Phi_k \equiv$ the set of points $\underline{a} = [a_1, \dots, a_n]$ such that:

$$0 \leq a_k$$

$$a_1 \geq a_k$$

$$a_2 \geq a_k$$

$$\vdots$$

$$a_{k-1} \geq a_k$$

$$a_{k+1} \geq a_k$$

$$\vdots$$

$$a_m \geq a_k$$

$$a_{m+1} \geq 0$$

$$\vdots$$

$$a_n \geq 0$$

(So Φ_k is just another way of writing the limits of integration in equation IV.13.)

Equation IV.29 says that $g(\underline{x})$ is 0 except in the set

$$\{\underline{x} \mid \underline{x} \geq \underline{\rho}\}$$

But

$$(Eq. IV.31) \quad \underline{x} \geq \underline{\rho} \iff \underline{N} \underline{a} \geq \underline{\rho}$$

Bring this restriction into the definition of the region of integration in equation IV.28 to get:

$$(Eq. IV.32) \quad S_k = \int \dots \int_{\Phi_k \cap \{\underline{a} \mid \underline{N} \underline{a} \geq \underline{\rho}\}} g(\underline{N} \underline{a}) \, d\underline{a}$$

Equation IV.30 provides n linear constraints on the region of integration, and equation IV.31 provides another n constraints. Thus equation IV.32 is an integral in n dimensional hyperspace, over an open convex set generated by $2n$ linear inequalities. The equation is probably best solved by transforming variables to give a rectangular region of integration.^{1/} The ISTUM project team has not yet been able to solve the equation, however.

^{1/} Note the obvious similarity of these constraints to the constraint matrix of a linear program. It may be possible to introduce further constraints of the form $\underline{A} \underline{a} \leq \underline{b}$ into IV.32, thus making the ISTUM cost frequency approach capable of handling any problem that can be handled by point estimate LP's.

C. Behavioral Lags in Market Penetration

The nominal market share calculation determines the fraction of the market in which a technology is theoretically preferable to any alternative. This is based on the costs of the alternatives. Empirically, however, new technologies will at first not be used to supply energy to the extent indicated by their nominal market share. Two factors other than simple comparative economics act to constrain their use, especially in the years just after introduction.

The first factor can be referred to as "behavioral lag". Adoption of new things, because they are new, is only gradual. Even if a technology's nominal market share is ten percent the first year it is on the market, ten percent of those buying new equipment that year will not rush out and buy it. Instead, it will be picked up only gradually, as potential users become more familiar with it and with its characteristics. The nominal market share after adjustment for behavioral lags is called the technology's "actual market share". It is the subject of this section.

The second factor is capital turnover. The use of energy in any one year is heavily constrained by the nature of the capital stock in place at that time. Only as that capital stock "turns over" -- i.e., old stock is replaced, and new capacity is added -- can energy use shift. There are strong incentives to keep already installed equipment in operation until it "wears out". The capital costs are already sunk; therefore using old equipment incurs only the variable costs (fuel, operating, and maintenance), while purchasing new equipment also incurs the capital costs. The rate at which capital turns over depends both on growth in total demand, and on the retirement of old stock. This is discussed in section IV.D.

1. Causes of Behavioral Lags

"Behavioral lag" is the term used in ISTUM to refer to the fact that the adoption of innovations is persistently slower than naive models of profitability anticipate. Therefore the direct use of the nominal market shares calculated in section IV.B would systematically overstate the rapidity with which newer and better energy technologies will move into the marketplace.

Unfortunately behavioral lags are not well understood, at least on a practical level. Their causes are not susceptible to easy modeling, especially since their impact depends on the personality and knowledge of the individuals who actually make the decisions on what technology to use. Therefore their treatment in ISTUM is only heuristic; it is subject to empirical verification and modification. This is one reason for the distinct separation of the nominal market share calculations, which are grounded in rigorous theory and data, from the behavioral lag calculations. Nevertheless these lags are too important to leave out of the analysis entirely.

Several closely related reasons exist for behavioral lags in the adoption of new technologies. None of these factors are peculiar to energy technologies.^{1/}

- Decision maker aversion to risk.
- Lags in the transfer of information.
- Vendor and distribution network "supply side" constraints.

These are very briefly discussed in turn.

^{1/} There is still a debate concerning the extent to which the factors listed are "rational". This debate is not relevant here. Proponents of both sides admit they do not have the data to predict behavior a priori in real situations.

a. Risk Aversion

A new technology may work as well as claimed, but it probably will not. Depending on how thorough the pre-commercialization trial period was on the part of vendors, there will be a need to "shake the bugs out" of new designs. Even for designs which have been in use for several years, there may be peculiar characteristics of any individual plant or process which might affect performance. Particularly if an entire production line is dependent on the new equipment, the potential "down side" risk could be very large. The cost of an unplanned plant shutdown can be more than the original cost of the offending equipment.^{1/} Even in those rare cases when there may be no "objective" reason to consider a new technology riskier than a conventional counterpart, there may be subjective reasons due to the reward structure of individual firms.

The rational response to this risk is for individual purchasers to move slowly, and initially avoid heavy commitments to the new technology. There is a sophisticated literature on how to make optimal decisions in the presence of risk^{2/}. This literature shows that as more information becomes available (see the comments on information lag below) the perceived risk will diminish, inducing potential users who were formerly at the margin to try out the new technology. (The first users will generally be those who have the most favorable costs for the new technology, i.e., are toward the left of its cost frequency distribution.) The net effect is a gradually increasing use of the new technology.

1/ Of course redundancy is normally built into a plant so that no single failure would be likely to bring the whole plant down. But building in this redundancy also has a cost.

2/ A practically oriented introduction is: Readings in Decision Analysis, SRI International, Menlo Park, CA 1973.

b. Lags in Information

Another factor retarding the introduction of any new technology is the availability of information about it. Potential users who are unaware of the option obviously cannot select it. More common is to have heard of an innovation but not know enough about it to realize that it is applicable and would be profitable in one's own operations. Information is also needed to reduce the risk referred to above; knowledge about actual operating experience counteracts the initially perceived risk.

There are at least three channels by which such information is transferred in the industrial sector:

- From vendors of the equipment.
- From other firms or plants who use the same process.
- From other users within the firm who use a similar enough process that it might provide useful information. (Many firms are now hiring "energy coordinators" who will play a role in this channel, and also the other two).

It is important to note the potential users may often require fairly broad information, not limited just to the narrow technology under consideration. For example, low Btu gasifiers of coal might be considered a proven technology about which there is complete information. But it is the specifics of using low Btu gas in a particular process (e.g., glass melting) which are not presently well known in the relevant industry.

Another issue which can be loosely included under "information transfer" is that of skills in the work force. Some conservation devices, once installed, require little attention.

But the vast majority of the technologies modeled in ISTUM require attention in order to get the best performance. Fluid bed boilers, for example, will need operator monitoring; the amount depends on the sophistication of the control system. Trained operators for a new technology will be rare, especially if it is radically different than anything familiar to the firm adopting it. Time and mistakes will be the price to train new operators and maintenance staff.

c. "Supply Side" Constraints

Some new energy technologies may be constructable by a plant's own engineering staff, using only standard components. Most, however, will be purchased from outside vendors. These vendors will have to "gear up" their production lines, sales force, distribution system, and repair network to handle the new technologies. Particularly if a dedicated production line is required, this will take time, and the vendor will wait until it is reasonably sure of being able to sell its output before making major capital investments.

The earlier research and development stages will also take time. R and D is risky and expensive; to finally perfect a technology is time consuming. This is reflected in ISTUM in the year of availability for specific technologies, rather than their behavioral lags.

d. The Role of the Government

There are several ways in which government can reduce the impact of the above sources of behavioral lag. Government intervention is a very involved subject, and ISTUM documentation is not an appropriate place to discuss it in detail. Briefly, the available mechanisms are:

- Research and development, to advance the year of initial commercialization.

- Demonstration programs, keyed to the particular characteristics of the potential market, to produce and disseminate information about a technology's performance under actual operating conditions.
- Taxes and direct monetary incentives enter ISTUM through the nominal market share calculation.
- Performance bonds, to guarantee to a new user that any losses will be made up if a new technology fails, shutting down an entire plant. The size of the bond would often exceed the cost of the technology.
- Acting as an information clearinghouse and disseminator, to reduce information lags.
- Speeding up regulatory decisions concerning new technologies, to reduce one source of uncertainty in their adoption.

Each of these actions costs the government money. To achieve the greatest effect per unit of money spent, the specific program should be carefully tailored to the characteristics of both the technology and the industry it is being targeted into. For example, in industries with considerable information flow among different firms at trade meetings and through journals, only one firm need be targeted for a demonstration. However if an industry is fragmented, with little information exchanged between different firms or sub-industries, a different approach would be needed.

Another example is the use of performance bonds to remove the risk from adopting a new technology. This would be most

appropriate where a technology failure could have serious consequences for an entire plant and firm. This would be mainly for large investments, such as medium Btu gasifiers, or entirely new methods of production.

In most cases government intervention will not make the difference between existence and nonexistence of a new technology. Given the anticipated growing cost of conventional technologies as oil and gas prices rise, any new technology would eventually become potentially profitable enough to overcome all of the above barriers. But the government action might significantly shortcut this process.

ISTUM has two non-cost levers to use when modeling government intervention's effects. One is the year of availability of a technology. The other is its "initial technology behavioral lag time", defined below. The impact of a given change in either of these levers on a technology's performance is quantified by ISTUM. However, there is presently no way to accurately estimate the effect of a specific government action on these behavioral lag factors. Hence quantifying the effect of government action on behavioral lag, in ISTUM or any other framework, cannot be done rigorously, but only tentatively.

2. Use of the Blackman Behavioral Lag Model

The previous formulation of the MOPPS industrial sector model adapted the Blackman penetration formulation^{1/} to

^{1/} This is the well known "S-curve" model of technological change first developed in Edwin Mansfield, "Technical Change and the Rate of Imitation," Econometrica, Vol. 29, October, 1961, pp 741-765.

The adaptations and data developed by Blackman are presented in A.W. Blackman, "The Market Dynamics of Technological Substitution," Technological Forecasting and Social Change, Vol. 3, 1972, pp 441-452.

cover the behavioral lag aspects of penetration. Further consideration of Blackman's analysis suggests that it suffers from serious theoretical shortcomings and that it cannot be adapted to ISTUM without introducing biases of an unknown magnitude. The Appendix to this chapter discusses the theoretical shortcomings of the Blackman analysis while the present discussion focuses on the problem of adapting the Blackman analysis to the ISTUM framework.

The Blackman analysis looks at a market from a perspective of one new technology's replacement of one existing technology. The ISTUM perspective is different. Within the ISTUM framework many new technologies are vying for market shares from many existing technologies. Although these two situations are analogous, they are not identical, and one cannot be sure how this difference in their perspectives biases the ISTUM results.

The Blackman analysis is also inappropriate for the ISTUM behavioral lag formulation because its coefficient values are derived from a holistic perspective. This perspective overlaps with the ISTUM formulation and use of profitability as embodied within the cost distributions and the calculation of nominal market shares. Blackman's coefficients and equations combine the roles of nominal market shares and behavioral lag into one. In order for the Blackman analysis to be useful to the ISTUM framework the Blackman profitability coefficient values would have to be reestimated. Without reestimation of these coefficients, the Blackman analysis when used in conjunction with the rest of the ISTUM framework introduces a bias in the results. As might be expected, the existence of one market penetration model within another has reduced the calculated penetration rates (requiring

more time to reach 100 percent penetration) below those penetration rates witnessed in the Blackman data. The use of the Blackman analysis as a substitute for an empirically derived formulation of industrial behavioral lag has created bias in the results. The next section will discuss the alternative approach built within ISTUM to estimate the effects of behavioral lag on the rate of penetration.

In light of the previous few sentences, it is necessary to expand the meaning of the term "rate of penetration" to indicate the final result of the entire ISTUM process. Nominal and actual market shares should be looked upon as intermediate results leading up to this final result.

The previous MOPPS behavioral lag formulation was an adaptation of Blackman's penetration analysis. For the reasons mentioned above, this adaptation was inappropriate. Blackman's analysis was originally chosen, however, because of a deficiency of empirical studies relating technological penetration to risk aversion and information transfer. Lacking the empirical evidence necessary for the development of a rigorous formulation, the ISTUM project team developed an algorithm which agrees at least qualitatively with behavioral lag as seen in practice.

3. The ISTUM Behavioral Lag Algorithm

Risk aversion is a manager's reluctance to adopt a new technology due to the large uncertainty in its expected profitability. However, the expected profitability of a technology can be sufficiently high to make the perceived risk more palatable, and the project using that technology worth pursuing. The behavioral lag resulting from the information transfer component will also be less for more profitable technologies.

Within the ISTUM framework, nominal market share is a measure of relative profitability; a higher nominal market share indicates a more profitable technology. Thus, a technology's nominal market relative to the size of its market can be used as a variable to indicate the expected degree of behavioral lag associated with it.

Since the ISTUM model calculates nominal market shares every five calendar years, the nominal shares of technologies which enter the market place in intervening years have to be adjusted. The adjustment made in ISTUM assumes that at a technology's year of introduction the nominal market share is always equal to zero. In subsequent years the nominal share ramps up to equal the nominal share assigned to the technology at the first model calculation following the year of its inception. This nominal share adjustment has the property of awarding four-tenths of the calculated nominal share to a technology coming on stream four years before a model calculation, three-tenths of the calculated nominal share to one coming on stream three years before a model calculation, and so on.

Before discussing the ISTUM behavioral lag algorithm the measurement of both behavioral lag and market size need to be stated. The overall ISTUM analysis calculates service demands filled by a technology as a function of time. Consequently, the ISTUM measure of behavioral lag should affect the rate of penetration, and would do so if it were measured in units of time. Behavioral lag is thus defined as the amount of time, in years, required for actual market shares to equal nominal market shares. Behavioral lag is consequently a time lag function controlling the rate at which actual market shares approaches nominal market shares

and fits into the ISTUM information flow as shown in Figure IV-6. A technology's market size is a measure of the service demands which it could possibly fill. In the ISTUM framework, this measure is already embodied in the concept of a technology's maximum market fraction. Thus, nominal market shares should be compared to the maximum market fraction as indicative of a technology's relative profitability and in turn the expected degree of behavioral lag.

The behavioral lag associated with each technology at its inception should reflect the amount of time, in the extreme, required to overcome the barriers imposed by risk aversion and information transfer lags as found in decision making groups. Since the initial behavioral lag associated with each technology is a function of the characteristics of decision making groups rather than the attributes of a technology, one could assign this initial lag in one of two ways. Either all the new technologies in all industries would be assigned the same initial behavioral lag or all the technologies within a particular industrial SIC could be assigned the same initial lag. In both cases, the lack of empirical evidence makes the assignments somewhat arbitrary. Although there is evidence of different behavioral lags in different industries, estimating them properly would require considerable effort. Consequently ISTUM was formulated in terms of a uniform assignment of 15 years even though the basic algorithm could work with either scheme.

As mentioned above, the behavioral lag time is a function of two variables:

- ⊙ Nominal Market Shares
- ⊙ Maximum Market Fraction

FIGURE IV-6

*Also known as Actual Market Shares

The behavioral lag time was made a function of nominal shares and maximum market fraction in the following manner:

$$BLT(t) = ITBL \times BLM(t)$$

$$BLM(t) = \begin{cases} 0 & \text{when } LTS \times PTP(t) > 1 \\ 1 - (LTS \times PTP(t)) & \text{when } 0 \leq LTS \times PTP(t) \leq 1 \end{cases}$$

$$PTP(t) = \frac{NMS(t)}{MMF}$$

where:

BLT = Behavioral Lag Time (expressed in years)

ITBL = Initial Technology Behavioral Lag Time (a constant expressed in years) set equal to 15 years.

BLM = Behavioral Lag Multiplier

LTS = Lag Time Slope (a dimensionless constant) set equal to 5.

PTP = Perceived Technology Profitability (dimensionless)

NMS = Nominal Market Share

MMF = Maximum Market Fraction

The behavioral lag time equals the initial technology behavioral lag time multiplied by the behavioral lag multiplier. The initial technology lag time is a constant equal to the maximum number of years one could imagine that both risk aversion and information transfer could delay commercial acceptance of a technology. A reasonable upper limit would be 15 years. The risk aversion multiplier is a downward sloping straight line dependent on the nominal market shares relative to the maximum market fraction. Figure IV-7 illustrates this relationship wherein the slope (LTS) was set equal to 5.0.

Under the behavioral lag formulation given above, all the technologies have an ITBL equal to fifteen years at the start of the model. As soon as the nominal share exceeds zero the behavioral lag time will begin to drop. If nominal

FIGURE IV-7

THE BEHAVIORAL MULTIPLIER AS A FUNCTION OF
NOMINAL MARKET SHARE

shares grows to equal or exceed 0.20 of the maximum market fraction then the lag time equals zero.

On completing the behavioral lag time calculation for each technology, the actual market share can then be computed using the following formula:

$$AMS(t) = \begin{cases} 0 & \text{when } t - YTA < 0 \\ \frac{NMS(t) \times (t - YTA(t))}{BLT(t)} & \text{when } 0 \leq t - YTA \leq BLT(t) \\ NMS(t) & \text{when } t - YTA > BLT(t) \end{cases}$$

where:

AMS(t) = Actual Market Share

YTA = Year Technology is Available

t = time (i.e. calendar year)

The above formulation insures that the actual market share will always be greater than or equal to zero and less than or equal to the nominal market share. Before a technology is available the actual market share will always equal zero. Once a technology has come into existence its actual market share will increase with the passage of time. However, once time (t) exceeds the year the technology is available (YTA) by the technology behavioral lag time BLT(t), which in the case of ISTUM is at most 15 years, then actual market share will always equal the nominal market share. This equation in conjunction with the equation set outlined above reveals two ISTUM assumptions regarding behavioral lag. Namely, the barriers to market penetration are completely overcome by a technology either because it is highly profitable or because it has been in existence for a relatively long period of time.

Since nominal shares are lagged on the basis of relative profitability, the actual market shares summed up across all technologies for one industry will add up to less than one. One minus the sum of the actual shares is distributed to those technologies whose penetration lag equals zero. This residual is distributed proportionally based on the relative size of these technologies' nominal market shares. Behaviorally, this corresponds to the fact that once a technology's penetration lag reaches zero, it is fully accepted as a "conventional" technology.

D. Capital Turnover

1. Introduction

Capital turnover represents the changes in the capital stock due to demand growth and capital retirement. Since, in ISTUM, the service demand growth rates are exogeneous to the behavior of the model and are based on DRI projections of national economic trends, this section primarily will focus on the ISTUM formulation of capital retirement.

Before discussing the ISTUM treatment of capital retirement a brief digression is necessary in order to outline the empirical circumstances associated with industrial retirement. Both the endogenous and exogeneous attributes of retirement need to be considered. From the endogenous perspective the question arises over the degree to which attributes of the capital stock need to be embodied within a retirement algorithm. From the exogenous perspective the question arises as to how external factors, such as tax policies, affect the rate of retirement.

The primary endogenous attribute of the capital stock is its age. As a piece of capital stock ages capacity is lost through output decay until the capital is no longer economic to maintain. At this point the capital is scrapped.

Under the conditions of a constant growth in output this dynamic process is well approximated by a retirement rate set equal to a constant proportion of the capital stock. However, a constant growth rate in output is contrary to the reality of historical economic behavior. A proportional retirement algorithm would fail to capture the cyclical behavior that has occurred in the past.

The alternative to a constant proportion algorithm is to keep track of the age of the capital stock by a process known as vintaging. The vintaging process in conjunction with a production function specifies the level of output for a specific age class of capital that can be expected due to output decay and scrapping. Because it was important to capture the effects of historical business cycles, ISTUM used a capital stock vintaging process. More will be said about the ISTUM treatment of vintaging later on.^{1/}

Even if output growth were constant, exogenous influences would alter the rate of retirement. Changes in tax laws, prices, interest rates, and the nature of technical progress would alter the economics of production and therefore influence the planned life of equipment and the decision to replace existing equipment. The ideal retirement algorithm should also reflect the lags and other aspects of timing associated with the changes in the economic climate, the perception of those changes, and the implementation of decisions commensurate with those changes. While it would be desirable to include the exogenous factors affecting retirement and their associated lags, economic literature is deficient in empirical studies identifying these factors and the magnitude of their

^{1/} Chapter VI discusses in more depth the pros and cons of a proportional retirement algorithm vis-a-vis that of vintaging.

influence. Consequently, these exogenous factors are not incorporated in the ISTUM retirement algorithm. The ISTUM formulation of retirement is an endogenous algorithm based on technical necessity.^{1/}

One other topic is that of "premature retirement". Premature retirement occurs when a piece of capital stock of type "A" is retired before it normally would have been, because of the existence of a new and superior technology, type "B". The existence of a better technology made it economic to retire the old equipment prematurely. A variant is when changes in energy prices, rather than a new invention, are the driving force which makes premature retirement optimal. Ideally this should be included explicitly in ISTUM's calculation of retirement rates. For example, the imposition of National Energy Plan type fuel taxes should cause a wave of retirements of oil and gas burning equipment. A related issue is the retrofit of old equipment. Many conservation technologies, for example, can be retrofit into the existing base of capital stock, without waiting for any retirement.

Modeling retrofit and premature retirement would require a completely new set of logic - in effect, a parallel ISTUM model. The capital, O&M, and fuel costs of new technologies would be competed against the O&M and fuel costs of the old technologies. This would involve a new cost frequency diagram and new nominal market share calculation. The age of the old technologies would be relevant, which would demand high accuracy in the capital vintaging model (see below). It

^{1/} A good albeit completely theoretical discussion of these issues is by Martin S. Feldstein and Michael Rothschild, "Towards an Economic Survey of Replacement Investment," Econometrica 42, May 1974, pp. 393-423. A broader and more empirical survey is by J.C.R. Rowley and P.K. Trivedi Econometrics of Investment, John Wiley & Sons, 1975.

might be necessary to model how maintenance cost varies with equipment age, which would take us into areas where there is no empirical data.

For this reason neither retrofit nor premature retirement is embodied in the present version of ISTUM. The retirement rates used are based on empirical data (see Ch. VI), hence do include whatever premature retirement was going on in the period measured. But this may either over or understate the amount in the future.

The ISTUM capital retirement algorithm combines the concepts of capital vintaging with that of a capital decay function. Each of these aspects of ISTUM's capital retirement will be discussed first separately to highlight their intrinsic properties and then together to point out their embodiment within the ISTUM framework.

The first graph in Figure IV-8 illustrates the depreciation behavior of the vintaging process when embodied in a computer algorithm.^{1/} Assume that at t_0 , X number of plants are built and that each graph indicates the number of plants in existence in successive time periods. Also assume that the physical lifetime of these plants is, on the average, equal to t_1 years. The vintaging algorithm will keep all the plants built at t_0 in existence until t_1 , at which time they all leave the system. The vintaging algorithm intuitively appeals to one's notion how a single piece of capital is depreciated due to its physical attributes. If all the

^{1/} The depreciation behavior illustrated in the first graph of figure 3 is the result of using a vintaging computer algorithm, by itself, without a production function. The embodiment of the vintaging process within a computer algorithm which gives rise to this behavior will be explained later.

FIGURE IV-8
A COMPARISON OF VARIOUS DEPRECIATION ALGORITHMS

Observed Depreciation of Steel Industry (SIC 331)
Energy Capital Stock Built in 1925 - 1930,
Based on DRI Information

Decay Function for Steel Industry Based on
Information Presented on Previous Graph

capital plants were to leave the system at the same time as a single plant then the first graph in Figure IV-8 would be representative of the depreciation of the entire capital stock.

However, capital vintaging, by itself, is not reconcilable with the observed behavior of plant depreciation. As an example, the second graph in Figure IV-8 shows the observed depreciation of steel industry energy capital stock built in 1926 through 1930 in terms of Btu's; based on DRI information.^{1/} Firstly, capital built at the same time will be retired at different ages. Secondly, the quantity of goods a piece of capital can produce generally degrades with time. The capacity of a capital good lessens with age as maintenance requirements increase the amount of down time.^{2/}

The decay function implicitly accounts for these two tendencies by being an empirically derived formulation of physical capital depreciation and thereby having the same shape as observed depreciation. The decay function, is a normalized function (i.e., the fraction of capital remaining at t_0 equals one) giving the productivity of a stock of capital t years after being built (last graph in Figure IV-8). Even though the decay function is an empirical formulation of capital depreciation, it represents only the depreciation of a capital stock initiated at the same time. In order to find out how much capital is retired for any particular year across all age groups the concept of a decay

1/ The graph is slightly inaccurate because this capital stock was built for a period in time rather than for one point in time. This inaccuracy is introduced strictly for purposes of illustration and does not reflect ISTUM's treatment of the capital stock.

2/ Of course both maintenance costs and operating rate are decision variables under control of the owner. (Skimping on maintenance now will increase down time later.) This again points to the difficulty of an accurate empirical microanalytic model of retirement. A theoretical discussion is in Stephen Nickell "A Closer Look at Replacement Investment," Journal of Economic Theory 10, 1975, pp. 54-88.

function needs to be integrated with that of capital vintaging. How this integration occurs within the ISTUM formulation will now be discussed.

2. The ISTUM Integration of Vintaging and Decay

The ISTUM vintaging algorithm is a discrete time analytical model. The vintaging algorithm is embodied in the computer model as a set of computer storage and retrieval instructions. The instructions specify a given number of age distribution classes. Each class represents a particular segment of the population distribution.

Figure IV-9 illustrates the ISTUM formulation. Given the population distribution as shown in Figure IV-9, any number of age distribution classes can be specified. In ISTUM, ten classes are specified each containing all the members of the age distribution for successive five year intervals. As in Figure IV-10 the computer instructions would then specify that the contents of each class are transferred to its successor class at the end of every five "model years". The contents of the tenth age class would be erased every five years before the contents of the ninth class are transferred to the tenth^{1/}. Capital is vintaged by the computer by physically being displaced within its memory units.^{2/}

At this time it is important to note the units assigned to the capital stock and capital stock age groups within

1/ Note that each class would be associated with a specific computer storage unit and thus the algorithm consists of transferring a number from one storage unit to another until it is erased from the last storage unit

2/ This is a discrete time difference equation approach. Most of the mathematics needed for empirical modeling of capital turnover can be found in Nathan Keyfitz, Introduction to the Mathematics of Population, Addison-Wesley, Reading, Mass., 1968. This book covers discrete, continuous, deterministic, and stochastic models. Retirement of capital stock is analogous to deaths in animal populations.

FIGURE IV-9
HYPOTHETICAL AGE DISTRIBUTION AND AGE CLASS BREAKDOWN

FIGURE IV-10
The Computer Mechanics Associated with Vintaging

The contents of each age class are transferred to the next storage unit every 5 "model years"

the ISTUM framework. ISTUM capital stocks are measured in terms of Btu's of service demand provided by a type of capital stock (e.g., coal combustors) within the course of a year. The equating of service demands filled with capital stocks is valid so long as one can expect the load factor to remain constant over time. It is also valid if the decay function incorporates changes in load factor.

In order to determine the size of the capital stock in a specific year the number of members within each age group is multiplied with the decay function coefficient appropriate for that age group and then summed over all age groups. The following equation expresses this same concept analytically:

$$CS(t) = \sum_{n=1}^{10} D_n C(t-n)$$

where: $CS(t)$ = Capital stock at time t in terms of annual service demand Btu's provided. Note that it must equal total demand in year t .

D_n = Decay function coefficient for capital stock of age n . The fraction of the original population which will survive to age n without being retired.

$C(t-n)$ = Number of units of capital stock originally built at time $t-n$.

t = Time, measured in periods equal to the length of each age group (e.g., 5 years).

The amount of capital retired during a period of time equals the decay function coefficient for the previous period minus the present period's coefficient multiplied by the number of members within each age group, summed over all age groups. The analytical form of this concept is:

$$CSR(t-1, t) = \sum_{n=1}^{10} (D_{n-1} - D_n) C(t-n)$$

where:

$CSR(t-1,t)$ = the amount of capital stock retired from time $t-1$ through t (expressed in Btu's).

D_{n-1} = Decay function coefficient for time $n-1$.

Data Resources Inc. (DRI) provided three sets of data which were used to estimate the historical values of C_n and D_n . Note that these three sets are industry specific (i.e., by SIC):

- The maximum amount of energy conversion stock in existence for 1971-1975 measured in terms of Btus (ECS)^{1/}.
- The amount of investment in energy conversion stock for ten five year periods also measured in Btus (INECS)^{2/}.
- The percentage of energy conversion capital investment retired for each of the ten five year periods (PECSR).

These three data sets were converted into the 1974 values of $C_{n,SS,I,T}$ and $D_{n,I}$ ^{3/} in the following manner:

1/ These DRI numbers were taken to be representative of the energy conversion stock extant in 1974, the starting point for the ISTUM model.

2/ The ten periods span the years 1926 through 1975.

3/ Subscripts have been added to both C_n and D_n to indicate their degree of specificity. SS indicates specificity to service sectors, I to industries, and T to technologies.

$$C_{n,SS,I,T} = (SD_{SS,I,T} \times INECS_{n,I}) / ECS_I$$

where:

$SD_{SS,I,T}$ = The 1974 service demands of technology T in industry I in service sector SS in terms of Btus.

$C_{n,SS,I,T}$ = Energy conversion stock for age group n for technology T in 1974 in industry I in service sector SS in terms of Btus.

similarly:

$$D_{n,I} = 1 - PECSR_{1,I} - PECSR_{2,I} - \dots - PECSR_{n,I}$$

Since the variable $C_{n,SS,I,T}$ is specific to a particular technology, industry, and service sector so too are the variables $CS(t)$ and $CSR(t-1,t)$ (i.e., $CS_{SS,I,T}(t)$ and $CSR_{SS,I,T}(t-1,t)$). In order to calculate the amount of capital retiring within a particular industry for a specific period of time $CSR_{SS,I,T}$ has to be summed up across all technologies in the following manner:

$$CSR_{SS,I}(t-1,t) = \sum_{\text{All } T} CSR_{SS,I,T}(t-1,t)$$

Once retirement for a service sector, industry, and period has been calculated, using the methods outlined above, ISTUM then goes on to calculate the incremental service demands filled by each technology in the following manner:

$$ISD_{SS,I,T}(t) = (CSR_{SS,I}(t-1,t) + ND_{SS,I}(t-1,t)) \times AS_{SS,I,T}(t)$$

where:

$ISD_{SS,I,T}(t)$ = Incremental Service Demands filled by technology T at time t in industry I, service sector SS. (Incremental demand is defined as new demand plus retirement demand).

$CSR_{SS,I}(t-1,t)$ = Capital stock retirement from time t-1 through t in industry I, service sector SS.

$ND_{SS,I}(t-1,t)$ = New service demand in industry I, service sector SS.

$AS_{SS,I,T}(t)$ = Actual market share of technology T in industry I in service sector SS at time t. Calculated as discussed in section IVC.

The incremental service demands $ISD_{SS,I,T}$ in turn go on to become the capital stock $C_{SS,I,T}$ from which capital is retired in future periods.

The preceding discussion of ISTUM's capital turnover has implied that all technologies are retired in the same manner. This is not true. In fact only two classes of energy capital are retired in the manner described above: old conventional technologies, and new conventional technologies. All other technologies are not explicitly retired because their date of availability is 1980 or later. If most of the technologies are built after 1980 and their expected lifetime is 20 or more years, then little retirement will occur in this capital stock before the year 2000. To not retire capital in these technologies is a reasonable approximation for a model whose time horizon extends only to the year 2000. However, if the ISTUM model was run beyond the year 2000, then retirement of this capital stock would have to be explicitly modeled.

3. Retirement Rates Used

One interesting exercise is to calculate the retirement rates actually resulting from the DRI data, expressed as a fraction of existing capital stock. That is, what percent of energy equipment in place is projected to be retired each year in the future? This is given by:

$$\begin{array}{l} \text{Fraction of stock retired in} \\ \text{industry I, service sector SS} \\ \text{from time t-1 to time t} \end{array} = \frac{CSR_{SS,I}(t-1,t)}{CS_{SS,I}(t-1)}$$

Since capital stock depends on growth rates up to time t-1, this depends on how fast an industry has been growing, as well as on the age structure of its capital stock, and its decay function. Age structure also depends on how rapidly the industry was growing. For example, an industry which has been growing rapidly will have a low retirement rate.

The results are shown in Table IV-6. Retirement rates vary from 1.5 percent per year to about 5 percent per year, with only a few industries getting above 3 percent per year. The retirement rates appear low on casual inspection; this reflects the rapid growth of total demand projected in most SIC's. If equipment has an average life of 25 years, and the majority of the equipment has only been installed within the last 10 years, very little of it will be retired immediately.

One rule of thumb sometimes used for retirement rates is:

$$\text{retirement rate} = \frac{1}{\text{average life}}$$

Table IV-6 shows how drastically in error this is for energy equipment. For example, in the chemical industry (SIC 28)

TABLE IV-7

ANNUAL^{a/} RETIREMENT RATES^{b/}
(Steam Service Sector)

INDUSTRY	Period				
	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000
Food	.027	.025	.024	.025	.027
Tobacco	.016	.018	.021	.024	.023
Textiles	.015	.015	.014	.014	.014
Apparel	.017	.019	.020	.021	.021
Lumber, Wood	.037	.034	.037	.044	.046
Furniture	.014	.015	.016	.017	.020
Paper (Total)	.021	.021	.021	.021	.020
Printing, Publ.	.026	.023	.023	.026	.027
Chemicals-Total	.023	.019	.017	.017	.017
Petro. Refining	.027	.027	.028	.024	.023
Rubber Misc. Pl.	.011	.012	.012	.012	.012
Leather	.034	.035	.038	.048	.058
S,C,G, Concrete	.026	.028	.026	.025	.023
Steel	.035	.035	.033	.030	.027
Other Prim. Met	.021	.021	.021	.025	.028
Fabric Metals	.013	.013	.015	.017	.017
Machinery	.018	.017	.017	.016	.017
Elec Mach	.017	.019	.022	.025	.029
Transport Equip	.026	.022	.018	.016	.016
Measuring Eq	.015	.015	.016	.019	.021
Misc. Manufac.	.016	.016	.017	.021	.024
Livestock	.013	.012	.013	.015	.015
Metal Mining	.028	.029	.028	.026	.027
NonMetal Min.	.029	.029	.028	.027	.027

a/ As a fraction of capital stock at the beginning of the interval. Rates are per year, assuming a constant rate for the five year interval. Thus total retirement over 5 years is 5 times the number shown.

b/ These rates depend on the industry growth rates used. The retirement rates here are for the Base Case. See Chapter VI.

average equipment life is about 18 years.^{1/} This would give a retirement rate of 5.5 percent/year using the above rule of thumb. In contrast, the corrected retirement rate is 2.3 percent/year in the near future, and 1.7 percent/year after 1985. The reason for the difference is again the rapid growth of total demand.

^{1/} Calculated from Chapter VI, Table 4-1, page VI-29.

APPENDIX TO CHAPTER FOUR

THE MANSFIELD-BLACKMAN MODEL OF TECHNOLOGICAL DIFFUSION RATES

The EEA MOPPS Industrial Model, the predecessor of ISTUM, incorporated a technology diffusion model developed by Edwin Mansfield (7) and Wade Blackman (2) to calculate the behavioral lag which would be encountered by new and unproven energy technologies. This model is a logistic growth model -- the fraction of the market controlled by a new technology in a given year depends in a simple way on the fraction it controlled the previous year.

This model is not used in ISTUM, although the concept of behavioral lag is retained. (A straight line model is used instead.) There are two main reasons for this change. First is that the Mansfield-Blackman approach simultaneously models profitability, behavioral lag, and capital turnover, while these three elements are treated separately in ISTUM. It would not be correct to use equations developed for the larger problem to handle a narrow portion of the problem, at least not without using empirical data to completely re-estimate the equations.

The second reason that the Mansfield-Blackman equations are not used in ISTUM is that they have tremendous problems. Mansfield's original work was limited in extent, and with the caveats he lists, probably valid. However it does not go far enough to be used in an actual predictive model. Blackman attempted to extend Mansfield's work to make it predictive.

Blackman's research is, however, superficial and probably invalid. The data he uses is completely inadequate for the uses he puts it to; his statistical work is incorrect, and his one published test of this methodology does not actually do what is claimed. As a result the parameter estimates he derives are useless for other work.

It is likely that more work has been done to strengthen the logistic model of technology penetration. At least one company, for example, is using it to help forecast sales of new equipment. However such work has not yet been published.

EEA is including this commentary on the Mansfield Blackman approach because of its apparent uncritical acceptance in the energy modeling field. We feel that it is worthwhile to warn potential users of the present inadequacies in the state of the art. This is not to say that the logistic model might not ultimately be found to be a useful and reliable predictor.^{1/} But much careful empirical validation, using difficult to gather data, will be needed first.

^{1/} In any case, the logistic model is a highly uncertain predictor. Chatfield (5) shows that if a logistic model indicates that production of a product will increase by a factor of ten in five years, the 95 percent confidence interval of that estimate would vary by a factor of 100 in either direction. Blackman (3, p. 447) recognizes this problem but downplays its importance.

A. The Development of the Logistic Diffusion Model of Technological Innovation

Edwin Mansfield first proposed a logistic model of technological diffusion in 1961 (7). He further suggested that three factors affected the rate at which a new technology diffused through industrial sector firms: the profitability of the new technology relative to that of the alternative investments, the required investment relative to the total assets of the firm, and the particular industry's propensity to innovate.

Blackman modifies and extends Mansfield's logistic model of technological diffusion (1,2,3,4). He modifies it by changing the definition of diffusion rates: Mansfield defines diffusion as the percent of the potentially adopting firms who adopt a technology in a given year. Blackman defines it as the percentage of the potentially adopting market that adopts the new technology in a given year. Blackman extends the Mansfield technology diffusion model by determining the factors which affect an industry's propensity to innovate -- primarily research and development expenditures, the number of mergers and acquisitions, and the rate of increase in productivity. He then claims he can predict the rate at which any industry will adopt a technology if he knows these factors and the technology's relative profitability and required investment.

Equation 1: $\ln \frac{m(t)}{n-m(t)} = \phi t + \gamma$

Mansfield expresses the logistic diffusion model mathematically as Equation 1. That equation implies that a new technology rate of diffusion depends on the proportion of potentially adopting firms that have not adopted the new technology yet.

Blackman uses the same equation to describe technological diffusion but changes the definitions of some of the terms. He defines "n" as the percent of the market that might adopt the innovation, and "m(t)" as the percent of the market that has adopted the innovation by year "t". However, he leaves "market" undefined, and assumes varying definitions of it later on.^{1/}

$$\text{Equation 2: } \Phi = \alpha_1 \pi - \alpha_2 s + z$$

Mansfield next calculates the value of " Φ " - the innovation index. He theoretically predicts that the innovation's profitability relative to the profitability of alternative investments, the size of the required investment relative to firm assets, and industry peculiarities will determine " Φ ". He then uses econometrics to calculate the relative importance of these three factors in determining " Φ " and the values of the 'propensity to innovate' constants (z) for four industries.

Blackman accepts Mansfield's Equation 2 as correct, and does not attempt to check Mansfield's factor weightings. In fact, he uses the same weights for the investment and profitability indexes in order to determine the 'propensity to innovate' constants (z) in three other industries.

TABLE IV-7

MANSFIELD-BLACKMAN DIFFUSION EQUATIONS

EQUATION: 1. $\ln \frac{m(t)}{n-m(t)} = \phi t + \gamma$

2. $\phi = z + \alpha_1 \pi - \alpha_2 s$

3. $z = \beta_1 I + \beta_2$

DEFINITION OF VARIABLES:

- γ - constant of integration
- $m(t)$ - the number of firms having adopted the innovation at time t - Mansfield
the percent of the market having adopted the technology at time t - Blackman
- n - the total number of firms being studied - Mansfield
the percent of the market that are potential adopters of the innovation - Blackman
- ϕ - the technology's diffusion rate
- z - the industry's innovation index
- π - the technology's profitability index
- s - the technology's investment index
- I - weighted average of industry research and development expenditures, number of mergers and acquisitions, and productivity increase index.

ESTIMATED VALUES OF COEFFICIENTS

$\alpha_1 = .530$
 $\alpha_2 = .027$ Mansfield

$\beta_1 = .2221$
 $\beta_2 = -.3165$ Blackman

ability indexes in order to determine the 'propensity to innovate' constants (z) in three other industries.

Equation 3:
$$z = \beta_1 I + \beta_2$$

Blackman develops Equation 3 in order to find a pattern in industry "z" values. He predicts that six research and development expenditure factors, the number of mergers and acquisitions in the industry, and the rate of increase in labor productivity will determine "z".^{1/} He combines these eight factors via first factor analysis to obtain a single variable "I". Then he uses econometrics with known values of "I" and "z" to determine " β_1 " and " β_2 " for Equation 3.

B. Inadequacies of the Methodology and Data

1. Mansfield Regressions

Mansfield tests 12 innovations of four industries for data in his examination of Equations 1 and 2. Table IV-8 lists these innovations. Mansfield only examines major innovations that require large heavy equipment investments by industrial users. He obtained his data through interviews with industry officials and extensive literature research.

1/ The eight variables are:

1. Total R/D expenditures 1970
2. R/D expenditures planned, 1974
3. Company sponsored R/D expenditures
4. R/D as percent of capital spending, 1970
5. Estimated new product sales as percentage of total sales
6. Value added, 1969
7. Number of mergers and acquisitions
8. Ratio of Federal reserve board index, 1968/1947

TABLE IV-8

INDUSTRIES AND INNOVATIONS EXAMINED BY MANSFIELD
(used to test and calculate constants for equations 1 and 2)

<u>Industry</u>	<u>Innovation</u>	Φ Diffu- sion Rate	S Invest- ment Index	Π Profit- ability Index
Railroads	Diesel locomotives	0.20	0.015	1.53
	Centralized traffic control	0.13	0.024	1.48
	Car retarders	0.11	0.785	1.25
Iron and Steel	Continuous wide strip mill	0.34	4.908	1.87
	Byproduct coke oven	0.17	2.083	1.47
	Continuous annealing	0.17	0.554	1.25
Bituminous Coal	Shuttle car	0.32	0.013	1.74
	Trackless mobile loader	0.32	0.019	1.65
	Continuous mining machine	0.49	0.301	2.00
Brewing	Tin container	0.36	0.575	1.20
	High-speed bottle filter	2.40	0.267	5.07
	Patlet-loading machine	0.55	0.115	1.67

Regression on all data ($R^2 = .99$)

$\Phi = (-.29) + .530\Pi - .027S - .308RR - .227IS - .282CO$ (where RR = dummy variable for railroads, IS = dummy variable for iron and steel, and CO = dummy variable for coal)

Regression on 11 data points (leaving out the highest point) ($R^2 = .92$)

$\Phi = (-.09) + .379\Pi - .009S - .303RR - .245IS - .218CO$

Mansfield's thoroughness and consistency led to some problems in data collection. One was the small amount of data; he only studied three innovations in each industry. His data on the brewing industry, for example, must be questioned since he included the prohibition era in the time period studied. The length of time Mansfield studied - from before 1900 until after World War II - also detracts from the credibility of his data. The propensities to adopt new technologies varied widely in this time span. Few firms invested during the depression, while many invested during the World Wars. Some industries, such as steel and the railroads, grew rapidly during part of this period and not at all during other parts. Mansfield's lack of data allows his equation 2 to yield very high but spurious " R^2 " values. Eleven of his data points have Φ values between .1 and .6, while the twelfth has a Φ value of 2.4. His regression (see Figure IV-11) merely connects the clustered data with the odd point, a connection that has very little variability and a high R^2 value.

When Mansfield's peculiar data point is dropped from his data base his results change notably. A regression on the data still yields an adjusted R value of .92, significant even when one takes the small data base into account. But the coefficient of the investment index () drops by 2/3 and becomes insignificant. The coefficient of the profitability index () drops by 30 percent, though it remains important to the fit.

Then what conclusions about the factors affecting diffusion rates can be drawn from Mansfield's work? First, he needs to obtain more data; twelve data points will often provide spurious fits in a regression with five degrees of

FIGURE IV-11

MANSFIELD'S REGRESSION

Mansfield's regression of Equation 2 merely connects the data in Cluster Y to Point X.

freedom. Second, the profitability of an innovation seems to affect the rate at which the innovation is adopted; the π statistic was significant in both regressions. And third, his data does not yield a consistent coefficient for the effect of profitability on a logistic diffusion rate; when one data point is dropped from the regression, the value of the coefficient drops by 30 percent.

2. Blackman Extension of the Mansfield Model

In a series of Technological Forecasting and Social Change articles (1,2, 3,4), Blackman extends and modifies the Mansfield diffusion model. In "The Rate of Innovation in the Commercial Jet Engine Market" (4) he calculates the Mansfield "z" value (industry willingness to innovate) for the aerospace industry from two similar innovations - first and second generation turbofans.

Blackman's calculation of the aerospace "z" value has two severe shortcomings. First, he generalizes from an inadequate data base; he cannot justify a calculation of the industry's willingness to adopt innovations on the basis of how fast it adopted turbofans. Second, Blackman determines a "z" value for Mansfield's formula ($\phi = z + \alpha_1 \pi = \alpha_2 s$) but uses a new definition of penetration when he plugs ϕ into the logistic equation ($\ln \frac{m(t)}{n-m(t)} = \phi t + \gamma$)! Blackman defines penetration as the percentage of the market captured by an innovation, Mansfield defines it as the percentage of firms adopting the innovation.

In "A Mathematical Model for Trend Forecasts" (3), Blackman examines innovations in the electric utility and auto industries. Without trying to fit the penetration rates to the actual Mansfield model, Blackman determines that they follow

the predicted logistic pattern. However, his variable definitions differ from Mansfield's. In the electric utility industry, Blackman defines penetration as the percentage of total capacity captured by the new technology. In the auto industry, he defines it as the percentage of annual vehicle production equipped with the innovation. In one case capital turnover is included; in the other it is not!

Blackman also does not study typical heavy industrial equipment purchases in either industry. Auto firms introduce product changes such as power steering, power brakes and air conditioning when consumers will buy them. Industry willingness to innovate has little effect on the penetration rate of such innovations because firms are always willing to make them. Utility innovations require multimillion dollar investments. Information about such investments will spread much faster than information about relatively minor innovations in other industries, and the penetration rate depends on the information flow. In addition the innovativeness of a regulated industry may differ from that of an unregulated industry. Some economists believe that utilities invest in projects that are more capital intensive than necessary because public utility commissions allow them to earn profits in direct proportion to the amount invested.

3. Blackman Innovation Indexes

In "An Innovation Index Based on Factor Analysis" (1), Blackman derives a general form for the calculation of "z" in Equation 2. He uses factor analysis on eight research and development variables to calculate an Innovation Index, I. He then regresses I against the "z" values already determined for five industries in the general equation:

$$z = \beta_1 I + \beta_2 \quad (\text{Eq. 3 in Table I}).^{1/}$$

^{1/} Blackman calculates β_1 as .222., and β_2 as -.3216

Weak data detracts from most parts of Blackman's analysis, and it especially prevents his innovation indexes from having any credibility. He examines five industries: primary metals, aircraft and missiles, transportation equipment, food and kindred products, and electric machinery and equipment. He uses these groupings because the Department of Commerce provides data for several of his Innovation Index components by SIC code. Blackman employs the following previously calculated "z" values as surrogates for industry "z" values:

<u>industry that has calculated "z" value</u>	<u>Blackman surrogate SIC</u>
iron and steel ^{1/}	primary metals
breweries ^{1/}	food and kindred products
autos ^{2/}	transportation equipment
aerospace ^{2/}	aircraft and missiles
utilities ^{2/}	electric machinery and equipment

Aside from the questionable use of Mansfield's "z" values Blackman's innovation index regression suffers from the weaknesses in "z" value calculations mentioned earlier. Table IV-9 summarizes the problems: different definitions of penetration, not enough data on innovations, and different consumers of innovations for each "z" value.

Blackman assumes throughout his analysis that Mansfield has absolutely determined the effects of innovation profitability

^{1/} z values calculated by Mansfield.

^{2/} z values calculated by Blackman.

TABLE IV-9

BLACKMAN'S REGRESSIONS OF $z = \beta_1 I + \beta_2$

<u>Industry</u>	<u># of Innovations</u>	<u>Definition of Penetration</u>	<u>Consumers of Innovation</u>	<u>z</u>	<u>I₈</u> *	<u>I₆</u> **
Brewers	3	% of firms adopting	Industry	-.30	-.35	-.703
Steel	3	% of firms adopting	Industry	-.53	Not in Regression	-.725
Aerospace	2 (turbojet 1, turbojet 2)	% of passengers carried	Industry	.27	2.29	3.004
Electric Utility	2	% of total capacity	Utility	0	1.76	1.418
Automotive	4	% of new production	Individuals	-.37	.29	.718
					Electric Machinery transportation equipment	

* 8 variable model $z = .2221I - .3216$ Adj. $R^2 = .77$

** 6 variable model $z = .4221I - .2107$ Adj. $R^2 = .24$

and size of required investment (α_1 and α_2 in Eq. 2: $\phi = z + \alpha_1\pi - \alpha_2s$). Mansfield calculated tentative α_1 and α_2 values, but those calculations are sensitive to slight changes in his data. Blackman never checked Mansfield's α_1 and α_2 values with his own data; he assumed his data fit Eq. 2 with the same α_1 and α_2 values as Mansfield's data.

Table IV-9 also lists Blackman's attempts to determine the correlation of his innovation index and the previously calculated industry "z" values (willingness to adopt innovations). Though he does not investigate a causal relationship, Blackman uses an econometric regression to determine this correlation (Eq. 3: $z = \beta_1 I + \beta_2$). In Blackman's first run through this model, he determines I from a six variable factor analysis. When he regresses Equation 3, he obtains an adjusted R^2 value of .24 for the line $z = .4221I - .2107$. To obtain such a low R^2 when fitting a line to only five points indicates that his variables are not very predictive.

Next Blackman calculates a new value of I based on an eight variable model (his previous 6 + 2 more). He does not determine a value for the steel index, leaving him with only four data points. When he regresses this data in Equation 3, he obtains an adjusted R^2 value of .77 for the line $z = .2221I - .3216$. His coefficient of I has dropped in half, his constant term has decreased by 50 percent, his fit is still weak, and he only has four data points, but Blackman decides that his fit is not spurious and uses the resulting parameters without further testing.

Finally, Blackman calculates innovation indexes for a number of industries for which he has no "z" values. Table IV-10 lists these indexes. Blackman and Mansfield only calculated

TABLE IV-10

<u>Industrial Sector</u>	<u>Innovation Index</u>
*1. Aircraft and Missiles	2.29
*2. Electrical Machinery and Communication	1.76
3. Chemicals and Allied Products	0.60
*4. Transportation Equipment	0.29
*5. Food and Kindred Products	-0.35
6. Professional and Scientific Instruments	-0.37
7. Fabricated Metals and Ordinance	-0.60
8. Petroleum Products	-0.64
9. Stone, Clay, and Glass	-0.70
10. Paper and Allied Products	-0.75
11. Textile Mill Products and Apparel	-0.75
12. Rubber Products	-0.76

*Industries for which data was available, to calculate an innovation index.

SOURCE: Blackman [1], p. 310.

"z" values for the first, second, fourth, and fifth entries on this table. Nevertheless, Blackman assumes that the innovation indexes of all the other entries will fit Equation 3 - extrapolating far beyond the extent of his data.^{1/} The four industries he has data for are clearly atypical.

4. Validation of the Model

In "The Market Dynamics of Technological Substitutions" (2) Blackman shows how he can predict diffusion rates of future innovations as long as he is given the industry, the profitability of the innovation, and the size of investment required. He can obtain an innovation index using equation 3 ($z = .2221I - .3216$). Using "z", the size of required investment, and the profitability of the investment, Blackman calculates ϕ in Equation 2 ($\phi = z + .530\pi - .027s$). Finally Blackman assumes the innovation can eventually penetrate the entire market and calculates penetration rates from Equation 1.^{2/}

Blackman makes one test of his ability to predict diffusion rates; he predicts diffusion in the motor boat industry. He calculates the profitability and investment indexes for the switch from wooden to fiberglass hulls. Then Blackman uses historical data to calculate "z" for the industry. Next

^{1/} This sentence assumes that Equation 3 is correct and that Blackman has obtained an exact fit with his four data point regression. This is unlikely, as previously noted.

^{2/} Blackman never discusses how to calculate ultimate penetration, but he needs that calculation for his version of Equation 1: $\ln \frac{m(t)}{n-m(t)} = \phi t + \gamma$. In his own work Blackman assumes values for "n", the ultimate penetration, with explaining how he determined them. In some cases these values are less than 100 percent.

he uses this "z" value with profitability and investment indexes for the switch from inboard-outdrive engines to compute a ϕ value for that innovation. Finally he compares the diffusion rate predicted in Equation 1 with the historical diffusion rate, and finds they correlate highly.

Blackman's examination of motor boats does not validate his model. No one test could, since it might work by sheer chance. Blackman made several arbitrary assumptions in calculating investment and profitability indexes - for example he assumed that motor boat users have a required rate of return of only eight percent. Small changes of this type could affect diffusion rates substantially.

The second and more important problem with Blackman validation technique is that it doesn't test his innovation indexes. This takes his "z" value for the motor boat industry from another innovation in the same industry. Blackman neither tests Equation 3 ($z = .2211 - .3106$) nor requires any assumptions about the use of industry surrogates. He ignores his innovation indexes completely in his validation of the model.

C. Conclusion

For his model, Mansfield's data is sparse but accurately collected. Mansfield demonstrates that the profitability of an innovation affects that innovation's penetration rate, but cannot calculate the extent of this effect.

Blackman extends Mansfield's model considerably without increasing the data base enough. He changes definitions of industry, consumer, and penetration variables, but he continues to use Mansfield's data base. He obtains very weak, and

possibly spurious, fits for his model. And Blackman's validation of his model turns out not to validate it at all. Consequently, these shortcomings in Mansfield's work and especially Blackman's extension are serious enough to preclude the use of their analyses within the ISTUM framework.

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CHAPTER V

ENVIRONMENTAL FACTORS IN ISTUM

A. Introduction

The initial MOPPS modeling effort necessarily could not give full treatment to environmental factors. ISTUM has been developed, however, with careful consideration of the environmental issues associated with alternative energy technologies. The strategy in developing ISTUM was to generate a reasonably consistent method of examining the environmental factors affecting alternative technologies. The baseline scenario developed in this manner provides useful information when subjected to sensitivity analyses in which environmental parameters are varied to reflect different possible environmental regulation scenarios.

B. Environmental Control Issues

Several types of environmental concerns affect emerging energy technologies. Environmental effects can typically be classified according to medium (air, water) or impact area (health, safety). These impact areas are generally viewed from the perspective of both ambient quality and the kind and rate of pollutant discharge. In addition, there are concerns associated with meeting existing or proposed environmental regulations, resource constraints (e.g., water availability, land requirements), and known effects which may not be directly regulated (e.g., carcinogenicity, odor). Three basic environmental factors affecting emerging energy technologies are considered in ISTUM. These are discussed below. An element of

uncertainty is associated with all of these environmental concerns since environmental information is not adequate for many developing technologies and the status of environmental regulation is currently not clear in all cases.

Pollutant standards are the first major factor. They concern the pollutants and impact areas for which regulations presently exist or are proposed. These standards typically address both human health and general welfare. Standards normally cover pollutant discharges from point sources by type and rate of discharge and ambient levels of the pollutant in the environment. For example, under the Clean Air Act and Amendments, technology-specific New Source Standards of Performance specify rates of discharge of certain pollutants and ambient air quality standards specify maximum allowable ambient levels for pollutants in regions. It is presently unclear what standards EPA will set for emerging energy technologies. This complicates the effort to model environmental factors affecting new technologies.

Environmental parameters based on known, but not directly regulated concerns are a second factor. These concerns may not be directly regulated but may be limited in terms of desirability or controlled in some measure. An example of this would be a technology whose process or waste streams are known to contain carcinogenic or potentially carcinogenic substances. Various pressures, either regulatory or non-regulatory (public opinion, union pressures, etc.) may combine to affect the potential market penetration of technologies with such characteristics.

Resource concerns are the third major factor. These concerns include water requirements and availability, land requirements, and air capacity (clean air being a resource).

The three factors outlined above will affect different technologies in different and uncertain ways. "Demand-side" technologies, which ISTUM focuses upon, will in many cases be affected differently than the larger "supply-side" technologies (e.g., low-Btu coal gasification which is generally a "demand-side" technology versus high-Btu gasification which is "supply-side").

C. Regional Air Pollution Capacity

Regional air pollution capacity is the amount of new air pollution which can be tolerated in a region. This capacity is determined by ambient air quality standards.

Under the present regulatory framework, regional air pollution capacity (with respect to a particular pollutant) can be divided into two types: attainment and nonattainment. An attainment region (with respect to a particular pollutant) is a region in compliance with an ambient air quality standard. A nonattainment region is one which does not comply with a pollutant's ambient standards. Both designations are accompanied by restrictions specified on both new sources and expansion of existing facilities.

In attainment regions, the number of new sources is limited by the decline in ambient air quality allowed in the area and the stringency (and, hence, cost) of required pollution control. In nonattainment regions, the number of new sources is limited by the ability of existing sources to reduce emissions to an extent that standards are attained while allowing some new source growth to occur as well as the stringency of pollution control required under these conditions.

Many subtle factors need to be examined to measure the impact of regional air pollution capacity on new and existing technologies. In many cases, the impact is simply the diversion of new facilities to another location. In other cases, the primary effect is to place a technology at a competitive disadvantage with its alternatives because of the costly control required for that technology in a particular region. For example, coal use in a nonattainment region would be at an economic disadvantage with gas or oil use in the same region, due to the cost of control needed to achieve emissions parity with gas or oil.

In the original MOPPS run, nonattainment factors were modeled by putting a constraint on the share of new markets that could be captured by coal. The "maximum fraction" for coal-based technologies was limited to 70 percent, being based on the assumption that non-attainment areas would not allow the use of coal in 30 percent of all new energy consuming applications. These assumptions were applied also to the current ISTUM model.

A recent study by the Environmental Protection Agency examined the issue of potential constraints to siting new coal burning facilities^{1/}. In its study, EPA forecast that 37 percent of the new coal demand in the industrial sector (as projected by the President's original energy program) would experience potential siting problems. This number at least superficially corroborates the use of the 70 percent maximum fraction. Several factors can intervene, however.

^{1/} "Potential Siting Problems for Increase Coal Use" U.S. Environmental Protection Agency, Research Triangle Park, N.C., Oct. 19

The EPA study is very conservative in some of its assumptions. A "potential siting problem" is defined as a projected violation of primary or secondary ambient standards anywhere within a county. Also, all industrial growth is assumed to be sited at existing industrial sites. This can clearly overstate the constraint on new coal siting.

Moreover, the primary nonattainment pollutant is suspended particulates. Total suspended particulates (TSP) were involved in 75 percent of the violations. SO_2 was involved in only 40 percent of the cases. Both pollutants were in violation in 15 percent of the cases. NO_2 was a much less serious problem and never was the cause of a nonattainment violation on its own.^{1/}

Both TSP and SO_2 are "hot spot" pollutants. An area that is in non-attainment with respect to either of these does not necessarily have all of its land area in violation. A case study was performed for the Baltimore AQCR. This AQCR is in non-attainment status and was projected to remain in non-attainment under all scenarios in 1985. Figure V-1 was taken from this study and shows the worst-case scenario involving

^{1/} It is not yet known what effect a new short-term (1-3 hr) NO_2 standard will have on energy technology patterns. A simultaneous question with any new NO_2 ambient constraint is what differential penalty coal would have relative to other fossil fuels for an ambient NO_2 standard. Proposed NO_x New Source Performance Standards for coal-fired boilers have brought coal into close proximity with emission rates for oil and natural gas. Nonetheless, it is hard to predict what effect the short-term NO_2 standard will have on the siting of new stationary sources, whether coal-fired or otherwise.

FIGURE V-1
BALTIMORE AIR QUALITY
CONTROL REGION

1985 COAL SUBSTITUTION PROGRAM
TSP ($\mu\text{g}/\text{m}^3$) AGM

the maximum new industrial coal use. All use is sited at existing industrial locations. A visual estimate suggests that somewhat less than 10 percent of the total land area is actually in non-attainment status in this worst-case projection. More significantly, the area shown to be in non-attainment is not the area expected to accommodate the majority of industrial expansion in the Baltimore area.

Such studies imply that the 30 percent constraint on new coal burning applications may be excessive. Thus, future study on the implications of removing this siting constraint from coal will be useful to measure the overall impact on the industrial sector fuel mix.

Energy and Environmental Analysis, Inc., is working to measure the locational impacts of non-attainment standards. As results from such efforts become available, it will be beneficial to respecify the non-attainment parameters in ISTUM to obtain a more accurate reflection of the impact of regional air pollution capacity.

D. New Source Performance Standards

The methodology used in ISTUM to generate technology costs includes provisions for including the costs of pollution control equipment. As mentioned earlier, New Source Performance Standards (NSPS), are a primary focus, although other potential effluent regulations or concerns (e.g., water effluents or carcinogenic emissions) could be significant for many technologies.

However, within ISTUM, primary attention has been devoted to NSPS since they provide one of the more consistent scenarios for required performance. Two primary factors are involved in modeling NSPS:

- ② Determining a set of baseline regulatory assumptions and applying them consistently over all technologies in each service sector.
- ③ Determining the optimal technology configuration for each process in each service sector, once the regulatory scenario is established. For example, two possible configurations exist for low-Btu gas sulfur removal: removal of H_2S prior to combustion or removal of resultant SO_2 after combustion.

The following are brief summaries of key technology issues faced in the ISTUM effort.

1. Coal-fired boilers

The regulatory issues are relatively clear for coal-fired boilers. For sulfur control, the issue is what size boiler (in heat input per hour) will be required to apply either 80 or 90 percent control. For particulates, the control required ranges between 0.03 and 0.1 lb/ 10^6 Btu depending on boiler size. Thus, the issue is how boiler sizes will be distributed according to this range of control.

2. Oil-fired Boilers

The regulatory circumstances facing this technology are not clear. The situation is confounded by the wide range among fuel characteristics in this category. The 1977 Clean Air Act amendments leave open the question of whether or not residual oil will have to be scrubbed. This would add a substantial cost penalty to oil fired boilers. Additionally, there is the possibility that ESECA provisions could preclude the use of oil.

3. Atmospheric Fluidized Bed Combustion

NSPS standards are a primary issue with AFB. A 90 percent standard on sulfur removal efficiency may be a problem, adding to costs if this high level of sulfur removal is required. Of course, it could turn out that 90 percent is required for units greater than 250 MMBtu/hr. but only 80 percent for units less than this size. This could hurt AFB in one of its primary markets - utilities - but might not hurt it in the size ranges that ISTUM is focusing on. In addition, limestone could present incremental cost difficulties for AFB compared to conventional systems with scrubbers.

4. Low-Btu Gasification

This is a key technology in the ISTUM evaluation. There is some general concern about the 80 percent or 90 percent sulfur standard and its implication for this technology.

A Stretford sulfur removal system for small LBG applications has a large impact on the cost of the gas produced. In some small direct-heat applications it was assumed that no sulfur removal would be required. This left the question of whether removal of tars and oil from the product gas before combustion was necessary in these direct heat applications. In applications where sulfur removal was required it was clear that the inordinate costs of the Stretford unit in these small sizes would cause direct coal fired boilers with scrubbers to dominate LBG/Stretford technologies. An alternative solution would involve firing the gas without removal of sulfur tars or oils, and then scrubbing the exhaust gases. LBG, like other gasification technologies, has unanswered questions concerning polycyclic

organic matter and heavy metals as well as requirements of waste water treatment to remove oils, tars, phenols, and dissolved solids.

5. Medium-Btu Gasification

Most of the environmental control questions for this technology parallel those for LBG. Some additional questions however, pertain to the applications of medium Btu gasification. For example it is possible to assume non-scrubbed uses of low-Btu gas, but probably not of MBG because of its fuel supply nature. If some of an MBG plant's output requires sulfur removal it most likely will be necessary to treat the entire gas stream - not only because of improvements in the marginal economics with larger sulfur removal systems, but also because producing gas with and without sulfur removal could easily require multiple gas transmission systems.

6. Direct Coal Technologies

The uses of direct coal combustion in direct heat applications are many. In cases where direct coal has not been a primary fuel, environmental issues have not been clarified. Many of these applications will involve small combustors in highly decentralized industries. It is difficult to speculate on how environmental regulations will be promulgated and enforced in these cases.

7. Cogeneration

Cogeneration in the industrial sector consists of different technologies likely to face differing environmental circumstances. In cases where the cogeneration technology is an adjunct to a primary system, such as topping or bottoming cycles, the environmental controls will be determined

by the primary system. An economic question arises as to whether a topping system should absorb some of the environmental cost of the primary system if it involves a higher fuel throughput to both cogenerate and meet basic process needs.

8. Conservation

Most conservation technologies will reduce environmental emissions rather than increase them. This leaves only a question of whether it is appropriate to credit a conservation technology with any capital cost savings associated with smaller environmental control systems on the primary technology. There is currently some consideration of allowing for pollution credits with conservation technologies. This would effectively position many conservation technologies as pollution control systems themselves.

E. Environment Assumptions Used In ISTUM's Base Case

As indicated in the previous sections there are many uncertainties in projecting future environmental circumstances for existing and emerging energy technologies. The strategy for establishing the baseline environmental assumptions for ISTUM was to base input parameters largely on a status-quo forecast of regulatory factors. This is not because this is necessarily the most likely outcome of environmental regulation, but instead because it allowed the greatest opportunity to treat different technologies consistently. The ISTUM model offers a great deal of opportunity for evaluating new environmental regulatory policy. The environmental factors used in the model provide a good baseline from which to measure these policy alternatives.

The following discussion is a tabulation of the environmental assumptions made for the base case of the model. It is divided by service sector rather than by technology since some technologies were treated quite differently across service sectors.

1. Steam Service Sector

For conventional coal-fired boilers 80 percent removal efficiency for sulfur using a lime/limestone scrubber system was assumed. Once it was determined that a low-Btu gasification (LBG) system with a Stretford clean-up unit producing gas for a conventional boiler would be consistently dominated by a conventional coal fired boiler in the industrial sizes modeled, an uncleaned LBG gas in a conventional boiler with stack gas scrubbing was chosen. With atmospheric fluidized-bed combustion (AFB), the assumptions were again 80 percent sulfur removal, although costs for a 90 percent removal system were developed. Medium-Btu gasification (MBG) was assumed to be a cleaned gas burned in a conventional natural gas boiler.

Oil-fired systems offered the opportunity to assume either scrubbing or a price increase of oil to allow for refinery desulfurization. For the base case, however, neither was assumed. This puts oil at somewhat of an advantage since the greatest portion of boiler fuel oil in the industrial sector is residual which in all likelihood will require scrubbing. A factor that mitigates this assumption is the impact of the Energy Supply and Environmental Coordination Act (ESECA) or other legislative provisions which preclude the use of oil or natural gas as a boiler fuel in large new units. In ISTUM we assumed that oil and natural gas will

not be allowed as fuels in units greater than 100 MMBtu/hr. (steam output) in the future.

For particulates, an electrostatic precipitator unit was assumed for oil-fired boiler systems. Coal boilers used fabric filters for particulate control. This can achieve a standard of .03 lbs/MMBtu input.

2. Intermediate Direct Heat Service Sector

In this service sector the small size of combustors causes uncertainty as to whether or not Federal standards (10 and 50 MMBtu per hour of steam output) will apply. With the general requirement of this service sector for a clean non-contaminating hot gas, the use of an air-to-air heat exchanger was assumed for direct oil and coal technologies. Particulate control, but not sulfur control, was assumed for direct coal. Oil technologies were assumed to have neither sulfur nor particulate controls in this service sector.

For LBG, a Stretford clean-up system was assumed in this service sector. In these small sizes this system causes a sharp increase in the cost of LBG product gas. It is possible that an air-to-air heat exchanger would be a more attractive economic alternative for LBG in this service sector.

3. Dirty Direct Heat Service Sector

No sulfur removal was assumed for any technology in this service sector. For LBG this assumption included not removing tars and oils from the product gas. This implies that the gasification system for LBG is always located close to the combustor (less than 100 yards) to keep the tars and oils from condensing out. Particulate controls were assumed for coal but not oil in this service sector.

4. Indirect Heat Service (coal capable) Sector

The majority of the energy consumed in this service sector is in the tube-still heaters in the petroleum industry. These are large applications which are likely to be closely regulated. Sulfur removal was assumed for all coal-based technologies (80 percent removal efficiency). For LBG it was again assumed that sulfur removal would occur after combustion rather than by a Stretford unit. Removal of tars and oils was not assumed to be necessary before combustion for LBG. Particulate controls were included for both coal and oil-based technologies in this service sector. MBG was assumed to produce a clean pipeline quality gas here as in all service sectors.

5. Machine Drive and Electrolytic Service Sectors

Both of these service sectors deal with the on-site production of electricity. For all topping and self-generating technologies the environmental assumptions are consistent with those used in the steam service sector. The only exception is that ESECA limits were not applied. Gas turbine systems were assumed to not use water-injection for NO_x control.

6. Space Heat Service Sector

For all steam or hot water producing systems the environmental control assumptions for this service sector are the same as the steam service sector. The sizes in this service sector were assumed to be too small to be affected by ESECA regulations precluding the use of oil and gas.

7. Indirect Heat (non-coal capable) Service Sector

Environmental control assumptions in this service sector paralleled those for the Indirect Heat Service Sector (item 4 above).

8. Process-Specific Direct Heat Service Sectors

This is actually five different service sectors in the model - calcining, glass melting, brick firing, ironmaking and steel reheating. Most of the applications tend to be quite small. As a result, no sulfur removal or particulate removal was assumed. Again, for LBG, removal of tars and oils was not required. MBG was consistently specified as a clean pipeline quality gas.

F. Summary

It must be recognized that a great deal of uncertainty is involved in the development of environmental control assumptions for the base case of ISTUM. The uncertainties are associated with the status of various environmental statutes and their effect, (either actual or potential,) on emerging energy technologies; the unknown nature of pollutant types and quantities associated with these technologies and in many cases the lack of adequate data on resource constraints. It is clear, however, that environmental factors will directly affect the market penetration of certain energy technologies. The ISTUM model provides a framework for objectively evaluating the effects of these environmental factors.

PREFACE TO CHAPTER VI

This chapter discusses the work accomplished by Data Resources, Inc. in support of the Industrial Sector Technology Use model (ISTUM). DRI was selected as a subcontractor to this modeling effort as a result of their broad capabilities in providing energy data and analysis. Their work in other energy models helps assure a level of consistency between the ISTUM model and other energy models.

This chapter is included as received from DRI, unedited by EEA. Time did not allow careful integration of this chapter into the format of the remainder of the documentation. This is evidenced by the inconsistency of the page numbering and the fact that this chapter of the primary document has its own chapters within it. Questions concerning the contents of this chapter can be directed to EEA or directly to Michael Smolinski at DRI in Lexington, Massachusetts. Mr. Smolinski was project manager for DRI's subcontracting effort.

Assistance in the
Development of
Industrial Sector Technology Use Sector Development
(ISTUM)

April 14, 1978

by

Data Resources Incorporated
1750 K Street, N. W.
Washington, D. C.

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CHAPTER 1: INTRODUCTION

This report summarizes Data Resources, Inc.'s assistance to Energy and Environmental Analysis, Inc. in the development of its Industrial Sector Technology Use Model (ISTUM) and subsequent analysis. DRI's objectives for this project have involved: (1) the development of an economic scenario which would provide the structure for the ISTUM analysis; and (2) the performance of more disaggregate analysis in the areas of capital stock turnover and inflation.

The assumptions, forecasts, and methodologies provided in support of the ISTUM development are inherent in the following four tasks performed by DRI:

1. Development of the base line economic scenario. The ISTUM analysis covers the period 1977 to 2000. The base line scenario consists of a stable growth, long-range simulation of the 1977 DRI Quarterly Model, TRENDLONG1277, extended to the year 2000. The economic scenario represented in this simulation is described in Chapter 2.
2. Forecasts of industrial production, energy prices, and demands. Industrial energy price and demand forecasts, by fuel type, by region of the country were developed using the DRI U.S. Annual Energy Model. Inflation forecasts were developed using the DRI Cost Forecasting Service Models. Industrial production forecasts were direct outputs of the DRI Quarterly Macroeconomic Model. These forecasts are described in Chapter 3.
3. Development of an improved method of predicting capital stock turnover by industry. The method of predicting capital turnover typically involves the assumption that a constant percentage of the existing stock is retired every period. The previous MOPPS investigation used the same constant percentage for all industries.

Under this task a highly innovative approach was developed which allowed capital stock retirement to be predicted as a function of investment, in the specific industry, in previous periods. Energy capital stock, investment, and retirement data were developed for each industry. The methodology is described in Chapter 4.

4. Analysis of possible biases introduced by inflation. The complex nature of inflation can play havoc with the results of a constant dollar comparative analyses. To assess the possibility of inflationary bias, indexes were prepared for several technologies in order to compare their inflation rates with the index used for all technologies. This analysis is described in Chapter 5.

Chapters 2 through 5 contain a summary description of the analysis with subsequent descriptions of the methodology and assumptions made, where appropriate. Chapter 6 is devoted to conclusions and suggestions for further improvements. Complete results of the effort are presented in Appendix 1. Details of proofs and descriptions of methodology are presented in Appendices 2 through 4.

This effort has been performed by the DRI Energy Group under the direction of Alvin A. Cook, Jr. Assistance was provided by the DRI Macroeconomic Forecasting Group and the DRI Cost Forecasting Group under Paul Earl. The principal investigator was Michael D. Smolinski with assistance from Deborah Habel. Helpful comments have been provided by Phillip Budzick and Roger Bohn of EEA.

CHAPTER 2: ECONOMIC OVERVIEW

The ISTUM analysis covers the period 1977 to 2000. To insure ISTUMS's capability as a policy analysis tool, the base line scenario consists of a stable growth long-range simulation of the 1977 DRI Quarterly Model, TRENDLONG1277.¹ This simulation incorporates DRI's forecast of the business cycle through 1982, a departure from DRI's previous approach to trend solutions. Beyond 1982, the trend forecast abstains from cyclical variations in the economy.

The principal highlights of the forecast are:

- o Real GNP grows 4.2% annually over the 1977-1983 period and 3.0% from 1983 to 1990;
- o The unemployment rate falls gradually from 7% to the 4.6 to 4.7% range by 1984;
- o Inflation persists in the 5-1/2 to 6% range over the next six years, then decelerates to 4-1/2% in the late 1980's;
- o The population grows 0.9% annually, with the highest growth seen in the 30 to 45 year age group.

A summary of the forecast follows in Table 2-1 and a complete Forecast Summary is contained in Appendix 2.

¹Data Resources U.S. Long-Term Review, Winter 1977.

TABLE 2-1

Long-Term Forecasts of the U.S. Economy: December 1977

TRENDLONG1277	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
GNP and Its Components---Billions of Dollars															
Total Consumption.....	1033.9	1208.5	1331.5	1461.5	1603.2	1753.7	1913.8	2097.3	2276.0	2454.4	2641.4	2842.2	3055.8	3280.3	3517.4
Nonres. Fixed Investment.....	161.9	184.6	206.3	232.2	262.7	297.2	326.0	365.2	406.1	443.7	487.2	536.4	577.1	621.1	673.2
Res. Fixed Investment.....	68.0	89.9	100.4	108.9	126.1	135.3	140.3	165.5	175.9	181.3	187.2	190.9	198.7	207.6	216.7
Inventory Investment.....	13.3	18.2	18.4	13.8	20.2	25.5	25.4	32.6	31.4	32.8	34.6	37.9	41.4	45.0	46.7
Net Exports.....	7.8	-7.8	-5.4	-4.5	-3.4	-1.1	5.9	5.7	4.0	3.2	0.7	-1.2	1.6	2.2	2.6
Federal Purchases.....	130.1	146.4	163.0	176.8	191.8	210.4	230.8	251.7	273.6	296.6	321.0	346.4	373.6	402.9	433.7
State and Local.....	231.2	250.5	281.7	310.0	342.9	381.3	420.1	460.1	503.6	549.6	598.1	650.3	708.0	770.3	835.3
Gross National Product.....	1706.4	1890.3	2095.8	2298.8	2543.5	2802.2	3063.2	3378.1	3670.6	3961.6	4270.1	4602.9	4956.2	5329.4	5725.5
Real GNP (1972 Dollars).....	1274.7	1336.8	1397.5	1451.7	1519.2	1578.0	1633.9	1707.0	1763.8	1815.0	1868.9	1925.8	1982.4	2040.2	2100.5
Prices and Wages --- Rates of Change															
Implicit Price Deflator.....	5.3	5.6	6.1	5.6	5.7	6.0	5.6	5.6	5.2	4.9	4.7	4.6	4.6	4.5	4.4
Fixed Weight Deflator.....	5.6	5.9	6.1	5.6	5.7	6.1	5.7	5.8	5.4	5.1	4.9	4.9	4.9	4.8	4.6
Consumer Price Index.....	5.7	6.6	6.2	5.6	5.4	5.4	5.3	5.2	4.9	4.9	4.7	4.5	4.4	4.3	4.3
Wholesale Price Index.....	4.6	6.2	6.3	5.9	6.4	6.2	5.6	6.3	5.2	4.8	4.6	4.6	4.5	4.3	4.3
Compensation per Hour.....	8.6	8.7	8.4	7.9	8.0	8.5	8.4	8.3	8.3	8.1	7.8	7.6	7.4	7.3	7.2
Production and Other Key Measures															
Industrial Production (67=1).....	1.298	1.372	1.443	1.510	1.613	1.702	1.774	1.888	1.966	2.030	2.112	2.202	2.285	2.374	2.476
Rate of Change.....	10.1	5.7	5.2	4.6	6.8	5.5	4.2	6.4	4.2	3.2	4.0	4.3	3.8	3.9	4.3
Housing Starts(Mil. Units).....	1.541	1.958	1.837	1.817	1.980	1.921	1.959	2.291	2.270	2.217	2.137	2.073	2.049	2.005	1.965
Retail Unit Car Sales(Mil. Units)	10.1	11.2	11.0	11.2	11.4	11.5	11.7	12.3	12.3	11.9	11.9	12.0	12.1	12.3	12.3
Unemployment Rate (%).....	7.7	7.1	6.6	6.3	5.9	5.5	5.4	4.9	4.7	4.7	4.7	4.6	4.6	4.6	4.6
Federal Budget Surplus (NIA).....	-54.0	-49.7	-51.0	-50.1	-29.4	-20.2	-19.5	-10.5	-8.0	-8.8	-8.3	-5.4	-4.0	-5.3	-6.8
Money and Interest Rates															
Money Supply (M1).....	311.1	334.4	352.8	375.5	401.8	424.1	444.6	469.2	488.5	507.8	527.2	546.9	568.3	588.7	608.5
Rate of Change.....	5.6	7.5	5.5	6.4	7.0	5.6	4.8	5.6	4.1	3.5	3.8	3.7	3.9	3.6	3.4
New AA Corp. Utility Rate (%).....	8.67	8.34	8.02	8.66	8.84	8.93	8.96	8.64	8.30	7.97	7.74	7.84	7.78	7.84	7.80
New High-Grade Corp. Bond Rate (%)	8.33	8.06	8.50	8.33	8.52	8.60	8.63	8.32	7.99	7.68	7.47	7.55	7.47	7.53	7.48
Federal Funds Rate (%).....	5.05	5.56	6.83	6.15	6.53	7.24	6.59	5.89	5.83	5.81	5.80	5.80	5.79	5.79	5.83
Prime Rate (%).....	6.84	6.83	7.98	7.56	7.73	8.17	7.68	7.21	7.10	6.95	6.89	6.82	6.79	6.80	6.81
Incomes---Billions of Dollars															
Personal Income.....	1382.7	1533.3	1690.2	1849.1	2037.9	2239.6	2455.5	2698.7	2927.5	3156.9	3400.4	3664.5	3946.8	4244.9	4562.4
Real Disposable Income (%Ch).....	3.9	4.1	4.4	3.7	4.0	4.0	4.1	4.7	3.4	2.9	3.0	3.3	3.4	3.5	3.5
Saving Rate (%).....	5.6	5.1	5.4	5.3	5.2	5.3	5.6	5.9	5.8	5.7	5.7	5.7	5.8	6.0	6.1
Profits Before Tax.....	156.8	170.9	184.9	199.7	225.1	242.6	257.0	286.6	303.8	325.0	351.7	380.1	406.8	435.3	464.4
Profits After Tax.....	92.1	102.9	113.8	125.0	143.6	155.6	166.1	186.3	198.9	213.9	232.7	252.9	272.1	292.6	314.0
Percent Change.....	25.5	11.7	10.5	10.6	14.2	8.3	6.7	12.2	6.8	7.5	8.8	8.7	7.6	7.5	7.3
Composition Of Real GNP --- Rates of Change															
Gross National Product.....	6.0	4.9	4.5	3.9	4.6	3.9	3.5	4.5	3.3	2.9	3.0	3.0	2.9	2.9	3.0
Final Sales.....	4.5	4.6	4.6	4.2	4.4	3.8	3.6	4.3	3.4	2.9	3.0	3.0	2.9	2.9	3.0
Total Consumption.....	6.0	4.5	4.0	4.1	4.1	3.8	3.8	4.4	3.6	3.1	3.2	3.3	3.4	3.3	3.3
Nonres. Fixed Investment.....	3.6	8.4	5.4	6.9	7.4	6.2	3.9	5.4	5.2	3.9	4.5	4.7	2.3	2.5	3.4
Equipment.....	4.2	10.8	5.2	7.0	7.1	6.8	4.0	5.5	5.2	4.0	4.7	5.0	2.6	2.8	3.6
Nonres. Construction.....	2.2	3.3	5.7	6.7	7.9	5.0	3.6	5.1	5.0	3.7	3.9	4.0	1.6	1.9	2.7
Res. Fixed Investment.....	23.1	18.4	3.9	1.4	8.3	-0.1	-2.5	10.6	0.2	-2.5	-2.0	-3.0	-0.9	-0.3	-0.3
Exports.....	6.5	3.4	7.0	6.5	5.0	4.2	3.9	4.8	4.5	5.1	4.3	4.3	4.3	4.4	4.4
Imports.....	18.4	10.2	3.9	4.7	4.0	3.7	2.3	6.9	5.9	5.2	5.2	6.0	5.3	5.9	5.9
Federal Government.....	-0.1	5.7	4.7	2.1	1.9	2.7	2.8	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
State and Local.....	1.0	1.4	5.1	3.5	3.5	3.6	3.7	3.5	3.6	3.4	3.2	3.1	3.0	2.9	2.8

The long-range simulation, TRENDLONG1277, is a projection to the year 1990. To fulfill the requirements of ISTUM, it was necessary to continue projections for a subset of variables to the year 2000. This was done by extending the 1990 value of a variable, in accordance with its growth rate developed under a special DRI study, "The Extended DRI Long-Term Projections, 1990-2002."² A copy of this study is contained in Appendix 3.

² Johnson, Sara and Douglas C. Rice, "The Extended DRI Long-Term Projections -- 1990-2002", unpublished paper.

CHAPTER 3: FORECAST RESULTS

FORECASTS

The industrial sector technology use model (ISTUM) is driven by industrial production, over the years 1977 to 2000, by industry. Production is a key factor in determining the quantity of energy required by each industry. Given energy demands, energy prices and inflation forecasts are necessary for ISTUM to perform a comparative analysis among technologies. An overview of DRI's effort in support of ISTUM is provided in Chart 3-1.

INDUSTRIAL PRODUCTION

The industrial production forecasts have been developed using the DRI Quarterly Model of the U.S. economy. The model forecasts industrial production for more than 60 industries. The forecasts are based upon the simulation TRENDLONG1277 and extended to the year 2000 as described in Chapter 2.

Overall production is forecast to grow at a compound annual rate of 4.7% over the interval 1977-1990 with a healthy 5.6% rate in 1977-1983 yielding to a more sustainable 3.9% in the 1984-1990 period. The forecast for the period 1977-2000 is shown in Table 3-1 for the following industries: all manufacturing; chemicals; stone, clay and glass; and primary metals.

Although DRI forecasts production indices for more than 60 industries, there are several industries which are either not forecasted, or are not forecasted at the requested level of detail. In those cases, an acceptable proxy was selected from among the other industries. Industries are listed in Table 3-2, including a listing of the industry used as the proxy.

CHART 3-1

DATA RESOURCES ISTUM SUPPORT OVERVIEW

TABLE 3-1

SELECTED PRODUCTION INDICES

INDUSTRY	1977	1980	1985	1990	1995	2000
All Manufacturing	1.372	1.618	2.049	2.513	3.016	3.555
Chemicals	1.808	2.242	3.046	4.078	5.146	6.494
Stone, Clay and Glass	1.458	1.720	1.983	2.297	2.632	3.015
Primary Metals	1.105	1.292	1.557	1.805	2.024	2.270

TABLE 3-2

Industry Requested		Industry Used As Proxy	
<u>SIC</u>	<u>Industry Name</u>	<u>DRI Mnemonic</u>	<u>Industry Name</u>
011	Crops (Fruits & Vegetables)	JQIND20	Food
012	Crops (Grains)	JQIND20	Food
019	Crops (Other Farm Products)	JQIND20	Food
013	Livestock	JQIND20	Food
20	Food	JQIND20	Food
21	Tobacco	JQIND21	Tobacco Products
22	Textiles	JQIND22	Textile Mill Products
23	Apparel	JQIND23	Apparel Products
24	Lumber	JQIND24	Lumber and Products
25	Furniture	JQIND25	Furniture and Fixtures
26	Paper	JQIND26	Paper and Products
27	Printing	JQIND27	Printing and Publishing
28	Chemicals	JQIND28	Chemicals and Products
29	Petroleum Refining	JQIND29	Petroleum Products
30	Rubber	JQIND30	Rubber and Plastics Products
31	Leather	JQIND31	Leather and Products
32	Stone, Clay & Glass (General)	JQIND32	Clay, Glass & Stone Products
321	Glass	JQIND32	Clay, Glass & Stone Products
322	Glass	JQIND32	Clay, Glass & Stone Products
323	Glass	JQIND32	Clay, Glass & Stone Products
324	Other Stone, Clay & Glass	JQIND32	Clay, Glass & Stone Products
325	Brick and Clay	JQIND32	Clay, Glass & Stone Products
326	Other Stone, Clay & Glass	JQIND32	Clay, Glass & Stone Products
327	Other Stone, Clay & Glass	JQIND32	Clay, Glass & Stone Products
328	Other Stone, Clay & Glass	JQIND32	Clay, Glass & Stone Products
329	Other Stone, Clay & Glass	JQIND32	Clay, Glass & Stone Products
33	Primary Metals	JQIND33	Primary Metals
331	Steel	JQIND331	Basic Steel and Mill Products
332	Other Primary Metals	JQIND332	Iron and Steel Foundries
333	Other Primary Metals	JQIND333VR	Nonferrous Metals
3331	Other Primary Metals	JQIND333VR	Nonferrous Metals
3332	Other Primary Metals	JQIND333VR	Nonferrous Metals
3333	Other Primary Metals	JQIND333VR	Nonferrous Metals
3334	Aluminum	JQIND333VR	Nonferrous Metals
3339	Other Primary Metals	JQIND333VR	Nonferrous Metals
334	Other Primary Metals	JQIND33	Primary Metals
335	Other Primary Metals	JQIND33	Primary Metals
336	Other Primary Metals	JQIND33	Primary Metals
339	Other Primary Metals	JQIND33	Primary Metals
34	Fabricated Metals	JQIND34	Fabricated Metal Products
35	Nonelectrical Machinery	JQIND35	Nonelectrical Machinery
36	Electrical Machinery	JQIND36	Electrical Machinery
37	Transportation Equipment	JQIND37	Transportation Equipment
38	Instruments	JQIND38	Instruments
39	Miscellaneous Manufacturing	JQIND39	Miscellaneous Manufacturing
10	Metal Mining	JQINDMI	Mining
14	Nonmetal Mining	JQINDMI	Mining

INFLATION

To meet ISTUM's constant dollar format, DRI provided two inflation forecasts. The first, the GNP deflator, was forecasted under the U.S. Macroeconomic simulation TRENDLONG1277 and extended to the year 2000 as discussed in Chapter 2. The second, a composite facility inflation index, was developed to forecast increases in ISTUM technology cost estimates due to inflation. The forecast for each is shown in Table 3-3.

The ISTUM price forecasts provided herein have been deflated by the GNP deflator to make them constant, 1977 dollars. The composite facility inflation index was developed by DRI as representative of the material and labor input for a typical ISTUM technology. Adjustments for facility inflation were made within ISTUM. A more detailed discussion of the composite facility index and inflation is contained in Chapter 5.

ENERGY PRICES AND DEMANDS

Forecasts of industrial energy prices and demands by type of fuel and by region of the country were developed using a simulation of the DRI U.S. Annual Energy Model, ECONTROL0378. This simulation is the most recent DRI energy forecast and is based upon the macroeconomic forecast TRENDLONG1277.

Price forecasts from DRI Energy simulation ECONTROL0378 are in current dollars. Therefore, the forecast assumptions described below deal in current dollars and simple annual rates of growth. Forecasts of price and demand are made for the nation as a whole and for 13 regions within the nation. For a listing of states included in each region, see Table 3-4. The forecast period for ECONTROL0378 is 1977 to 1990. Assumptions are made for that period. For the period 1990 to 2000, each series from the energy model was grown out at a compound annual growth rate equal to the growth rate for the series from 1985 to 1990.

TABLE 3-3

FACILITY INDEX AND GNP DEFLATOR

	1974	1977	1980	1985	1990	1995	2000
FACILITY INDEX	0.794	1.000	1.231	1.792	2.413	3.253	4.395
GNP DEFLATOR	0.821	1.000	1.184	1.544	1.928	2.414	3.023

TABLE 3-4

REGIONAL DEFINITIONS USED IN THE DRI ENERGY MODEL

<u>Region</u>	<u>Abbreviation</u>	<u>States</u>
New England	NENG	MA,ME,VT,RI,NH,CT
Middle Atlantic	MATL	PA,NJ,NY
South Atlantic	SATL	DE,MD,DC,VA,WV,GA,FL,SC,NC
East North Central	ENC	OH,WI,IN,MI,IL
West North Central	WNC	KS,NB,ND,SD,MN,IA,MO
East South Central I	ESC1	KY,TN
East South Central II	ESC2	AL,MS
West South Central I	WSC1	OK
West South Central II	WSC2	TX,AR,LA
Mountain I	MTN1	NM
Mountain II	MTN2	MT,CO,WY,ID,UT
Mountain III	MTN3	NV,AZ
Pacific	PAC	CA,OR,WA,AK,HI

The latest energy simulation differs from the previous simulation, ECONTROLIII107, reported in the DRI Energy Review, Autumn 1977, in several areas. There is a decrease in total energy consumption in 1990 from 108.2 quadrillion Btus (quads = 10^{12} Btu's) to 107.8 quads. This is due to the effect of the drought on expectations of hydropower capability in the West and the effect of the coal strike on coal output and prices. In addition, natural gas supplies are carried upward as a result of a new allocation algorithm and new assumptions about the imports of natural gas. Total consumption of natural gas in 1990, by all sectors, has increased from 18.6 quads to 21.3 quads.

The largest fraction of the increase in natural gas supply goes to the industrial sector and decreases its demand for electricity and petroleum. The reduced demand for electricity, in turn, reduces fuel demand by electric utilities. This is the principle reason overall coal consumption is decreased in the current forecast from 27.4 quads to 25.8 quads. New concerns about labor difficulties also contribute to the reduction in coal demands.

A new DRI ENERGY REVIEW will be published in the next several weeks detailing the revised energy forecasts for the U.S.

The following paragraphs outline the major forecast assumptions by fuel type. Also, the methodology utilized for determining the ISTUM forecasts is described. The ISTUM national energy price and demand forecasts are presented in Table 3-5 and plotted on Charts 3-2 and 3-3. The forecasts themselves are presented in their entirety in Appendix I.

TABLE 3-5A

PRICE OF FUELS NATIONALLY
IN DOLLARS PER MILLION BTUS
(DEFLATED BY GNP DEFLATOR)

	<u>1977</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>	<u>1995</u>	<u>2000</u>
ELECTRICITY	6.702	7.213	8.152	9.630	11.347	13.371
NATURAL GAS	1.727	2.255	2.860	3.250	3.683	4.174
COAL	0.977	1.047	1.199	1.436	1.716	2.050
DISTILLATE	2.568	3.083	3.406	3.881	4.411	5.012
RESIDUAL	1.915	2.346	2.609	3.035	3.520	4.083

TABLE 3-5 B

DEMAND FOR FUELS NATIONALLYIN TRILLION BTUS

	<u>1977</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>	<u>1995</u>	<u>2000</u>
ELECTRICITY	2,588.971	3,100.370	4,365.520	5,731.878	7,526.907	9,884.077
NATURAL GAS	5,921.00	6,577.768	7,333.510	8,315.678	9,431.396	10,696.811
COAL	1,593.7571	1,946.5476	2,604.2697	3,549.6251	4,838.2303	6,594.6322
DISTILLATE	925.381	875.918	706.536	355.363	178.755	89.918
RESIDUAL	1,483.258	1,458.711	1,148.949	791.126	544.778	375.140

CHART 3-2

COMPONENTS OF DEMAND
BY TYPE OF FUEL

ELECTRICITY (LINE) NATURAL GAS (DOT)
COAL (DASH) PETROLEUM (DDASH)

CHART 3-3

PRICE LEVELS
BY TYPE OF FUEL
ELECTRICITY (LINE) NATURAL GAS (DOT)
COAL (DASH) RESIDUAL (DDASH)
DISTILLATE (LDASH)

NATURAL GAS

Underlying the demand and price forecasts for natural gas is the assumption that the proposed taxes on the industrial and utility use of gas are enacted in 1978. Fuel and power uses of natural gas by industry are taxed so as to bring the price of natural gas to within \$.30 per MMBTU of the price of distillate fuel oil (which also includes a user tax) by 1985. Thus, the differential of \$.75 in 1979 is gradually reduced to \$.30 by 1985. Moreover, presumed exemptions from the industrial tax are such that only 33% of the industrial users actually pay the tax.

While the simulations resulting in price and quantity forecasts included these use taxes, the actual tax has been netted out of the prices in this report. This exclusion of the proposed taxes was the result of discussions with EEA. Among factors considered in making this decision was an alternative simulation of the DRI Energy Model, excluding the industrial user taxes. The price forecasts resulting from this simulation were not significantly different from those of ECONTROL0378.

Natural Gas Prices

DRI has assumed that the price of new natural gas, in both the intrastate market and the interstate market, will be \$1.85 per thousand cubic feet (MCF) in 1978. The price of new natural gas will be allowed to increase annually at the rate of inflation plus 4% over the period 1978 to 1984, at which time it will be deregulated. After 1984 the price is assumed to rise at the rate of inflation plus 1.3%. The price of "old" interstate natural gas and the lower-48 border price of Alaskan natural gas are both projected to increase with the rate of inflation.

Canadian and Mexican imports of natural gas are priced equally: The prices are projected to increase from \$2.00 per mcf in 1977, by an equivalent percentage in the refiner acquisition price of crude oil. Prices of synthetic gas from oil and coal and of liquefied natural gas are forecasted to change with both the general price level and the refiner acquisition price of crude oil.

The ISTUM natural gas prices, by region of the country, are a direct output of the energy model. The national price for natural gas was computed as a demand weighted average using the forecasted regional demand values.

Demand for Natural Gas

Although production of natural gas in the lower 48 states is expected to decline slightly until 1985 and then level off, anticipated increases in imports of Canadian and Mexican natural gas and LNG result in a net increase in gas available for industrial use. In addition government policies designed to shift electric utilities from natural gas to coal, further increase amounts of natural gas available to industry. Even though the price is increasing at a rate higher than the rate of inflation, gas is available to those industries willing to pay the price. The result is a steadily increasing industrial demand for natural gas, from 5921 trillion Btus in 1977 to 9884 in 2000.

DRI forecasts national demand for natural gas, by industry, for both 1) fuel and power use and 2) total demand (fuel and power use plus raw material use). Total demand is also forecasted at the regional level. However, fuel and power use is not. To obtain regional fuel and power use figures, the regional raw material demand was computed and subtracted from the regional total demand forecast. The national fuel and power demand forecast is the sum of the regional figures.

Regional raw material demand for natural gas was computed by assuming that the regional percent distribution of raw material demand in 1976 remained constant over the period 1977 to 2000. Each region's share was calculated using 1976 American Gas Association data. The shares were computed by dividing each region's large volume sales of natural gas for chemicals and allied products and rubber and miscellaneous plastic products by total national demand in these two areas. The national raw material demand forecast was then multiplied by the share percentage to determine raw material demand by region.

ELECTRICITY

In forecasting electricity demand and prices, several basic assumptions were made in ECONTROL0378. In comparison with ECONTROL111107, increased utilization of nuclear capacity has resulted in a greater forecast of nuclear-generated electricity. Assumptions about user taxes on electric utilities have had a strong impact on the price of electricity. These user taxes are designed to force electric utilities to switch from natural gas and oil to coal, by 1990. Electric utilities' use of natural gas is taxed \$.55 per MMBTU in 1983, \$.65 per MMBTU in 1984, and \$.75 per MMBTU in 1985 and beyond. It is assumed that 90% of electric utilities' use of gas will be subject to the tax. The user tax on petroleum will be about \$1.50 per barrel, or \$.239 per million Btus (MMBTU) beginning in 1983. As with the tax on natural gas use, it is assumed that 90% of the utilities will pay the tax after exemptions.

Electricity Prices

Electricity prices are average prices to industrial users. They are based upon historical data from the Edison Electric Institute. The average price is calculated as total electric utility revenue from industrial customers divided by total KWH delivered to industrial customers. Average prices are considered to be the most appropriate single price forecasts for the ISTUM analysis. Since the prices are average prices, they are not expected to be affected by changes to industrial rate structures.

DRI forecasts that electricity prices to industry increase at simple annual rates of about 6.3% annually to 2000. This high growth rate reflects the increasing prices utilities are paying for fossil fuels, as well as costs of conversion to generation with coal and meeting environmental standards.

The ISTUM regional electricity prices are a direct output of the energy model. The national price is computed as a demand weighted average of the regional figures.

Electricity Demand

The demand for electricity shows a steady increase throughout the forecast period in terms of the absolute level of Btus demanded as well as the share of the total quantity of all fuels demanded. (see Chart 3-3) However, in the context of rising electricity prices and increased availability of natural gas for industrial use, the demand levels are lower than would have been expected in the absence of these factors. The regional demand figures were obtained directly from the DRI U.S. Energy Model Forecast ECONTROL0378, and converted from kwh to Btus. The national figure is the sum of the regional demand levels.

OIL

Forecasting price and demand levels for oil involves the consideration of numerous policy factors. Domestic supplies of crude oil are projected to increase gradually from 8.58 million barrels per day (MMBD) in 1978 to 8.86 MMBD in 1990. These increases come from upper tier oil in the early years of the forecast period, Alaskan oil in the early and middle years, and enhanced recovery oil during the middle and later years, with stripper oil contributing throughout the forecast period. This is due to government policies that grant world prices to stripper and enhanced recovery oil. Increases in domestic production are an improvement over pre-1977 levels, but are not sufficient to reduce imports to levels targeted by the Carter administration. Imports of crude oil and petroleum products will be 10.3 mmbd in 1990. This level reflects lower U.S. petroleum demands due to conservation efforts.

Oil Prices

In forecasting petroleum prices, ECONTROL0378 includes proposed taxes on petroleum used by industry and electric utilities. Industrial fuel and power use of petroleum will be taxed at \$.30 per barrel in 1979, \$.60 per barrel in 1980, and \$3.00 per barrel by 1985. About 1/3 of industry users are expected to be subject to the tax after exemptions. Electric utilities will be taxed at \$1.50 per barrel beginning in 1983 and 90% of all electric utilities are expected to be subject to the tax.

Prices of imports are expected to remain relatively constant through 1979. Although posted OPEC prices should remain frozen throughout 1978, there will be an effective increase of approximately 3% due to the uncertainty of two OPEC policy issues: cutbacks in production to deal with the current oil glut, and removal of prices from the dollar standard. Effective OPEC prices are assumed to increase 6% in 1979, 9% in 1980, and at about 7.8% per year for the rest of the forecast period. At the same time domestic prices will increase 6% and 6.2% annually for lower and upper tier domestic crude oil respectively. Prices for crude oil from stripper wells and enhanced recovery techniques are equated to the price of imported crude oil. The price of Alaskan North Slope crude oil is equated with the pre-tax price of domestic crude oil or the price of imported crude oil less Alaskan transportation costs. Crude oil equalization taxes have been added to prices for lower and upper tier domestic oil. The tax on lower tier oil in 1978 will bring the price to \$8.27 per barrel excluding U.S. transportation costs. The price of lower tier oil would then be raised to equal that of upper tier oil in 1979, and both upper and lower tier prices would be equated to imported crude oil prices from 1980 on.

All of the factors mentioned above combine to increase the ISTUM price of both residual and distillate fuels to industry by 8.07% and 7.34% at compound annual rates in the period 1977-1980. These price increases decelerate after 1980 to 2%-2.5% for distillate and 2-3% for residual, at compounded annual rates. As was the case for natural gas, the ISTUM prices provided do not include industrial user taxes.

DRI forecasts prices for distillate and residual on a national level. In order to regionalize these prices for ISTUM, they were shared out by the demand weighted average of the price paid for distillate and residual by electric utilities in each of the 13 regions of the U.S. After regionalization, all prices were converted from \$/barrel to \$/million Btus.

The ISTUM distillate and residual price forecasts represent the price at the wholesale level, adjusted for inflation using the GNP implicit price deflator. The quantity of oil used is the primary determinant of whether or not industry may buy at the wholesale level. Where the ISTUM analysis requires a retail price, DRI

recommends the addition of a \$.16 per million Btu retail premium (\$1.00 per barrel). According to Department of Energy Data provided in the Monthly Energy Review and the Petroleum Industry Monthly Report for product Prices, the differential between wholesale and retail prices during 1977 has averaged approximately \$1.00 per barrel.

Oil Demand

Due to a combination of conservation efforts and increasing prices, demands for both distillate and residual fuels fall throughout the forecast period. This demand response is lagged somewhat relative to price, as can be seen from the increasing declines in demand in the 85 to 90 period relative to the earlier years of the forecast. In addition to the price response, the industrial demand for petroleum is reduced due to increased availability of natural gas for use by industry, and the government's coal conversion policies. The demand figures for residual and distillate fuels were derived using methods similar to those for prices. The national industrial demand for residual and distillate fuels from ECONTROL 0378 were shared out regionally by the potential industrial demand for oil for fuel and power use. All the figures were then converted from barrels to btus.

COAL

The recent miners strike has focused special attention on supply, demand and the price of coal during the past few months. Assumptions made in generating the coal forecast included rising transport costs from 1978 to 1990 averaging 9.9% annually, and scrubbing costs increasing at an average annual rate of 6.5% over the same period. Mining machinery costs rise at an annual rate of 7.6% and miners wages are up 9.5% per year from 1978 to 1990. Federal severance taxes are assumed to be \$.15 per ton for deep-mined coal and \$.35 for stripmined coal. Reclamation costs vary by supply region ranging from \$4.54 per ton in Appalachia to \$.02 in Montana-Wyoming. Finally, a 10% return on equity is assumed over the forecast period with the recoverable portion of the coal reserve base assumed to be 80% for strip-mined and 50% for deep mined coal.

Coal Prices

The price of coal to electric utilities is forecasted through a joint solution of the Annual U.S. Energy Model and the DRI/Zimmerman Coal Model. The price of coal to industry, on a regional basis is not forecasted within the two models. Therefore, ISTUM forecasts are the average price of coal to electric utilities, by region. These prices were then increased by 12% within the ISTUM analysis. DRI believes a 12% premium to industrial users is most appropriate for the period of the ISTUM analysis. The historical relationship between the average price paid by industry and the average price paid by electric utilities is provided in Table 3-6.

Coal Demand

Demand figures for coal were obtained directly from the DRI/Zimmerman Coal Model.

TABLE 3-6

AVERAGE PRICE OF COAL(TOTAL DOLLAR COSTS/TOTAL TONS AND CONVERTED TO $\$/10^6$ BTU)

YEAR	INDUSTRY*	ELECTRIC UTILITIES**	PERCENT DIFFERENCE
1962	\$.2729	\$.256	6.6
1967	.2801	.252	11.1
1971	.409	.363	12.6
1974	.865	.619	39.7
1975	1.1206	.864	29.6

* SOURCE: CENSUS OF MANUFACTURERS DATA FOR THE TOTAL U.S.

** " : EDISON ELECTRIC INSTITUTE DATA FOR THE TOTAL U.S.

CHAPTER 4: CAPITAL STOCK TURNOVER

Under this phase of the project, DRI has developed the information necessary for ISTUM to utilize a vintaging approach to predicting capital stock turnover. Performing our analysis over five year periods, DRI developed data, by industry, for 1) energy capital stock, 2) investment in energy equipment and 3) retirement coefficients. This information allows ISTUM to predict capital stock retired in a period, based upon the industry's investment in energy equipment in prior periods and the retirement coefficients appropriate to the industry.

Background

Typically, capital stock turnover is predicted using a proportional approach. The assumption is made that a constant percentage of the current stock is retired every period. Retirement thus depends upon the percentage value chosen and the rate of growth of the capital stock. The latter determinant is one of the more disturbing characteristics of the proportional approach. Retirement is likely to be overstated during periods of high growth and understated during periods of low growth.

The proportional approach is appropriate in an equilibrium setting where the capital stock is growing at a constant rate and where market and technology transitions are smooth. The approach has been used in previous investigations because it is straight forward and simple to apply. A retirement percentage can be determined given an estimate of the growth rate of the capital stock and an estimate of its expected life. Unfortunately, industries do not grow at constant rates. Also, selection of the percentage value can be arbitrary and therefore either bias the results or fail to capture technological or other structural differences among industries.

The vintaging methodology has its foundation in the following principles: first, capital stock is dependent upon the kinds of equipment embodied in the industry's stock. Retirement therefore, is dependent upon the useful life for which the equipment was designed. Secondly, retirement is dependent upon the use to which it has been put. Equipment operated at a moderate, steady state will last longer than equipment operated at full throttle or in a highly cyclical mode. Finally, retirement is dependent upon the present age profile of the capital stock. Retirement will be greater given a stock that is 80% old and 20% new versus 20% old and 80% new.

The vintaging methodology has been hindered by the lack of data. In fact, there are no data available providing historical information on investment in energy equipment. DRI's method utilizes data on industry's investment and retirement of plant. It is based upon the following two critical assumptions. First, we have assumed that investment by industry in plant over five year periods is proportional to investment by industry in energy capital equipment, for the years prior to 1971. Secondly, we have assumed that industry's retirement of plant is representative of industry's retirement of energy capital equipment, for the years prior to 1971.

We begin with the determination of the retirement characteristics of each industry. Coefficients were determined at the two and three digit SIC level of detail. These coefficients reflect the kind of equipment utilized by the industry and the use to which it is put. Next, the energy capital stock of the industry was estimated for the periods 1966 to 1970 and 1971 to 1975, using energy consumption data from the census of manufacturers. Then, using a constraining index, developed from data on the industry's investment in plant and the retirement coefficients, investment in energy capital equipment was determined. The methodology is summarized below and described in Appendix 4.

Retirement Coefficients

The coefficients were determined by regressing retirement of plant in a five year period by investment in plant in previous five year periods. The specification is as follows:

$$\text{Ret}_{i,j} = C_{i,j-1} * \text{Inv}_{i,j-1} + C_{i,j-2} * \text{Inv}_{i,j-2} \\ + \dots + C_{i,j-n} * \text{Inv}_{i,j-n}$$

where $\text{Ret}_{i,j}$ = Retirement of Plant in industry i in period j

$C_{i,j-n}$ = The coefficient representing the quantity of retired plant in period j that is contributed by plant investment in period j-n

$\text{Inv}_{i,j-n}$ = The investment in plant in period j-n in industry i.

The data used had been prepared for the Office of Emergency Preparedness,³ from 1890 to 1966 and subsequently updated to 1971. Retirement of plant was summed over five year periods and regressed by the summed value of investment in plant over previous five year periods. For example, the sum of retirement of plant in Industry 28, Chemicals, over the period 1966 to 1970 was viewed as a percentage of the sum of investment in plant in Industry 28 in the previous five year periods; Period 1 = 1961 to 1965, 2 = 1956 to 1960, 3 = 1951 to 1955, 4 = 1946 to 1950, 5 = 1941 to 1945, etc.

The regression coefficients represent the contribution to this period's retirement from the investment in previous periods. Although, under all cases, the coefficients nearly summed to one, they were normalized to insure summation to one. The values of the coefficients for several industries are provided in Table 4-1.

Data was also available on the "wear and tear" of plant. Wear and tear is the difference between the industry's gross plant stock and net plant stock. This data was also developed, by industry, as a function of investment in prior years. Technically, the effects of "wear and tear" require replacement investment be made to preclude a reduction in productive capacity. Therefore, it should be added to retirement to determine total replacement capacity. However, "wear and tear" was omitted from this analysis. First, the quantity was small relative to retirement. Second, sufficient time was not available to include it.

³ Jack Faucett Associates, Inc., Development of Capital Stock Series By Industry Sector, TR-81, March 1973

TABLE 4-1

EXAMPLE RETIREMENT COEFFICIENTS

<u>INDUSTRY</u>		<u>PERIOD</u>								
<u>SIC</u>	<u>DESCRIPTION</u>	66-70	61-65	56-60	51-55	46-50	41-45	36-40	31-35	26-30
26	Paper	.073	.032	.056	.165	.216	.284	.174	0	0
28	Chemicals	.032	.098	.197	.250	.275	.148	.000	0	0
29	Petroleum	.067	.043	.040	.211	.260	.203	.176	0	0
32	Stone Clay and Glass	.029	.061	.134	.223	.254	.208	.091	0	0
33	Primary Metals	.037	.056	.149	.252	.269	.172	.065	0	0

Energy Capital Stock

Given the retirement coefficients, the historical investment in energy capital stock was developed. The total energy capital stock for each industry was estimated for the periods 1966 to 1970 and 1971 to 1975. This was done using Census of Manufacturers data on energy consumption of the four major fuel types, by industry, for the years 1967, 1971 and 1974. The stock was represented as the total Btu's consumed by the industry in a year. This approach was used to be consistent with the ISTUM analysis. The stock for 1966 to 1970 was estimated as the average of the industry's consumption in 1967 and 1971. The stock for the period 1971 to 1975 was more difficult to estimate because of the period's economic swings and dramatic shifts in energy consumption. Therefore, the stock was estimated as the sum of the maximum consumption of each fuel type, in either 1971 or 1974. For example, if consumption of coal was greatest in 1971 but consumption of electricity, oil and natural gas were greatest in 1974, the stock was the sum of 1971's coal consumption and 1974's consumption of the remaining fuels.

Investment In Energy Capital Stock

Next, the investment in plant series was used as a constraint in order to solve for investment in energy capital stock. An index was developed by dividing investment in plant during the 10 five-year periods from 1921 to 1970, by the investment in the period 1966 to 1970. The specification is as follows:

$$\text{Index}_{i,j-n} = \text{Inv}_{i,j-n} / \text{Inv}_{i,-1} \quad \text{for } n = 1 \text{ to } 10$$

where $\text{Index}_{i,j-n}$ = The value of the constraint index in period j-n for industry i

$$\text{Inv}_{i,j-n} = \text{Investment in plant in period j-n for industry i}$$

Note: Period j = 0 is 1971 to 1975; Period -1 is 1966 to 1970; Period -2 is 1961 to 1965, etc.

We then solved for energy investment in the prior periods by relating stock to investment -- the stock in the 1966 to 1970 period is equal to the investment in that period plus the investment in prior periods less retirement. The specification is as follows:

$$\begin{aligned} \text{Stock}_{i,j} = & \text{Einv}_{i,j} + (1 - C_{i,j-1}) * \text{Einv}_{i,j-1} \\ & + \dots + (1 - \sum_{x=1}^n C_{i,j-x}) * \text{Einv}_{i,j-n} \quad \text{for } n = 1 \text{ to } 10 \end{aligned}$$

where

$\text{Stock}_{i,j}$ = the stock of energy capital equipment for industry i in period j

$\text{Einv}_{i,j-n}$ = the investment by industry i in energy capital equipment in period j-n

$C_{i,j-n}$ = the retirement coefficient in period j-n for industry i determined above.

Investment is determined by substituting the following in the above equation and solving it for Y_i :

$$\text{Einv}_{i,j-n} = \text{Index}_{i,j-n} * Y_i$$

The solution is performed for the conditions

$$j = -1 \text{ (66 to 70); } n = 1 \text{ to } 10.$$

Finally, the investment in energy capital stock in the 1971 to 1975 period (period j=0), was estimated as the sum of new investment and replacement investment. New investment was computed as the difference between the 1966 to 1970 period stock and the 1971 to 1975 period stock. Replacement investment was computed using the calculated energy stock investment data and the retirement coefficients. Investment in energy capital equipment for several industries are presented in Table 4-2.

TABLE 4-2

EXAMPLE INVESTMENT IN ENERGY CAPITAL EQUIPMENTTRILLION BTU'S

INDUSTRY											
SIC	DESCRIPTION	71-75	66-70	61-65	56-60	51-55	46-50	41-45	36-40	31-35	26-30
26	Paper	331.9	349.0	232.6	259.6	186.4	221.9	75.2	59.3	20.6	138.6
28	Chemicals	1,037.7	808.7	543.8	447.7	462.5	501.1	214.6	158.5	33.3	40.5
29	Petroleum	389.3	322.4	244.1	364.2	307.0	326.5	110.0	225.8	94.8	306.8
32	Stone Clay & Glass	274.2	260.9	236.9	340.8	216.5	250.6	72.6	121.5	23.7	119.4
33	Primary Metals	606.8	532.1	391.4	565.6	539.4	311.4	152.6	284.3	297.8	914.2

Summary

The vintaging approach to predicting capital stock turnover is a significant improvement over the proportional approach. This effort allows ISTUM to incorporate a more realistic method of determining the retirement market. Improvements result from the industry specific analysis and the elimination of distortion caused by industry growth fluctuations.

CHAPTER 5: INFLATION

This chapter presents DRI's analyses of inflation's effect on a range of ISTUM technologies. The purpose of the investigation was to assess the ability of the composite index to represent inflation of capital costs of all ISTUM technologies. The investigation has yielded the following conclusions:

- 1) The composite index is a good approximation of the broad range of ISTUM technologies. It eliminated the significant downward capital equipment bias (as high as 30% in 1990 and rising to 59% in 2000), that occurs when the GNP deflator is used to account for inflation.
- 2) Although the composite index reduces inflationary bias, it does not eliminate it. In the year 2000, the composite index overestimates the cost of one technology by 7.8% and underestimates the cost of another by 9.3%. Future studies should incorporate a more rigorous approach to capturing the effects of inflation.

Background

Since the late sixties, energy/economic analysis has been the victim of inflation. Many studies have been made obsolete before they could be published. For example, in 1974, oil from shale was expected to be developed given a world oil price of \$7.00 per barrel.⁴ In just two years the estimate nearly doubled. In 1976 it was said to be marginally economic at \$13.00 per barrel.⁵ Today, estimates range as high as \$25.00. Inflation is one major cause of these increases.

⁴Project Independence Report, November 1974, Pg. 130

⁵National Energy Outlook, February 1976, Pg. 39

Inflation is a complex issue and has a tremendous impact on energy analysis. In a given year, its rate of change will vary across materials and labor. Each of these will also vary over time. The effect of inflation alone can prevent the expected appearance of a new fuel source or energy technology.

Like all energy/economic analysis, ISTUM involves the investigation of many complex substitutions. To be useful for decision making, it must reflect reality. DRI's inflation effort in support of ISTUM involved work in two areas. The first, described in Chapter 3, consisted of 1) forecasting the gross national product deflator and 2) developing and forecasting a composite cost index representative of the technologies investigated by ISTUM. The second, described here, consisted of an analysis of the single composite cost index's ability to represent the ISTUM technologies.

Methodology

The methodology used in DRI's inflation analysis is based on the technique of separating the total estimated cost of a technology into its basic material and labor inputs. A technology's cost is represented by the input components most appropriate to it and the share each has of the total initial cost estimate. An index for the technology is then developed by summing the product of the inflation forecast of each input component and its percent of the total.

The composite index was developed using nine components. The components and their weightings were selected by DRI and accepted by EEA as representative of the material and labor inputs of the ISTUM technologies. The makeup and forecasts of the composite index are provided in Table 5-1. Table 5-1 shows that a facility costing \$100 million in 1977 is expected to cost 439.5 million in the year 2000. Had the GNP deflator been used to account for inflation, it would have predicted a cost of \$303.2 million. This is a difference of 45 percent which would unrealistically bias the results away from energy efficient equipment.

TABLE 5-1

COMPOSITE CAPITAL COST ESCALATION INDEXEXPECTED ECONOMY

	<u>1977</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>	<u>1995</u>	<u>2000</u>
COMPOSITE INDEX	1.00	1.231	1.792	2.413	3.253	4.395
GNP DEFLATOR	1.00	1.184	1.544	1.928	2.414	3.023
DEFLATED INDEX	1.00	1.039	1.161	1.252	1.348	1.454
 <u>COMPONENTS</u>						
STEEL MILL PRODUCTS (.20)	1.00	1.237	1.900	2.551	3.430	4.612
FABRICATED STRUCTURAL METAL PRODUCTS (.10)	1.00	1.232	1.827	2.367	3.064	3.967
CONSTRUCTION MACHINERY AND EQUIPMENT (.02)	1.00	1.249	1.909	2.567	3.451	4.640
GENERAL PURPOSE MACHINERY AND EQUIPMENT (.03)	1.00	1.218	1.746	2.260	2.926	3.788
ELECTRICAL MACHINERY AND EQUIPMENT (.15)	1.00	1.175	1.564	1.922	2.361	2.900
CONCRETE PRODUCTS (.10)	1.00	1.217	1.743	2.307	3.058	4.054
AVERAGE HOURLY EARNINGS FABRICATED PRODUCTS (.05)	1.00	1.242	1.784	2.430	3.314	4.519
AVERAGE HOURLY EARNINGS NON ELECTRICAL MACHINERY (.05)	1.00	1.252	1.809	2.495	3.434	4.727
AVERAGE HOURLY EARNINGS CONSTRUCTION, U.S. (.30)	1.00	1.253	1.835	2.606	3.689	5.223

The composite index was then compared to indexes developed for six ISTUM technologies. The technologies were selected by EEA as representing a large spectrum of material and labor inputs. The components and weightings were selected by EEA and expanded by DRI. Six additional components were added to the nine used to form the composite index. The technologies, components and their weightings are shown in Table 5-2. The composite index was compared with the six ISTUM technologies for the expected economic scenario and a more cyclical economic scenario.

Results

The GNP deflator is not capable of capturing inflation's impact on the capital costs of ISTUM technologies. Table 5-3 shows the forecasted values for the GNP deflator, the composite facility index, and the six ISTUM technologies. In 1980, the GNP deflator is underestimating costs from 3.8 to 5.3 percent. By the year 2000, the differences have grown and vary from 34 to 58.9 percent. Table 5-4 provides the same information under the cyclical economic scenario. The differences here are smaller because of more severe inflation in the non-capital goods areas included in the GNP deflator. However, the conclusion is the same. The GNP deflator underestimates inflation's impact on capital costs.

The composite index is a good, single approximation of inflation for the ISTUM technologies. Table 5-5 shows the percent difference between the composite index and the ISTUM technologies. In 1980 the difference ranges from -.2 to 1.3 percent. By the year 2000 the differences range from -7.8 to 9.3 percent. Table 5-6 shows the percent difference under a cyclical economic scenario. Under the cyclical economy, as expected, it becomes more difficult to capture inflation of many kinds of facilities with a single index. The differences in 1980 range from -.5 to 1.8 percent. In 1990, the differences vary from -3.3 to 6.6.

Chart 5-1 shows how the ISTUM technology indexes vary from the composite index over time. The chart brings out the distortions inflation contributes in a substitution analysis. Small differences keep compounding each year and eventually introduce significant biases. For example, in the year 2000, under the

TABLE 5-2

INFLATION IMPACT

Alternative Technology Input Specification
(Percent of Total Cost)

	<u>Materials and Labor</u>		<u>Technologies</u>				
	<u>Typical</u>	<u>Monobeam Reheat Furnace</u>	<u>Boiler Air/Fuel Controls</u>	<u>High Temperature Recuperators</u>	<u>High Temperature Heat Pumps</u>	<u>Refuse Powered Cement Kilns</u>	<u>Cogeneration (Steam Topping)</u>
Steel Mill Products	20	17	--	--	8	10	16
Fabricated Structural Metal Products	10	4	--	55	4	--	4
Structural Steel Shapes	--	14	--	--	--	15	12
Construction Machinery and Equipment	2	--	--	2	2	2	2
General Purpose Machinery and Equipment	3	--	--	--	--	20	--
Electric Motors	--	4	--	10	64	--	--
Electrical Machinery and Equipment	15	3	--	--	--	--	24
Switchgear, Switchboards, and Equipment	--	--	70	--	--	--	--
Electrical Instruments	--	--	--	--	4	--	3
Concrete Products	10	--	--	3	2	25	4
Refractories	--	28	--	--	--	--	6
Average Hourly Earnings - Fabricated Products	5	30	--	--	--	--	--
Average Hourly Earnings - Nonelectrical Machinery	5	--	--	--	--	--	--
Average Hourly Earnings - Construction, U.S.	30	--	15	30	16	28	29
Average Hourly Earnings - Electrical Machinery	0	--	15	--	--	--	--

TABLE 5-3

COST ESCALATION INDEXESEXPECTED ECONOMY

	<u>1977</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>	<u>1995</u>	<u>2000</u>
GNP DEFLATOR	1.00	1.184	1.544	1.928	2.414	3.023
COMPOSITE FACILITY	1.00	1.231 (3.93)	1.792 (16.10)	2.413 (25.16)	3.253 (34.76)	4.395 (45.40)
MONOBEAM REHEAT FURNACE	1.00	1.244 (5.08)	1.813 (17.42)	2.448 (27.00)	3.327 (37.81)	4.527 (49.77)
BOILER AIR/FUEL CONTROLS	1.00	1.229 (3.77)	1.725 (11.71)	2.276 (18.05)	3.035 (25.71)	4.051 (34.01)
HIGH TEMPERATURE RECUPERATORS	1.00	1.238 (4.59)	1.833 (18.76)	2.459 (27.55)	3.307 (37.00)	4.456 (47.40)
HIGH TEMPERATURE HEAT PUMPS	1.00	1.237 (4.48)	2.854 (20.10)	2.521 (30.74)	3.478 (44.07)	4.802 (58.87)
REFUSE POWERED CEMENT KILNS	1.00	1.246 (5.26)	1.832 (18.68)	2.472 (28.20)	3.346 (38.61)	4.536 (50.07)
COGENERATION (STEAM TOPPING)	1.00	1.234 (4.23)	1.782 (15.44)	2.378 (23.35)	3.190 (32.14)	4.291 (41.96)

Note: The number in parenthesis represents the percent difference from the GNP deflator.

TABLE 5-4

COST ESCALATION INDEXESCYCLICAL ECONOMY

	<u>1977</u>	<u>1980</u>	<u>1985</u>	<u>1990</u>
GNP DEFLATOR	1.00	1.210	1.799	2.723
COMPOSITE FACILITY	1.00	1.247 (3.08)	2.051 (14.05)	3.301 (21.23)
MONOBEAM REHEAT FURNACE	1.00	1.265 (4.54)	2.110 (17.33)	3.520 (29.25)
BOILER AIR/FUEL CONTROLS	1.00	1.251 (3.40)	1.982 (10.18)	3.193 (17.24)
HIGH TEMPERATURE RECUPERATORS	1.00	1.245 (2.90)	2.036 (13.22)	3.355 (23.20)
HIGH TEMPERATURE HEAT PUMPS	1.00	1.241 (2.52)	2.062 (14.67)	3.426 (25.82)
REFUSE POWERED CEMENT KILNS	1.00	1.269 (4.89)	2.122 (17.98)	3.504 (28.66)
COGENERATION (STEAM TOPPING)	1.00	1.252 (3.48)	2.050 (13.99)	3.299 (21.16)

TABLE 5-5

PERCENT VARIATION OF THE ISTUM TECHNOLOGY INDEXES AND THE COMPOSITE INDEXEXPECTED ECONOMY

	<u>1980</u>	<u>1985</u>	<u>1990</u>	<u>1995</u>	<u>2000</u>
MONOBEAM REHEAT FURNACE	1.103	1.139	1.469	2.262	3.004
BOILER AIR/FUEL CONTROLS	-0.159	-3.781	-5.683	-6.715	-7.832
HIGH TEMPERATURE RECUPERATORS	0.638	2.291	1.911	1.656	1.375
HIGH TEMPERATURE HEAT PUMPS	0.531	3.442	4.462	6.905	9.267
REFUSE POWERED CEMENT KILNS	1.278	2.221	2.428	2.855	3.213
COGENERATION (STEAM TOPPING)	0.289	-0.567	-1.443	-1.946	-2.366

TABLE 5-6

PERCENT VARIATION OF THE ISTUM TECHNOLOGY INDEXESAND THE COMPOSITE INDEXCYCLICAL ECONOMY

	<u>1980</u>	<u>1985</u>	<u>1990</u>
MONOBEAM REHEAT FURNACE	1.423	2.882	6.618
BOILER AIR/FUEL CONTROLS	.313	-3.393	-3.287
HIGH TEMPERATURE RECUPERATORS	-.174	-.723	1.627
HIGH TEMPERATURE HEAT PUMPS	-.537	.544	3.793
REFUSE POWERED CEMENT KILNS	1.756	3.451	6.132
COGENERATION (STEAM TOPPING)	.394	-0.054	-0.056

Note: The number in parenthesis is the percent variation from the GNP deflator.

expected economic scenario High Temperature Heat Pump capital costs are underestimated by 9.3 percent and Cogeneration capital costs are overestimated by 2.4 percent. Thus the analysis will introduce an 11.7 percent capital bias in the year 2000 favoring the substitution of high temperature heat pump technology for cogeneration technology. Chart 5-2 shows the same variation. However, the Boiler Air/Fuels Controls technology has been excluded.

Summary

The composite facility index is a good approximation of inflation's impact over the broad range of ISTUM technologies. It is a significant improvement over the more simplistic approach of using the GNP deflator to capture capital cost inflation. However, the composite index does not totally eliminate inflationary bias. Inflation can still cause distortions in substitution analysis. In the future, a more rigorous approach to capturing the effects of inflation should be utilized.

CHART 5-1

PERCENT VARIATION OF THE ISTUM TECHNOLOGIES AND THE COMPOSITE INDEX

MAXIMUM AND MINIMUM VALUES

EXPECTED ECONOMY (LINE) CYCLICAL ECONOMY (DOT)

PERCENT VARIATION

CHART 5-2

PERCENT VARIATION OF THE ISTUM TECHNOLOGIES AND THE COMPOSITE INDEX

(BOILER AIR/FUEL CONTROLS ELIMINATED)

EXPECTED ECONOMY (LINE) CYCLICAL ECONOMY (DOT)

MAXIMUM AND MINIMUM VALUES

CHAPTER 6: SUMMARY

Data Resources, in support of Energy and Environmental Analysis Inc., has provided a consistent economic framework in which to conduct the ISTUM analysis. Starting with long term political and economic assumptions as of the beginning of 1978, forecasts were produced to the year 2000, in the areas of industrial production, energy prices, energy demands and inflation. Through the use of the U.S. Macroeconomic Model, U.S. Annual Energy Model and Cost Forecasting Models, a consistent set of forecasts were produced.

DRI has also made it possible for ISTUM to incorporate an improved method of predicting capital stock turnover. Energy capital stock, investment, and retirement data were developed. The data allows ISTUM to use a vintaging approach in predicting capital stock retirement. In comparison with the proportional approach, the vintaging approach is better able to differentiate industry characteristics and incorporate historical information.

Finally, DRI's inflation effort has diminished the bias of inflation within ISTUM's comparative analysis. A composite inflation index was developed so that capital cost estimates for the ISTUM technologies could be adjusted for inflation before they were compared with energy prices.

DRI is pleased with the results of this effort and our contribution to the development of ISTUM technology. Nevertheless, the following suggestions are provided for future work. First, an effort should be made to feed back the results of the ISTUM analysis into the determination of energy prices and escalated facility costs. Such an effort would ensure that the one direction linkage used here was adequate. It would also allow the investigation of managements adjustment over time, to a changing economic/energy/technology picture. If confined to a few industries, such an investigation could provide new insights into how such information leads to capital investment decisions.

Secondly, more information is needed on the energy capital stock and in particular, how it changes through time. The absence of historical, time series information is a serious problem. It greatly hinders the testing of hypothetical models of how the energy capital stock is affected by environmental requirements, energy prices and availability, capital costs, and technological changes. A basic investigation is needed in order to determine the kind of information that should be maintained.

Finally, future studies should include a more rigorous incorporation of inflation. Distortions due to inflation have a debilitating effect on any long term substitution analysis. They begin to skew the results immediately by favoring the substitution of underinflated factors. In general, compounding causes errors to grow rapidly. Finally, inflation distortions prevent the comparison of previous investigations with today's results thereby diminishing our ability to phase out weak methodology. The capital cost inflation methodology used here is a simple, straightforward approach. It minimizes the distortions of inflation and requires only that the capital cost estimation include a component specification.

APPENDIX I

APPENDIX I

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INDUSTRY AND SERVICE SECTOR GROWTH RATE PROJECTIONS

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YEAR

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1974 1977 1980 1985 1990 1995 2000

INDUSTRY:

FRUITS AND VEGETABLES	1.240	1.378	1.559	1.846	2.069	2.289	2.533
GRAINS	1.240	1.378	1.559	1.846	2.069	2.289	2.533
OTHER FARM PRODUCTS	1.240	1.378	1.559	1.846	2.069	2.289	2.533
LIVESTOCK	1.240	1.378	1.559	1.846	2.069	2.289	2.533
FOOD	1.240	1.378	1.559	1.846	2.069	2.289	2.533
TOBACCO PRODUCTS	1.096	1.131	1.216	1.315	1.387	1.516	1.657
TEXTILE MILL PRODUCTS	1.326	1.374	1.614	1.972	2.345	2.729	3.177
APPAREL PRODUCTS	1.143	1.246	1.428	1.659	1.882	2.075	2.287
LUMBER AND PRODUCTS	1.161	1.339	1.609	1.822	1.983	2.139	2.307
FURNITURE AND FIXTURES	1.376	1.410	1.673	2.104	2.572	3.022	3.552
PAPER AND PRODUCTS	1.344	1.376	1.566	1.979	2.338	2.728	3.184
PRINTING AND PUBLISHING	1.182	1.245	1.409	1.717	2.015	2.330	2.695
CHEMICALS AND PRODUCTS	1.594	1.808	2.242	3.064	4.078	5.146	6.494
PETROLEUM PRODUCTS	1.248	1.417	1.537	1.738	1.939	2.144	2.372
RUBBER AND PLASTICS PRODUCTS	1.954	2.325	2.918	3.993	5.610	7.210	9.267
LEATHER AND PRODUCTS	0.780	0.751	0.785	0.781	0.722	0.595	0.490
32 STONE, CLAY & GLASS (GENERAL)	1.331	1.458	1.720	1.983	2.297	2.632	3.015
321 GLASS	1.331	1.458	1.720	1.983	2.297	2.632	3.015
322 GLASS	1.331	1.458	1.720	1.983	2.297	2.632	3.015
323 GLASS	1.331	1.458	1.720	1.983	2.297	2.632	3.015
324 OTHER STONE, CLAY & GLASS	1.331	1.458	1.720	1.983	2.297	2.632	3.015
325 BRICK AND CLAY	1.331	1.458	1.720	1.983	2.297	2.632	3.015
326 OTHER STONE, CLAY & GLASS	1.331	1.458	1.720	1.983	2.297	2.632	3.015
327 OTHER STONE, CLAY & GLASS	1.331	1.458	1.720	1.983	2.297	2.632	3.015
328 OTHER STONE, CLAY & GLASS	1.331	1.458	1.720	1.983	2.297	2.632	3.015
329 OTHER STONE, CLAY & GLASS	1.331	1.458	1.720	1.983	2.297	2.632	3.015

INDUSTRY AND SERVICE SECTOR GROWTH RATE PROJECTIONS

=====

YEAR

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1974 1977 1980 1985 1990 1995 2000

INDUSTRY:

PRIMARY MATERIALS	1.230	1.105	1.292	1.557	1.805	2.024	2.270
STEEL	1.217	1.022	1.173	1.380	1.562	1.724	1.903
332 OTHER PRIMARY METALS	1.129	1.089	1.254	1.464	1.680	1.881	2.097
333 OTHER PRIMARY METALS	1.286	1.219	1.456	1.841	2.196	2.506	2.859
3331 OTHER PRIMARY METALS	1.286	1.219	1.456	1.841	2.196	2.506	2.859
3332 OTHER PRIMARY METALS	1.286	1.219	1.456	1.841	2.196	2.506	2.859
3333 OTHER PRIMARY METALS	1.286	1.219	1.456	1.841	2.196	2.506	2.859
ALUMINUM	1.286	1.219	1.456	1.841	2.196	2.506	2.859
3339 OTHER PRIMARY METALS	1.286	1.219	1.456	1.841	2.196	2.506	2.859
334 OTHER PRIMARY METALS	1.230	1.105	1.292	1.557	1.805	2.024	2.270
335 OTHER PRIMARY METALS	1.230	1.105	1.292	1.557	1.805	2.024	2.270
336 OTHER PRIMARY METALS	1.230	1.105	1.292	1.557	1.805	2.024	2.270
339 OTHER PRIMARY METALS	1.230	1.105	1.292	1.557	1.805	2.024	2.270
FABRICATED METAL PRODUCTS	1.242	1.309	1.514	1.797	2.109	2.378	2.682
Nonelectrical Machinery	1.401	1.446	1.775	2.398	2.995	3.632	4.404
Electrical Machinery	1.438	1.418	1.756	2.529	3.333	4.140	5.143
TRANSPORTATION EQUIPMENT	1.088	1.212	1.370	1.643	1.946	2.220	2.533
INSTRUMENTS	1.441	1.586	1.926	2.651	3.384	4.079	4.917
MISCELLANEOUS MANUFACTURES	1.374	1.489	1.766	2.193	2.725	3.180	3.710
METAL MINING	1.153	1.179	1.343	1.586	1.802	1.999	2.217
NONMETAL MINING	1.153	1.179	1.343	1.586	1.802	1.999	2.217

PRICE OF FUELS NATIONALLY AND BY REGION
=====

IN DOLLARS PER MILLION BTUS
(DEFLATED BY GNP DEFLATOR)

	YEAR						
	1974	1977	1980	1985	1990	1995	2000
ELECTRICITY:							
NATIONAL	5.526	6.702	7.213	8.152	9.630	11.347	13.371
NEW ENGLAND	10.030	10.589	11.747	13.651	15.473	18.233	21.484
MID ATLANTIC	7.983	8.632	9.094	9.999	11.613	13.685	16.125
SOUTH ATLANTIC	6.194	7.612	8.179	8.850	10.392	12.245	14.429
EAST NORTH CENT	5.675	6.827	7.170	7.986	9.566	11.272	13.282
WEST NORTH CENT	5.780	7.318	7.354	7.636	8.553	10.078	11.875
EAST SOUTH CENT 1	3.671	4.675	4.886	5.330	6.431	7.578	8.930
EAST SOUTH CENT 2	4.690	6.471	6.082	7.007	8.716	10.270	12.101
WEST SOUTH CENT 1	3.999	6.515	7.812	9.227	9.051	10.665	12.567
WEST SOUTH CENT 2	4.333	6.096	7.600	8.834	10.061	11.855	13.969
MOUNTAIN 1	5.154	7.009	6.810	7.145	7.705	9.079	10.698
MOUNTAIN 2	3.117	4.559	5.649	5.961	7.282	8.581	10.111
MOUNTAIN 3	5.890	6.646	6.496	7.395	8.353	9.843	11.599
PACIFIC	4.105	5.254	5.552	7.191	9.131	10.759	12.678
NATURAL GAS:							
NATIONAL	0.823	1.727	2.255	2.860	3.250	3.683	4.174
NEW ENGLAND	2.043	2.729	3.169	4.115	5.401	6.120	6.936
MID ATLANTIC	1.194	2.312	2.940	3.638	4.708	5.336	6.047
SOUTH ATLANTIC	0.916	1.708	2.510	3.276	3.650	4.136	4.687
EAST NORTH CENT	0.983	1.921	2.524	3.168	3.382	3.832	4.343
WEST NORTH CENT	0.653	1.220	1.708	2.251	2.696	3.055	3.463
EAST SOUTH CENT 1	0.765	1.421	2.129	2.746	3.251	3.684	4.175
EAST SOUTH CENT 2	0.715	1.377	1.903	2.619	3.218	3.646	4.132
WEST SOUTH CENT 1	0.580	1.415	1.887	2.486	2.677	3.260	3.695
WEST SOUTH CENT 2	0.688	1.776	2.092	2.437	2.593	2.939	3.330
MOUNTAIN 1	0.605	1.270	1.659	2.225	2.599	2.945	3.338
MOUNTAIN 2	0.578	1.317	1.774	2.187	2.487	2.818	3.194
MOUNTAIN 3	0.772	1.470	2.049	3.189	3.806	4.313	4.888
PACIFIC	0.841	1.641	2.444	3.210	3.695	4.188	4.746

OFFICE OF FUELS NATIONALLY AND BY REGION

IN DOLLARS PER MILLION BTUS
(DEFLATED BY GNF DEFLATOR)

	YEAR						
	1974	1977	1980	1985	1990	1995	2000
DISTILLATE:							
NATIONAL	2.258	2.568	3.063	3.406	3.881	4.411	5.012
NEW ENGLAND	2.376	2.371	2.933	3.242	3.680	4.182	4.753
MID ATLANTIC	2.500	2.515	3.116	3.435	3.903	4.435	5.040
SOUTH ATLANTIC	2.104	2.324	2.874	3.180	3.609	4.101	4.661
EAST NORTH CENT	2.095	2.811	3.476	3.815	4.340	4.932	5.605
WEST NORTH CENT	1.734	2.114	2.615	2.906	3.294	3.743	4.254
EAST SOUTH CENT 1	2.513	2.377	2.929	3.249	3.688	4.192	4.763
EAST SOUTH CENT 2	2.289	2.212	2.736	3.034	3.441	3.910	4.444
WEST SOUTH CENT 1	1.859	2.223	2.749	3.048	3.457	3.928	4.464
WEST SOUTH CENT 2	2.260	2.358	2.917	3.225	3.660	4.160	4.727
MOUNTAIN 1	2.126	2.835	3.507	3.848	4.378	4.975	5.654
MOUNTAIN 2	2.243	2.667	3.299	3.628	4.125	4.688	5.327
MOUNTAIN 3	2.067	2.850	3.525	3.867	4.400	5.000	5.683
PACIFIC	2.119	2.997	3.707	4.058	4.621	5.251	5.967
RESIDUAL:							
NATIONAL	2.154	1.915	2.346	2.609	3.035	3.520	4.083
NEW ENGLAND	2.266	1.766	2.232	2.484	2.878	3.338	3.872
MID ATLANTIC	2.384	1.875	2.371	2.632	3.052	3.540	4.106
SOUTH ATLANTIC	2.006	1.733	2.187	2.436	2.822	3.273	3.797
EAST NORTH CENT	1.998	2.096	2.645	2.923	3.394	3.937	4.566
WEST NORTH CENT	1.653	1.576	1.990	2.227	2.575	2.987	3.465
EAST SOUTH CENT 1	2.356	1.772	2.237	2.489	2.884	3.345	3.880
EAST SOUTH CENT 2	2.183	1.645	2.082	2.325	2.691	3.121	3.620
WEST SOUTH CENT 1	1.773	1.657	2.092	2.335	2.703	3.135	3.637
WEST SOUTH CENT 2	2.156	1.758	2.219	2.471	2.862	3.320	3.851
MOUNTAIN 1	2.027	2.114	2.669	2.948	3.423	3.871	4.606
MOUNTAIN 2	2.139	1.935	2.510	2.780	3.225	3.741	4.340
MOUNTAIN 3	1.971	2.125	2.683	2.963	3.441	3.991	4.629
PACIFIC	2.020	2.235	2.821	3.109	3.613	4.191	4.861

OFFICE OF FUELS NATIONALLY AND BY REGION

IN DOLLARS PER MILLION BTUS
(DEFLATED BY GNP DEFLATOR)

	YEAR						
	1974	1977	1980	1985	1990	1995	2000
COAL:							
NATIONAL	0.755	0.577	1.047	1.199	1.436	1.716	2.050
NEW ENGLAND	1.267	1.370	1.462	1.655	1.956	2.337	2.792
MID ATLANTIC	0.963	1.120	1.223	1.456	1.802	2.153	2.573
SOUTH ATLANTIC	1.040	1.200	1.256	1.376	1.574	1.881	2.248
EAST NORTH CENT	0.782	0.960	1.036	1.194	1.438	1.718	2.053
WEST NORTH CENT	0.522	0.780	0.769	0.764	0.792	0.946	1.130
EAST SOUTH CENT 1	0.548	0.898	1.019	1.272	1.659	1.972	2.356
EAST SOUTH CENT 2	0.805	1.195	1.252	1.372	1.566	1.871	2.235
WEST SOUTH CENT 1	0.490	0.800	0.849	0.952	1.115	1.332	1.592
WEST SOUTH CENT 2	0.207	0.640	0.778	1.069	1.507	1.801	2.152
MOUNTAIN 1	0.221	0.400	0.470	0.623	0.864	1.032	1.234
MOUNTAIN 2	0.398	0.430	0.425	0.424	0.442	0.528	0.631
MOUNTAIN 3	0.418	0.480	0.591	0.850	1.277	1.525	1.823
PACIFIC	0.506	0.750	0.820	0.968	1.193	1.425	1.702

PRICE OF FUELS NATIONALLY AND BY REGION

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GROWTH AT COMPOUNDED ANNUAL RATES

(DEFLATED BY GNP DEFLATOR)

YEAR

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ELECTRICITY:

	74-77	77-80	80-85	85-90	90-95	95-2000
NATIONAL	6.64	2.48	2.48	3.39	3.34	3.34
NEW ENGLAND	1.83	3.52	3.05	2.54	3.34	3.34
MID ATLANTIC	2.64	1.75	1.92	3.04	3.34	3.34
SOUTH ATLANTIC	7.11	2.43	1.59	3.26	3.34	3.34
EAST NORTH CENT	6.35	1.65	2.18	3.68	3.34	3.34
WEST NORTH CENT	6.19	0.16	0.76	2.29	3.34	3.34
EAST SOUTH CENT 1	6.39	1.49	1.75	3.83	3.34	3.34
EAST SOUTH CENT 2	11.33	-2.05	2.87	4.46	3.34	3.34
WEST SOUTH CENT 1	17.66	6.24	3.39	-0.39	3.34	3.34
WEST SOUTH CENT 2	12.05	7.63	3.05	2.63	3.34	3.34
MOUNTAIN 1	10.79	-0.96	0.96	1.52	3.34	3.34
MOUNTAIN 2	13.51	7.67	0.94	4.09	3.34	3.34
MOUNTAIN 3	5.14	-1.73	2.63	2.47	3.34	3.34
PACIFIC	8.57	1.85	5.31	4.89	3.34	3.34

NATURAL GAS:

	74-77	77-80	80-85	85-90	90-95	95-2000
NATIONAL	28.02	9.30	4.87	2.59	2.53	2.53
NEW ENGLAND	10.13	5.12	5.36	5.59	2.53	2.53
MID ATLANTIC	24.64	8.35	4.36	5.29	2.53	2.53
SOUTH ATLANTIC	23.08	13.69	5.47	2.18	2.53	2.53
EAST NORTH CENT	25.02	9.52	4.65	1.31	2.53	2.53
WEST NORTH CENT	23.21	11.85	5.68	3.67	2.53	2.53
EAST SOUTH CENT 1	22.92	14.42	5.22	3.43	2.53	2.53
EAST SOUTH CENT 2	24.43	11.37	6.60	4.20	2.53	2.53
WEST SOUTH CENT 1	34.57	10.07	5.67	2.97	2.53	2.53
WEST SOUTH CENT 2	37.17	5.60	3.11	1.25	2.53	2.53
MOUNTAIN 1	28.05	9.33	6.04	3.16	2.53	2.53
MOUNTAIN 2	31.59	10.42	4.28	2.60	2.53	2.53
MOUNTAIN 3	23.91	11.72	9.25	3.60	2.53	2.53
PACIFIC	29.86	9.90	5.60	2.86	2.53	2.53

PRICE OF FUELS NATIONALLY AND BY REGION

=====

GROWTH AT COMPOUNDED ANNUAL RATES

(DEFLATED BY GNP DEFLATOR)

YEAR

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74-77 77-80 80-85 85-90 90-95 95-2000

DISTILLATE:

NATIONAL	4.37	6.29	2.01	2.65	2.59	2.59
NEW ENGLAND	-0.07	7.34	2.02	2.57	2.59	2.59
MID ATLANTIC	0.26	7.34	1.97	2.59	2.59	2.59
SOUTH ATLANTIC	3.37	7.34	2.04	2.56	2.59	2.59
EAST NORTH CENT	10.28	7.34	1.88	2.61	2.59	2.59
WEST NORTH CENT	6.83	7.34	2.14	2.53	2.59	2.59
EAST SOUTH CENT 1	-1.84	7.34	2.02	2.57	2.59	2.59
EAST SOUTH CENT 2	-1.14	7.34	2.09	2.55	2.59	2.59
WEST SOUTH CENT 1	6.13	7.34	2.09	2.55	2.59	2.59
WEST SOUTH CENT 2	1.42	7.34	2.03	2.57	2.59	2.59
MOUNTAIN 1	10.08	7.34	1.87	2.62	2.59	2.59
MOUNTAIN 2	5.94	7.34	1.92	2.60	2.59	2.59
MOUNTAIN 3	11.31	7.34	1.87	2.62	2.59	2.59
PACIFIC	12.26	7.34	1.83	2.63	2.59	2.59

RESIDUAL:

NATIONAL	-3.84	7.01	2.15	3.07	3.01	3.01
NEW ENGLAND	-7.93	8.07	2.16	2.99	3.01	3.01
MID ATLANTIC	-7.64	8.07	2.11	3.01	3.01	3.01
SOUTH ATLANTIC	-4.77	8.07	2.18	2.98	3.01	3.01
EAST NORTH CENT	1.60	8.07	2.02	3.03	3.01	3.01
WEST NORTH CENT	-1.58	8.07	2.28	2.95	3.01	3.01
EAST SOUTH CENT 1	-5.57	8.07	2.16	2.99	3.01	3.01
EAST SOUTH CENT 2	-6.52	8.07	2.23	2.97	3.01	3.01
WEST SOUTH CENT 1	-2.23	8.07	2.23	2.97	3.01	3.01
WEST SOUTH CENT 2	-6.56	8.07	2.17	2.99	3.01	3.01
MOUNTAIN 1	1.41	8.07	2.01	3.03	3.01	3.01
MOUNTAIN 2	-2.40	8.07	2.06	3.02	3.01	3.01
MOUNTAIN 3	2.55	8.07	2.01	3.04	3.01	3.01
PACIFIC	3.42	8.07	1.97	3.05	3.01	3.01

PRICE OF FUELS NATIONALLY AND BY REGION

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GROWTH AT COMPOUNDED ANNUAL RATES

(DEFLATED BY GNP DEFLATOR)

	YEAR					
	74-77	77-80	80-85	85-90	90-95	95-2000
COAL:						
NATIONAL	6.98	2.36	2.73	3.68	3.62	3.62
NEW ENGLAND	2.65	2.18	2.51	3.40	3.62	3.62
MID ATLANTIC	5.17	3.13	3.46	4.36	3.62	3.62
SOUTH ATLANTIC	4.89	1.52	1.85	2.73	3.62	3.62
EAST NORTH CENT	7.07	2.56	2.89	3.78	3.62	3.62
WEST NORTH CENT	14.34	-0.47	-0.14	0.72	3.62	3.62
EAST SOUTH CENT 1	17.88	4.30	4.53	5.35	3.62	3.62
EAST SOUTH CENT 2	14.09	1.58	1.85	2.67	3.62	3.62
WEST SOUTH CENT 1	17.73	1.99	2.32	3.21	3.62	3.62
WEST SOUTH CENT 2	45.80	6.71	6.56	7.12	3.62	3.62
MOUNTAIN 1	21.78	5.49	5.83	6.75	3.62	3.62
MOUNTAIN 2	2.61	-0.37	-0.05	0.82	3.62	3.62
MOUNTAIN 3	4.76	7.19	7.54	8.47	3.62	3.62
PACIFIC	14.02	3.03	3.37	4.26	3.62	3.62

DEMAND FOR FUELS NATIONALLY AND BY REGION
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IN TRILLION BTUS

	YEAR						
	1974	1977	1980	1985	1990	1995	2000
ELECTRICITY:							
NATIONAL	2,353.042	2,588.971	3,100.370	4,365.520	5,731.878	7,526.907	9,884.077
NEW ENGLAND	69.202	69.328	86.748	127.651	174.085	228.602	300.192
MID ATLANTIC	310.249	305.964	372.080	554.160	752.475	988.125	1,297.572
SOUTH ATLANTIC	324.293	357.832	410.551	564.101	736.045	966.550	1,269.240
EAST NORTH CENT	524.759	578.542	703.541	1,029.569	1,351.068	1,774.176	2,329.788
WEST NORTH CENT	128.824	143.565	191.352	316.980	468.613	615.366	808.078
EAST SOUTH CENT 1	218.900	259.423	298.177	401.389	520.276	683.209	897.167
EAST SOUTH CENT 2	101.509	111.216	134.253	186.182	233.284	306.340	402.275
WEST SOUTH CENT 1	22.058	27.972	31.753	38.245	50.707	66.587	87.439
WEST SOUTH CENT 2	262.361	315.330	356.352	449.971	571.440	750.396	985.394
MOUNTAIN 1	5.280	7.576	9.282	13.042	17.724	23.274	30.563
MOUNTAIN 2	63.652	72.378	83.941	104.959	162.273	213.091	279.824
MOUNTAIN 3	26.949	28.982	36.518	53.880	74.201	97.438	127.953
PACIFIC	295.006	310.863	385.823	525.391	619.687	813.752	1,068.591
NATURAL GAS:							
NATIONAL	7,426.200	5,921.000	6,577.768	7,333.510	8,315.678	9,431.396	10,696.811
NEW ENGLAND	58.853	55.583	23.365	60.312	87.204	98.904	112.174
MID ATLANTIC	522.989	387.698	513.268	503.620	647.747	734.655	833.224
SOUTH ATLANTIC	617.357	400.698	551.820	587.366	880.461	998.593	1,132.575
EAST NORTH CENT	1,563.694	1,214.032	1,178.749	917.335	866.924	983.240	1,115.161
WEST NORTH CENT	797.387	557.198	473.859	278.225	229.282	260.045	294.935
EAST SOUTH CENT 1	214.490	151.570	216.806	228.922	271.022	307.385	348.627
EAST SOUTH CENT 2	261.077	205.090	199.310	207.556	255.432	289.704	328.573
WEST SOUTH CENT 1	113.009	261.942	351.812	485.072	656.181	744.221	844.074
WEST SOUTH CENT 2	1,931.398	1,505.317	1,878.879	2,284.678	2,615.388	2,966.295	3,364.284
MOUNTAIN 1	81.792	93.387	94.034	105.014	134.442	152.480	172.939
MOUNTAIN 2	303.054	229.977	174.118	91.638	64.535	73.194	93.014
MOUNTAIN 3	131.361	90.050	84.295	153.571	210.254	238.464	270.459
PACIFIC	829.739	768.458	837.453	1,350.201	1,396.807	1,584.217	1,796.772

DEMAND FOR FUELS NATIONALLY AND BY REGION

IN TRILLION BTUS

	YEAR						
	1974	1977	1980	1985	1990	1995	2000
DISTILLATE:							
NATIONAL	735.700	925.381	875.918	706.536	355.363	178.755	89.918
NEW ENGLAND	59.755	71.677	65.416	52.353	26.566	13.363	6.722
MID ATLANTIC	83.502	110.119	108.060	89.347	45.810	23.044	11.591
SOUTH ATLANTIC	127.510	155.056	142.679	113.856	57.298	28.822	14.498
EAST NORTH CENT	90.768	117.302	114.772	93.549	46.891	23.587	11.865
WEST NORTH CENT	28.453	37.430	36.258	29.531	14.781	7.435	3.740
EAST SOUTH CENT 1	7.558	9.418	8.913	7.244	3.693	1.858	0.934
EAST SOUTH CENT 2	11.120	13.414	12.429	9.917	4.965	2.498	1.256
WEST SOUTH CENT 1	4.891	6.185	5.869	4.726	2.365	1.189	0.598
WEST SOUTH CENT 2	223.286	280.026	264.280	212.688	106.726	53.686	27.005
MOUNTAIN 1	2.207	2.776	2.628	2.120	1.066	0.536	0.270
MOUNTAIN 2	18.378	23.675	22.560	18.145	9.071	4.563	2.295
MOUNTAIN 3	3.297	4.266	4.129	3.342	1.672	0.841	0.423
PACIFIC	74.975	93.987	87.926	69.718	34.460	17.334	8.719
RESIDUAL:							
NATIONAL	1,219.700	1,483.258	1,458.711	1,148.949	791.126	544.778	375.140
NEW ENGLAND	59.066	114.888	108.941	85.135	59.142	40.726	28.044
MID ATLANTIC	138.436	176.506	179.958	145.293	101.985	70.228	48.360
SOUTH ATLANTIC	211.395	248.534	237.610	185.149	127.559	87.839	60.487
EAST NORTH CENT	150.482	188.618	191.135	152.127	104.390	71.884	49.500
WEST NORTH CENT	47.171	60.075	60.382	48.022	32.907	22.660	15.604
EAST SOUTH CENT 1	12.530	15.096	14.843	11.781	8.222	5.662	3.899
EAST SOUTH CENT 2	18.436	21.500	20.898	16.127	11.053	7.611	5.241
WEST SOUTH CENT 1	8.109	9.913	9.774	7.685	5.264	3.625	2.496
WEST SOUTH CENT 2	370.180	448.843	440.119	345.867	237.599	163.613	112.666
MOUNTAIN 1	3.660	4.450	4.377	3.447	2.374	1.635	1.126
MOUNTAIN 2	30.468	37.948	37.570	29.506	20.194	13.906	9.575
MOUNTAIN 3	5.466	6.838	6.377	5.435	3.721	2.563	1.765
PACIFIC	124.299	150.648	146.427	113.374	76.716	52.827	36.377

DEMAND FOR FUELS NATIONALLY AND BY REGION
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IN TRILLION BTUS

	YEAR						
	1974	1977	1980	1985	1990	1995	2000
COAL:							
NATIONAL	1,679.5000	1,593.7571	1,946.5476	2,604.2697	3,549.6251	4,838.2303	6,594.6322
NEW ENGLAND	1.680	3.188	3.893	5.209	7.099	9.676	13.189
MID ATLANTIC	214.976	204.001	249.158	333.347	454.352	619.293	844.113
SOUTH ATLANTIC	262.002	267.751	327.020	437.517	596.337	812.823	1,107.898
EAST NORTH CENT	648.237	691.691	844.802	1,130.253	1,540.537	2,099.792	2,862.070
WEST NORTH CENT	172.988	125.907	153.777	205.737	280.420	382.220	520.976
EAST SOUTH CENT 1	78.936	94.032	114.846	153.652	209.428	285.456	389.083
EAST SOUTH CENT 2	85.655	57.375	70.076	93.754	127.787	174.176	237.407
WEST SOUTH CENT 1	0.000	1.594	1.947	2.604	3.550	4.838	6.595
WEST SOUTH CENT 2	85.655	51.000	62.290	83.337	113.588	154.823	211.028
MOUNTAIN 2	58.782	55.781	68.129	91.149	124.237	169.338	230.812
MOUNTAIN 3	3.359	7.969	9.733	13.021	17.748	24.191	32.973
PACIFIC	67.180	31.875	38.931	52.085	70.993	96.765	131.893

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DEMAND FOR FUELS NATIONALLY AND BY REGION

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% GROWTH AT COMPOUND ANNUAL RATES

YEAR

=====

74-77 77-80 80-85 85-90 90-95 95-2000

ELECTRICITY:

NATIONAL	3.24	6.19	7.08	5.60	5.60	5.60
NEW ENGLAND	0.06	7.76	8.03	6.40	5.60	5.60
MID ATLANTIC	-0.46	6.74	8.29	6.31	5.60	5.60
SOUTH ATLANTIC	3.33	4.69	6.56	5.47	5.60	5.60
EAST NORTH CENT	3.31	6.74	7.91	5.59	5.60	5.60
WEST NORTH CENT	3.68	10.05	10.62	8.13	5.60	5.60
EAST SOUTH CENT 1	5.82	4.75	6.13	5.33	5.60	5.60
EAST SOUTH CENT 2	3.09	6.48	6.76	4.61	5.60	5.60
WEST SOUTH CENT 1	8.24	4.32	3.79	5.80	5.60	5.60
WEST SOUTH CENT 2	6.32	4.16	4.78	4.90	5.60	5.60
MOUNTAIN 1	12.79	7.00	7.04	6.33	5.60	5.60
MOUNTAIN 2	4.38	5.06	4.57	9.11	5.60	5.60
MOUNTAIN 3	2.45	8.01	8.09	6.61	5.60	5.60
PACIFIC	1.76	7.47	6.37	3.36	5.60	5.60

NATURAL GAS:

NATIONAL	-7.27	3.57	2.20	2.55	2.55	2.55
NEW ENGLAND	-1.89	-25.09	20.88	7.65	2.55	2.55
MID ATLANTIC	-9.50	9.80	2.60	2.11	2.55	2.55
SOUTH ATLANTIC	-13.42	11.26	1.26	8.43	2.55	2.55
EAST NORTH CENT	-8.09	-0.98	-4.89	-1.12	2.55	2.55
WEST NORTH CENT	-11.26	-5.26	-10.10	-3.80	2.55	2.55
EAST SOUTH CENT 1	-10.93	12.67	1.09	3.43	2.55	2.55
EAST SOUTH CENT 2	-7.73	-0.95	0.81	4.24	2.55	2.55
WEST SOUTH CENT 1	12.34	10.33	6.63	6.23	2.55	2.55
WEST SOUTH CENT 2	-7.97	7.67	3.99	2.74	2.55	2.55
MOUNTAIN 1	4.52	0.23	2.23	5.06	2.55	2.55
MOUNTAIN 2	-8.79	-8.86	-12.05	-6.77	2.55	2.55
MOUNTAIN 3	-11.83	-2.18	12.75	6.48	2.55	2.55
PACIFIC	-2.53	2.91	10.02	0.68	2.55	2.55

DEMAND FOR FUELS NATIONALLY AND BY REGION

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X 1000TH AT COMPOUND ANNUAL RATES

YEAR

=====

74-77 77-80 80-85 85-90 90-95 95-2000

DISTILLATE:

NATIONAL	7.95	-1.81	-4.21	-12.84	-12.84	-12.84
NEW ENGLAND	6.25	-3.00	-4.36	-12.69	-12.84	-12.84
MID ATLANTIC	5.66	-0.63	-3.73	-12.51	-12.84	-12.84
SOUTH ATLANTIC	6.74	-2.74	-4.41	-12.83	-12.84	-12.84
EAST NORTH CENT	8.92	-0.72	-4.01	-12.90	-12.84	-12.84
WEST NORTH CENT	5.62	-1.10	-4.02	-12.93	-12.84	-12.84
EAST SOUTH CENT 1	7.61	-1.82	-4.06	-12.61	-12.84	-12.84
EAST SOUTH CENT 2	6.45	-2.51	-4.41	-12.92	-12.84	-12.84
WEST SOUTH CENT 1	6.13	-1.73	-4.24	-12.93	-12.84	-12.84
WEST SOUTH CENT 2	7.84	-1.91	-4.25	-12.88	-12.84	-12.84
MOUNTAIN 1	7.95	-1.81	-4.21	-12.84	-12.84	-12.84
MOUNTAIN 2	6.81	-1.60	-4.26	-12.95	-12.84	-12.84
MOUNTAIN 3	6.97	-1.08	-4.14	-12.94	-12.84	-12.84
PACIFIC	7.82	-2.20	-4.53	-13.15	-12.84	-12.84

RESIDUAL:

NATIONAL	6.74	-0.55	-4.66	-7.19	-7.19	-7.19
NEW ENGLAND	5.06	-1.76	-4.81	-7.03	-7.19	-7.19
MID ATLANTIC	6.44	0.65	-4.19	-6.83	-7.19	-7.19
SOUTH ATLANTIC	5.54	-1.49	-4.87	-7.18	-7.19	-7.19
EAST NORTH CENT	7.71	0.55	-4.46	-7.25	-7.19	-7.19
WEST NORTH CENT	6.39	0.17	-4.48	-7.28	-7.19	-7.19
EAST SOUTH CENT 1	6.40	-0.56	-4.52	-6.94	-7.19	-7.19
EAST SOUTH CENT 2	5.26	-1.26	-4.87	-7.28	-7.19	-7.19
WEST SOUTH CENT 1	6.92	-0.47	-4.69	-7.29	-7.19	-7.19
WEST SOUTH CENT 2	6.63	-0.65	-4.71	-7.23	-7.19	-7.19
MOUNTAIN 1	6.74	-0.55	-4.66	-7.19	-7.19	-7.19
MOUNTAIN 2	7.59	-0.33	-4.72	-7.30	-7.19	-7.19
MOUNTAIN 3	7.75	0.19	-4.60	-7.30	-7.19	-7.19
PACIFIC	6.62	-0.94	-4.99	-7.51	-7.19	-7.19

DEMAND FOR FUELS NATIONALLY AND BY REGION

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2 GROWTH AT COMPOUND ANNUAL RATES

YEAR

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74-77 77-80 80-85 85-90 90-95 95-2000

COAL:

NATIONAL	-1.73	6.89	5.99	6.39	6.39	6.39
NEW ENGLAND	23.81	6.89	5.99	6.39	6.39	6.39
MID ATLANTIC	-1.73	6.89	5.99	6.39	6.39	6.39
SOUTH ATLANTIC	0.73	6.89	5.99	6.39	6.39	6.39
EAST NORTH CENT	2.18	6.89	5.99	6.39	6.39	6.39
WEST NORTH CENT	-10.05	6.89	5.99	6.39	6.39	6.39
EAST SOUTH CENT 1	6.01	6.89	5.99	6.39	6.39	6.39
EAST SOUTH CENT 2	-12.50	6.89	5.99	6.39	6.39	6.39
WEST SOUTH CENT 1	NC	6.89	5.99	6.39	6.39	6.39
WEST SOUTH CENT 2	-15.87	6.89	5.99	6.39	6.39	6.39
MOUNTAIN 2	-1.73	6.89	5.99	6.39	6.39	6.39
MOUNTAIN 3	23.37	6.89	5.99	6.39	6.39	6.39
PACIFIC	-22.00	6.89	5.99	6.39	6.39	6.39

INFLATION INDEX FORECASTS
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EXPECTED ECONOMY
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	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
GNP DEFLATOR %	1.000 5.6	1.061 6.1	1.120 5.6	1.184 5.7	1.255 6.0	1.326 5.6	1.400 5.6	1.472 5.2	1.544 4.9	1.616 4.7	1.691 4.6	1.768 4.6	1.848 4.5	1.928 4.4
COMPOSITE FACILITY %	1.000 6.5	1.073 7.3	1.146 6.8	1.231 7.4	1.331 8.2	1.426 7.1	1.537 7.8	1.658 7.9	1.792 8.1	1.914 6.8	2.037 6.4	2.165 6.3	2.286 5.6	2.413 5.5
MONOBRAZ REHEAT FURNACE %	1.000 7.0	1.081 8.1	1.156 6.9	1.244 7.7	1.344 8.0	1.440 7.1	1.556 8.1	1.681 8.1	1.813 7.8	1.936 6.8	2.062 6.5	2.195 6.5	2.322 5.8	2.448 5.4
BOILER AIR/FUEL CONTROLS %	1.000 6.5	1.072 7.2	1.150 7.2	1.229 6.9	1.320 7.4	1.403 6.4	1.503 7.1	1.610 7.1	1.725 7.1	1.833 6.3	1.943 6.0	2.057 5.8	2.164 5.2	2.276 5.2
HIGH TEMPERATURE RECUPERATORS %	1.000 6.2	1.074 7.4	1.150 7.0	1.238 7.7	1.344 8.5	1.442 7.3	1.562 8.3	1.691 8.3	1.833 8.4	1.958 6.8	2.085 6.5	2.215 6.2	2.334 5.4	2.459 5.4
HIGH TEMPERATURE HEAT PUMPS %	1.000 6.8	1.071 7.1	1.151 7.5	1.237 7.5	1.342 8.5	1.441 7.4	1.562 8.4	1.702 8.9	1.854 9.0	1.989 7.3	2.122 6.7	2.261 6.6	2.387 5.6	2.521 5.6
REFUSE POWERED CEMENT KILNS %	1.000 6.0	1.072 7.2	1.153 7.5	1.246 8.1	1.350 8.3	1.449 7.4	1.571 8.4	1.698 8.1	1.832 7.9	1.958 6.9	2.084 6.5	2.218 6.4	2.345 5.7	2.472 5.4
COGENERATION (STEAM TOPPING) %	1.000 6.1	1.076 7.6	1.149 6.8	1.234 7.4	1.332 7.9	1.423 6.8	1.533 7.7	1.654 7.9	1.782 7.7	1.898 6.5	2.018 6.3	2.144 6.2	2.261 5.4	2.378 5.2

INFLATION INDEX FORECASTS
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EXPECTED ECONOMY
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	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
GNP DEFLATOR %	2.017 4.6	2.109 4.6	2.206 4.6	2.308 4.6	2.414 4.6	2.525 4.6	2.641 4.6	2.763 4.6	2.890 4.6	3.023 4.6
COMPOSITE FACILITY %	2.561 6.1	2.719 6.1	2.886 6.2	3.064 6.2	3.253 6.2	3.455 6.2	3.668 6.2	3.896 6.2	4.138 6.2	4.395 6.2
MONOBFAM REHEAT FURNACE %	2.603 6.3	2.767 6.3	2.942 6.3	3.129 6.3	3.327 6.3	3.538 6.3	3.763 6.3	4.002 6.4	4.256 6.4	4.527 6.4
BOILER AIR/FUEL CONTROLS %	2.411 5.9	2.553 5.9	2.705 5.9	2.865 5.9	3.035 5.9	3.215 5.9	3.406 5.9	3.609 5.9	3.823 5.9	4.051 6.0
HIGH TEMPERATURE RECUPERATORS %	2.609 6.1	2.768 6.1	2.937 6.1	3.116 6.1	3.307 6.1	3.510 6.1	3.725 6.1	3.954 6.1	4.197 6.1	4.456 6.2
HIGH TEMPERATURE HEAT PUMPS %	2.688 6.6	2.867 6.6	3.057 6.7	3.261 6.7	3.478 6.7	3.710 6.7	3.957 6.7	4.221 6.7	4.502 6.7	4.802 6.7
REFUSE POWERED CEMENT KILNS %	2.626 6.2	2.790 6.2	2.964 6.2	3.149 6.3	3.346 6.3	3.556 6.3	3.779 6.3	4.016 6.3	4.268 6.3	4.536 6.3
COGENERATION (STEAM TOPPING) %	2.521 6.0	2.674 6.0	2.835 6.0	3.007 6.1	3.190 6.1	3.384 6.1	3.591 6.1	3.810 6.1	4.043 6.1	4.291 6.1

INFLATION INDEX FORECASTS

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CYCLICAL ECONOMY

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	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
GNP DEFLATOR %	1.000 5.6	1.066 6.6	1.135 6.5	1.210 6.6	1.303 7.7	1.421 9.0	1.546 8.8	1.658 7.2	1.799 8.5	1.996 11.0	2.188 9.6	2.344 7.1	2.522 7.6	2.723 8.0
COMPOSITE FACILITY %	1.000 6.5	1.076 7.6	1.156 7.4	1.247 7.9	1.369 9.8	1.538 12.4	1.703 10.7	1.855 8.9	2.051 10.6	2.323 13.3	2.546 9.6	2.763 8.5	3.037 9.9	3.301 8.7
MONOBEAM REHEAT FURNACE %	1.000 7.0	1.083 8.3	1.165 7.5	1.265 8.6	1.387 9.6	1.544 11.4	1.722 11.5	1.903 10.5	2.110 10.9	2.379 12.8	2.643 11.1	2.910 10.1	3.224 10.8	3.520 9.2
BOILER AIR/FUEL CONTROLS %	1.000 6.5	1.075 7.5	1.158 7.8	1.251 8.1	1.362 8.9	1.502 10.2	1.661 10.6	1.810 8.9	1.982 9.5	2.231 12.6	2.477 11.0	2.711 9.4	2.931 8.1	3.193 8.9
HIGH TEMPERATURE RECIPIRATORS %	1.000 6.2	1.076 7.6	1.156 7.4	1.245 7.7	1.369 9.9	1.552 13.4	1.723 11.0	1.847 7.2	2.036 10.3	2.328 14.3	2.545 9.3	2.768 8.8	3.066 10.8	3.355 9.4
HIGH TEMPERATURE HEAT PUMPS %	1.000 6.8	1.072 7.2	1.154 7.6	1.241 7.5	1.359 9.6	1.542 13.4	1.723 11.7	1.864 8.2	2.062 10.7	2.389 15.8	2.649 10.9	2.849 7.6	3.094 8.6	3.426 10.7
REFUSE POWERED CEMENT KILNS %	1.000 6.0	1.075 7.5	1.154 8.2	1.269 9.1	1.395 9.9	1.558 11.7	1.742 11.8	1.919 10.2	2.122 10.6	2.391 12.7	2.652 10.9	2.913 9.8	3.206 10.1	3.504 9.3
COGENERATION (STEAM TOPPING) %	1.000 6.1	1.078 7.8	1.157 7.4	1.252 8.2	1.372 9.5	1.526 11.2	1.688 10.6	1.851 9.6	2.050 10.7	2.306 12.5	2.533 9.8	2.764 9.1	3.044 10.1	3.299 8.4

VI-1.17

INFLATION COMPONENT FORECASTS - EXPECTED ECONOMY

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
STEEL MILL PRODUCTS														
WPI1013NS	1.000	1.078	1.148	1.237	1.354	1.449	1.572	1.719	1.900	2.039	2.177	2.319	2.435	2.551
%	9.6	7.8	6.5	7.7	9.5	7.0	8.4	9.4	10.5	7.3	6.8	6.5	5.0	4.8
FABRICATED STRUCTURAL METAL PRODUCTS - WPI107NS	1.000	1.073	1.145	1.232	1.339	1.429	1.551	1.681	1.827	1.942	2.059	2.174	2.268	2.367
%	6.7	7.3	6.6	7.6	8.7	6.7	8.5	8.4	8.7	6.3	6.0	5.6	4.3	4.4
STRUCTURAL STEEL SHAPES														
WPI10130248NS	1.000	1.104	1.199	1.330	1.457	1.568	1.739	1.923	2.083	2.229	2.394	2.577	2.721	2.835
%	6.2	10.4	8.6	10.9	9.6	7.6	10.9	10.6	8.3	7.0	7.4	7.7	5.6	4.2
CONSTRUCTION MACHINERY AND EQUIPMENT - WPI112NS	1.000	1.073	1.155	1.249	1.381	1.520	1.654	1.768	1.909	2.036	2.158	2.290	2.423	2.567
%	7.7	7.3	7.6	8.2	10.5	10.1	8.8	6.9	8.0	6.7	6.0	6.1	5.8	5.9
GENERAL PURPOSE MACHINERY AND EQUIPMENT - WPI113NS	1.000	1.066	1.140	1.218	1.312	1.396	1.503	1.623	1.746	1.853	1.956	2.058	2.155	2.260
%	6.2	6.6	6.9	6.9	7.7	6.3	7.7	8.0	7.6	6.1	5.5	5.2	4.7	4.9
ELECTRIC MOTORS														
WPI11730INS	1.000	1.067	1.149	1.235	1.342	1.440	1.566	1.715	1.876	2.015	2.151	2.293	2.418	2.551
%	7.2	6.7	7.7	7.5	8.6	7.3	8.7	9.5	9.4	7.4	6.8	6.6	5.4	5.5
ELECTRICAL MACHINERY AND EQUIPMENT - WPI117NS	1.000	1.057	1.114	1.175	1.250	1.311	1.386	1.475	1.564	1.637	1.712	1.797	1.851	1.922
%	5.0	5.7	5.4	5.4	6.4	4.9	5.7	6.4	6.0	4.7	4.6	4.4	3.6	3.8
SWITCHGEAR, SWITCHBOARDS, AND EQUIPMENT - WPI1175NS	1.000	1.066	1.143	1.219	1.308	1.384	1.480	1.582	1.694	1.795	1.896	1.999	2.090	2.186
%	6.4	6.6	7.2	6.7	7.3	5.8	6.9	6.9	7.1	6.0	5.6	5.4	4.6	4.6
ELECTRICAL INSTRUMENTS														
WPI11720INS	1.000	1.083	1.157	1.215	1.277	1.334	1.396	1.462	1.539	1.608	1.670	1.739	1.805	1.866
%	4.1	8.3	6.9	5.0	5.1	4.5	4.6	4.8	5.2	4.5	3.9	4.2	3.8	3.3
CONCRETE PRODUCTS														
WPI1133NS	1.000	1.048	1.129	1.217	1.312	1.407	1.515	1.618	1.743	1.861	1.967	2.081	2.195	2.307
%	6.4	4.8	7.8	7.8	7.8	7.2	7.7	6.8	7.7	6.8	5.7	5.8	5.5	5.1
REFRACTORIES														
WPI1135NS	1.000	1.076	1.137	1.203	1.276	1.354	1.439	1.523	1.607	1.694	1.777	1.863	1.962	2.060
%	8.5	7.6	5.7	5.8	6.1	6.1	6.3	5.8	5.6	5.4	4.9	4.8	5.3	5.0
AVERAGE HOURLY EARNINGS														
FABRICATED PRODUCTS - AHE34NS	1.000	1.082	1.157	1.242	1.338	1.440	1.551	1.665	1.784	1.908	2.033	2.160	2.292	2.430
%	7.1	8.2	6.9	7.4	7.7	7.6	7.7	7.4	7.2	6.9	6.5	6.3	6.1	6.0
AVERAGE HOURLY EARNINGS														
NON-ELECTRICAL MACHINERY - AHE35NS	1.000	1.089	1.166	1.252	1.351	1.455	1.568	1.686	1.809	1.938	2.069	2.203	2.344	2.495
%	7.7	8.9	7.0	7.4	7.9	7.7	7.8	7.6	7.3	7.1	6.8	6.5	6.4	6.4
AVERAGE HOURLY EARNINGS														
CONSTRUCTION, U.S. - AHECNS	1.000	1.081	1.161	1.253	1.354	1.464	1.580	1.705	1.835	1.974	2.119	2.273	2.435	2.606
%	4.8	8.1	7.4	7.9	8.1	8.1	7.9	7.9	7.7	7.5	7.4	7.2	7.1	7.0
AVERAGE HOURLY EARNINGS														
ELECTRICAL MACHINERY - AHE36NS	1.000	1.091	1.171	1.250	1.340	1.434	1.534	1.642	1.757	1.872	1.989	2.112	2.237	2.367
%	8.7	9.1	7.3	6.7	7.3	7.0	6.9	7.1	7.0	6.6	6.3	6.2	5.9	5.8

INFLATION COMPONENT FORECASTS - EXPECTED ECONOMY
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	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
STEEL MILL PRODUCTS										
WPI1013NS	2,707	2,872	3,047	3,233	3,430	3,640	3,862	4,097	4,347	4,612
%	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1
FABRICATED STRUCTURAL METAL PRODUCTS - WPI107NS	2,492	2,624	2,763	2,910	3,064	3,226	3,397	3,577	3,767	3,967
%	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
STRUCTURAL STEEL SHAPES										
WPI1013024BNS	3,025	3,228	3,444	3,675	3,921	4,184	4,464	4,763	5,082	5,423
%	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7	6.7
CONSTRUCTION MACHINERY AND EQUIPMENT - WPI112NS	2,723	2,890	3,066	3,253	3,451	3,662	3,885	4,122	4,374	4,640
%	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1	6.1
GENERAL PURPOSE MACHINERY AND EQUIPMENT - WPI114NS	2,380	2,506	2,639	2,779	2,926	3,081	3,244	3,416	3,597	3,788
%	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3	5.3
ELECTRIC MOTORS										
WPI11730INS	2,725	2,910	3,108	3,319	3,545	3,786	4,044	4,319	4,612	4,926
%	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8	6.8
ELECTRICAL MACHINERY AND EQUIPMENT - WPI117NS	2,003	2,087	2,174	2,266	2,361	2,460	2,563	2,671	2,783	2,900
%	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
SWITCHGEAR, SWITCHBOARDS, AND EQUIPMENT - WPI1175NS	2,306	2,433	2,567	2,708	2,857	3,014	3,179	3,354	3,539	3,733
%	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5	5.5
ELECTRICAL INSTRUMENTS										
WPI11720INS	1,944	2,026	2,111	2,199	2,292	2,388	2,488	2,593	2,702	2,815
%	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2	4.2
CONCRETE PRODUCTS										
WPI133NS	2,440	2,582	2,732	2,890	3,058	3,235	3,423	3,621	3,831	4,054
%	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8	5.8
REFRACTORIES										
WPI135NS	2,167	2,279	2,398	2,522	2,654	2,792	2,937	3,090	3,250	3,419
%	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2	5.2
AVERAGE HOURLY EARNINGS FABRICATED PRODUCTS - AHE34NS	2,585	2,751	2,927	3,114	3,314	3,526	3,751	3,991	4,247	4,519
%	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4	6.4
AVERAGE HOURLY EARNINGS NON-ELECTRICAL MACHINERY - AHE35NS	2,659	2,835	3,022	3,221	3,434	3,660	3,902	4,160	4,434	4,727
%	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6	6.6
AVERAGE HOURLY EARNINGS CONSTRUCTION, U.S. - AHECNS	2,794	2,995	3,210	3,441	3,689	3,955	4,240	4,545	4,872	5,223
%	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2	7.2
AVERAGE HOURLY EARNINGS ELECTRICAL MACHINERY - AHE36NS	2,516	2,674	2,843	3,022	3,212	3,415	3,630	3,859	4,102	4,360
%	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3

INFLATION COMPONENT FORECASTS - CYCLICAL ECONOMY

	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
STEEL MILL PRODUCTS														
WPI10134S	1.000	1.079	1.147	1.230	1.369	1.591	1.769	1.942	2.198	2.569	2.770	2.960	3.326	3.542
%	9.6	7.9	6.3	7.2	11.3	16.2	11.2	9.8	13.2	16.9	7.8	6.4	12.4	6.5
FABRICATED STRUCTURAL METAL PRODUCTS - WPI107NS														
WPI107NS	1.000	1.075	1.147	1.228	1.355	1.559	1.727	1.819	2.011	2.330	2.506	2.710	3.036	3.301
%	6.7	7.5	6.7	7.0	10.3	15.1	10.8	5.3	10.5	15.9	7.5	8.1	12.1	8.7
STRUCTURAL STEEL SHAPES WPI10130248NS														
WPI10130248NS	1.000	1.105	1.208	1.366	1.530	1.687	1.917	2.240	2.572	2.871	3.223	3.723	4.244	4.678
%	6.2	10.5	9.3	13.1	12.1	10.2	13.6	16.9	14.8	11.6	12.3	15.5	15.4	8.9
CONSTRUCTION MACHINERY AND EQUIPMENT - WPI112NS														
WPI112NS	1.000	1.077	1.161	1.254	1.399	1.609	1.841	1.993	2.157	2.419	2.678	2.926	3.124	3.426
%	7.7	7.7	7.8	8.5	11.1	15.0	14.4	8.2	8.2	12.2	10.7	9.3	6.8	9.7
GENERAL PURPOSE MACHINERY AND EQUIPMENT - WPI114NS														
WPI114NS	1.000	1.070	1.148	1.233	1.351	1.522	1.689	1.835	2.020	2.315	2.537	2.727	2.944	3.251
%	6.2	7.0	7.3	7.4	9.6	12.6	10.9	8.7	10.0	14.6	9.6	7.5	8.0	10.4
ELECTRIC MOTORS WPI11730INS														
WPI11730INS	1.000	1.068	1.149	1.230	1.346	1.536	1.725	1.857	2.056	2.416	2.694	2.878	3.102	3.476
%	7.2	6.8	7.6	7.0	9.4	14.2	12.3	7.7	10.7	17.5	11.5	6.8	7.8	12.1
ELECTRICAL MACHINERY AND EQUIPMENT - WPI117NS														
WPI117NS	1.000	1.059	1.121	1.182	1.271	1.397	1.508	1.591	1.726	1.933	2.067	2.166	2.290	2.454
%	5.0	5.9	5.9	5.4	7.6	9.9	7.9	5.5	8.5	11.9	7.0	4.8	5.7	7.2
SWITCHGEAR, SWITCHBOARDS, AND EQUIPMENT - WPI1175NS														
WPI1175NS	1.000	1.068	1.147	1.238	1.346	1.484	1.643	1.785	1.953	2.213	2.458	2.685	2.889	3.138
%	6.4	6.8	7.5	7.9	8.8	10.3	10.7	8.7	9.4	13.3	11.0	9.3	7.6	8.6
ELECTRICAL INSTRUMENTS WPI11720INS														
WPI11720INS	1.000	1.083	1.164	1.270	1.384	1.483	1.596	1.722	1.886	2.073	2.224	2.374	2.534	2.659
%	4.1	8.3	7.4	9.1	9.0	7.1	7.6	7.9	9.6	9.9	7.3	6.8	6.7	4.9
CONCRETE PRODUCTS WPI113NS														
WPI113NS	1.000	1.051	1.143	1.245	1.359	1.521	1.715	1.870	2.034	2.297	2.566	2.749	2.936	3.174
%	6.4	5.1	8.7	9.0	9.1	11.9	12.7	9.0	8.8	12.9	11.7	7.1	6.8	8.1
REFRACTORIES WPI115NS														
WPI115NS	1.000	1.078	1.149	1.233	1.326	1.453	1.622	1.771	1.916	2.140	2.415	2.633	2.840	3.127
%	8.5	7.8	6.6	7.3	7.5	9.6	11.6	9.2	8.2	11.7	12.9	9.0	7.9	10.1
AVERAGE HOURLY EARNINGS FABRICATED PRODUCTS - AHE34NS														
AHE34NS	1.000	1.092	1.187	1.302	1.447	1.619	1.794	2.003	2.245	2.518	2.747	3.128	3.478	3.666
%	7.1	9.2	8.7	9.7	11.1	11.9	10.9	11.6	12.1	12.2	11.1	11.8	11.2	11.2
AVERAGE HOURLY EARNINGS NONELECTRICAL MACHINERY - AHE35NS														
AHE35NS	1.000	1.099	1.194	1.306	1.447	1.619	1.791	1.990	2.226	2.503	2.765	3.077	3.413	3.795
%	7.7	9.9	8.6	9.4	10.8	11.9	10.6	11.1	11.8	12.5	10.5	11.3	10.9	11.2
AVERAGE HOURLY EARNINGS CONSTRUCTION, U.S. - AHECNS														
AHECNS	1.000	1.085	1.176	1.281	1.401	1.543	1.707	1.881	2.069	2.293	2.556	2.831	3.118	3.426
%	4.8	8.5	8.4	9.0	9.3	10.2	10.6	10.2	10.0	10.8	11.4	10.8	10.1	9.9
AVERAGE HOURLY EARNINGS ELECTRICAL MACHINERY - AHE36NS														
AHE36NS	1.000	1.098	1.191	1.286	1.400	1.544	1.701	1.853	2.028	2.253	2.488	2.707	2.941	3.214
%	8.7	9.8	8.5	8.0	8.9	10.3	10.1	9.0	9.4	11.1	10.4	8.8	8.6	9.3

ENERGY INVESTMENT - TRILLION DOLLARS - BY SIC

SIC	71 to 75	66 to 70	61 to 65	56 to 60	51 to 55	46 to 50	41 to 45	36 to 40	31 to 35	26 to 30
SIC 20	236.404000	209.345883	167.467609	143.543870	130.243087	254.084920	60.463661	110.551673	95.842656	189.702660
SIC 21	3.022000	2.512400	2.737531	4.007556	2.426222	4.043324	0.619715	1.400886	0.504373	1.695096
SIC 22	72.893675	77.650639	42.741592	26.151988	37.462666	65.567316	14.169771	16.261596	12.934129	30.347678
SIC 23	11.233591	14.815315	7.456326	5.644231	4.998074	7.872842	3.411831	2.595832	2.006020	3.265055
SIC 24	79.020000	39.367733	45.752073	42.308700	41.761665	55.660576	13.045956	12.074940	7.446171	54.770456
SIC 25	25.103000	9.887128	6.668056	5.457202	4.138153	7.583581	1.361755	2.160570	0.747452	2.231557
SIC 25	331.997564	349.018363	232.621554	259.662214	186.466261	221.931203	75.292017	59.374250	20.604861	134.674142
SIC 27	30.309000	20.502128	14.065455	13.391652	8.810422	13.252073	13.166517	16.092961	12.044517	62.227801
SIC 28	1,037.782970	808.746514	543.899272	447.781244	462.547689	501.160947	214.690496	158.530324	33.383659	40.576373
SIC 29	389.399804	322.429852	244.124987	364.284394	307.000504	326.533852	110.052651	225.880354	94.873057	306.868628
SIC 30	64.624124	75.223854	38.514708	25.276271	21.076301	25.745947	8.006593	5.236192	2.961574	14.847052
SIC 31	4.262000	7.243148	3.589228	3.241784	3.350235	6.600763	3.178710	4.118212	3.604686	9.479504
SIC 32	274.204574	260.054647	236.980224	340.844732	216.543644	250.642437	72.677567	121.592280	25.701096	119.418044
SIC 321	16.874054	14.813936	8.914424	21.634443	8.844566	8.559535	1.638389	2.673215	0.614260	2.503510
SIC 322	63.263944	66.886634	45.954484	37.632302	25.306574	41.963914	16.189868	29.289577	6.071151	24.547436
SIC 323	4.016497	2.273073	2.003224	2.165733	2.047151	1.097147	0.216452	0.598231	0.164463	0.677156
SIC 324	85.057944	60.271042	101.307474	208.403419	92.364838	52.314617	14.673154	14.916255	1.704751	9.799127
SIC 325	24.879038	22.203825	23.458538	32.914636	29.037462	48.715480	23.946937	34.952254	9.060749	58.862521
SIC 326	9.820803	5.602524	2.448635	4.135775	4.417826	8.533476	4.220068	8.570435	1.845514	10.853860
SIC 327	49.452556	41.424714	40.322264	47.046326	31.582201	41.714655	6.159358	14.807358	1.792080	4.701196
SIC 328	1.040756	0.746881	0.499196	1.157185	0.667911	1.229543	0.204425	0.150244	0.020431	0.049187
SIC 329	47.038825	23.422639	18.401155	24.655704	23.187253	21.252194	4.312377	4.534821	0.517049	2.042615
SIC 331	408.924932	254.775742	232.673549	352.747845	317.178812	185.229546	55.584606	210.620114	243.317647	738.322257
SIC 332	42.447729	37.871430	20.643472	13.978695	23.649029	18.913878	7.766971	3.120502	1.086736	3.192748
SIC 333	177.033142	126.259430	54.322068	110.170204	159.922314	36.580116	21.155542	11.020476	2.433762	18.302481
SIC 334	13.507075	6.949848	4.004417	2.187653	4.001682	3.786543	1.788050	0.951080	0.341725	1.955691
SIC 335	49.053858	51.242762	23.839198	36.999512	22.033703	17.469462	28.311653	3.667712	0.440446	2.615699
SIC 336	11.266961	9.340803	6.852712	6.344484	6.614015	5.370422	10.274411	8.456258	0.140078	0.630469
SIC 339	24.120660	31.704637	14.158145	9.968349	13.154826	12.552661	9.032414	3.744259	1.332544	10.850454
SIC 34	20.731000	62.204771	43.008891	43.172222	45.601097	42.034760	12.157764	11.325122	4.185467	18.931007
SIC 35	101.288666	87.025732	44.524090	49.770153	47.559618	50.474042	17.547615	12.929430	2.665405	12.667331
SIC 36	78.910722	73.444977	41.668158	39.383600	36.004535	29.604827	8.215641	8.824217	2.626460	29.817548
SIC 37	85.295341	73.476166	60.745530	44.273148	63.429079	68.553672	57.959155	40.746921	10.199429	61.760187
SIC 38	26.396360	20.073979	9.026571	7.425584	6.483672	5.604427	1.688659	1.127023	0.070698	0.623497
SIC 39	28.158282	9.528783	5.763443	6.001062	4.423287	6.737045	1.979686	1.150643	0.047159	0.239602

ENERGY CONVERSION STOCK BY SIC - TRILLION BTU'S

<u>SIC</u>	<u>1966 to 1970</u>	<u>1971 to 1975</u>
SIC 20	786.721554	670.075072
SIC 21	16.326145	17.684555
SIC 22	258.750291	304.255518
SIC 23	39.303207	47.245892
SIC 24	132.240522	167.768493
SIC 25	30.162525	50.829136
SIC 26	1,146.861752	1,329.491894
SIC 27	61.064729	79.063774
SIC 28	2,276.760668	2,828.865126
SIC 29	1,425.153577	1,560.217225
SIC 30	173.652216	266.065462
SIC 31	24.282711	24.350677
SIC 32	1,140.283873	1,207.963793
SIC 321	56.115895	64.580786
SIC 322	193.259967	223.840078
SIC 323	8.810566	11.655499
SIC 324	456.964840	467.124090
SIC 325	134.652444	125.883213
SIC 326	21.631106	26.092385
SIC 327	175.069044	194.383571
SIC 328	3.635171	3.754300
SIC 329	101.626121	130.657553
SIC 331	1,165.452677	1,348.570720
SIC 332	99.755559	124.045359
SIC 333	424.259765	524.326342
SIC 334	18.264379	28.553509
SIC 335	136.376841	161.072563
SIC 336	31.222167	35.732019
SIC 339	72.658635	84.736582
SIC 34	244.377186	351.269111
SIC 35	256.246956	320.601453
SIC 36	195.773511	245.234304
SIC 37	332.763940	352.643740
SIC 38	42.700796	62.596558
SIC 39	27.123676	48.267775

RETIREMENT FUNCTION - BY SIC

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PRIOR PERIODS - SUM OF FIVE YEAR INTERVALS

SIC	1 to 5	6 to 10	11 to 15	16 to 20	21 to 25	26 to 30	31 to 35	36 to 40	41 to 45
SIC 20	0.024826	0.056301	0.123876	0.223220	0.265844	0.194712	0.085100	0.026121	0.000000
SIC 21	0.014567	0.030629	0.043631	0.073324	0.105303	0.146104	0.201263	0.254514	0.130660
SIC 22	0.000000	0.012611	0.047693	0.111104	0.169862	0.213690	0.202013	0.150120	0.092907
SIC 23	0.065949	0.080532	0.095013	0.065473	0.100288	0.193487	0.199422	0.199336	0.000000
SIC 24	0.059330	0.201717	0.385641	0.284750	0.068562	0.000000	0.000000	0.000000	0.000000
SIC 25	0.035456	0.048310	0.103060	0.205444	0.231890	0.210107	0.165733	0.000000	0.000000
SIC 25	0.073791	0.031842	0.056391	0.165537	0.215598	0.283572	0.173269	0.000000	0.000000
SIC 27	0.031512	0.069142	0.182417	0.283662	0.261065	0.136703	0.035498	0.000000	0.000000
SIC 28	0.032154	0.098287	0.197858	0.249116	0.274677	0.147905	0.000000	0.000000	0.000000
SIC 29	0.067123	0.042870	0.040179	0.211177	0.260034	0.203019	0.175598	0.000000	0.000000
SIC 30	0.075681	0.084309	0.078405	0.056684	0.117063	0.212703	0.235023	0.140132	0.000000
SIC 31	0.013981	0.043426	0.088421	0.157379	0.214297	0.216974	0.163918	0.101203	0.000000
SIC 32	0.029163	0.061128	0.134045	0.223331	0.253945	0.207695	0.090693	0.000000	0.000000
SIC 321	0.034641	0.043629	0.124453	0.245607	0.197954	0.218206	0.135510	0.000000	0.000000
SIC 322	0.039262	0.068103	0.133303	0.232205	0.252745	0.176992	0.097390	0.000000	0.000000
SIC 323	0.023316	0.058082	0.112823	0.176520	0.201647	0.193351	0.119436	0.114825	0.000000
SIC 324	0.034461	0.045763	0.156275	0.178476	0.196606	0.388419	0.000000	0.000000	0.000000
SIC 325	0.030106	0.056767	0.129490	0.233950	0.262006	0.193822	0.093360	0.000000	0.000000
SIC 326	0.062155	0.098067	0.139873	0.197208	0.196088	0.142872	0.100572	0.063165	0.000000
SIC 327	0.023054	0.066524	0.137368	0.174451	0.277206	0.321397	0.000000	0.000000	0.000000
SIC 328	0.021433	0.065601	0.112065	0.160665	0.392346	0.227890	0.000000	0.000000	0.000000
SIC 329	0.026345	0.062096	0.129974	0.171522	0.290805	0.319257	0.000000	0.000000	0.000000
SIC 331	0.029446	0.059439	0.149412	0.249336	0.270099	0.175540	0.066227	0.000000	0.000000
SIC 332	0.033936	0.055686	0.149152	0.250711	0.310083	0.200432	0.000000	0.000000	0.000000
SIC 333	0.039049	0.062615	0.126303	0.235805	0.359427	0.178802	0.000000	0.000000	0.000000
SIC 334	0.034947	0.059964	0.146910	0.251665	0.276317	0.159980	0.070226	0.000000	0.000000
SIC 335	0.043490	0.071568	0.163972	0.251001	0.269176	0.200793	0.000000	0.000000	0.000000
SIC 336	0.035573	0.066493	0.160886	0.259430	0.275537	0.202081	0.000000	0.000000	0.000000
SIC 339	0.041461	0.055534	0.154840	0.250043	0.271649	0.163095	0.063378	0.000000	0.000000
SIC 34	0.012646	0.014753	0.053423	0.085907	0.097812	0.139141	0.172195	0.253717	0.170407
SIC 35	0.032711	0.045669	0.093556	0.196014	0.240123	0.223894	0.168032	0.000000	0.000000
SIC 36	0.042023	0.050639	0.135179	0.245506	0.265221	0.183663	0.077776	0.000000	0.000000
SIC 37	0.000000	0.000000	0.008898	0.210974	0.236938	0.397389	0.145801	0.000000	0.000000
SIC 38	0.029875	0.076901	0.194001	0.272071	0.243736	0.183416	0.000000	0.000000	0.000000
SIC 39	0.028549	0.076554	0.180446	0.250067	0.294466	0.169917	0.000000	0.000000	0.000000

Note: Coefficients used in ISTUM were adjusted to 3-digit accuracy.

APPENDIX II

Economic Projections to 1990

The long-range outlook for the U.S. economy envisions a continuing rise in living standards, with a gradual return to high employment. The next six years will be a period of above-trend growth in real gross national product, as the economy converges on its potential growth path. The optimism for the future must be tempered with a recognition that the problems of high inflation, dwindling energy resources, and substantial Federal deficits will not see early resolution. The ambitious goals set by the Carter Administration will be hard to achieve even by 1983; the timetable in this forecast would aim for achieving low unemployment, moderate inflation and a balanced budget by the mid-1980s.

The principal highlights of the forecast are summarized as follows:

- Real GNP grows 4.2% annually over the 1977-1983 period and 3.0% from 1983 to 1990;
- The unemployment rate falls gradually from 7% to the 4.6 to 4.7% range by 1984;
- Inflation persists in the 5-1/2 to 6% range over the next six years, then decelerates to 4-1/2% in the late 1980s;

The population grows 0.9% annually, with the highest growth seen in the 30-to-45-year age group.

CHART 1.1

Real GNP Growth
(Percent)

POTENTIAL REAL GNP

Potential GNP is a measure of the economy's capacity to produce goods and services when labor and capital resources are fully employed. The growth of potential GNP will decline from a rate of 3.5% in recent years to 3.2% in the first half of the 1980s and 3.0% after 1984. The

TABLE 1.1

Full-Employment Labor Force by Age-Sex Groups
(5-Year Compound Annual Growth Rates)

	1955 to 1960	1960 to 1965	1965 to 1970	1970 to 1975	1975 to 1980	1980 to 1985	1985 to 1990
Men.....	0.8	0.9	1.1	1.8	1.3	1.0	0.8
Ages 16 to 24...	3.8	4.0	3.1	5.5	1.3	-1.1	-1.6
Ages 25 to 54...	0.4	0.2	0.7	1.2	1.6	2.0	1.9
Ages 55 to 64...	0.8	1.2	0.7	-0.2	0.3	-0.2	-1.4
Ages 65 and over	-1.6	-1.6	-0.3	-2.4	-0.7	0.4	0.9
Women.....	2.4	2.5	3.7	3.6	2.4	2.4	2.2
Ages 16 to 24...	2.4	4.4	6.8	5.1	2.1	0.9	0.2
Ages 25 to 44...	0.9	1.1	3.1	4.9	4.2	4.5	3.9
Ages 45 to 64...	4.2	3.1	2.4	1.2	0.4	0.3	0.9
Ages 65 and over	2.5	1.9	1.2	0.3	0.5	0.9	1.1
Total.....	1.3	1.4	2.0	2.5	1.8	1.6	1.4
Ages 16 to 24...	2.8	4.2	4.6	5.3	1.7	-0.2	-0.8
Ages 25 to 64...	1.0	1.0	1.4	1.9	1.8	2.2	2.1
Ages 65 and over	-0.6	-0.6	0.2	-1.5	-0.3	0.6	1.0

Forecast Summary

major factor contributing to the decline is a slower growth of the working age population. Population growth in the 18-to-64 age group will drop from 1.6% in 1975-1980 to 1.2% in 1980-1985 and to 0.8% in 1985-1990. The upward trend in labor force participation of women will contribute to a labor force growth rate which exceeds population growth by 0.4% per year.

CHART 1.2

Civilian Labor Force vs.
Working Age Population
(Annual Rates of Growth)

The reduced rate of capital formation over the past four years will further detract from the economy's potential output. The stock of productive capital, excluding pollution control capital, will expand at a 3.6% rate between 1975 and 1990, compared with 4.0% growth from 1960 to 1975.

DRI's estimates of potential GNP include energy as an input, measured in BTU equivalents. The DRI Energy Service projects a reduction in the growth of energy consumption from a rate of 3.3% in 1975-1980 to 3.0% in 1980-1985 and to 2.6% in 1985-1990. Energy input accounts for approximately 5% of total factor costs.

The gap between potential and actual output, which equalled 5.3% of potential in 1977, will gradually be bridged over the 1978-1984 interval.

CHART 1.3

The Gap Between Potential
and Actual Real GNP
(Percent of Potential GNP
in 1972 Dollars)

DEMOGRAPHIC TRENDS AND THEIR ECONOMIC IMPACT

Underlying population trends are an important factor in determining the long-run macroeconomic outlook. As mentioned above, the slowdown in growth of the working age population has had an important impact in constraining production growth through the limits placed on possible labor force expansion. On the demand side, the changing age composition is an important determinant of allocation of spending among consumption and housing investment categories.

Although growth in the working age population slows from 1980 to 1990, overall population growth is projected to average 0.8% a year from 1975 to 1980, then to actually increase to 0.9% a year from 1980 to 1990. Chart 1.4 breaks out the components of population change between natural increase (births minus deaths) and net immigration. The dominant element of population change is the birth rate. DRI relies on the Bureau of Labor Statistics' Series II population projections which assume a fertility rate (average number of lifetime births per woman) of 2.1.

Forecast Summary

The maturing of the postwar baby-boom generation to childbearing age creates a mini-boom in the birth rate in the 1980s. The birth rate, which averaged 2.46 (births per 100 people) from 1948 through 1961 but has fallen ever since to a low of 1.46 in 1976, is therefore expected to increase again. The average for the six years from 1982 to 1987 is projected at 1.71, with a peak in the number of new births occurring in 1988 at 4,019,000. The birth rate should decline in the 1990s as the age distribution of the female population shifts again, leaving an average birth rate of 1.52 for the 10 years between 1990 and 2000.

will rise to 11.2% by 1980 and up to 12.1% by 1990. This upward drift does have a slight impact in reducing population growth, although the movement of the birth rate remains the dominant force. Net immigration is assumed to stabilize at 400,000. This influx keeps population growth from actually reaching zero, which it would have done under the 2.1 fertility assumption, absent immigration, around the middle of the 21st century.

CHART 1.4

Components of Population Change,
1940-1999 (Percent)

Changes to the death rate and net immigration are not expected to have a major impact in shifting the pattern created by the birth rate. The death rate has fallen from the 1.17 per 100 peak in 1945 to a low of 0.89 in 1976. However, it is now projected to start rising slightly. This increase results as a greater proportion of the population moves into older age brackets: in 1975, 10.4% of the population was over 64; this

Changes to the age distribution of the population which will result, given the present population mix and these assumptions about births, deaths, and immigration, are summarized in Table 1.2. The differences in projected growth rates between those of working age and others are striking. The population under 20 declines over the next two 5-year periods, and even with a 0.7% rise from 1985 to 1990, the population in this age group will be below its 1975 level in 1990. This has obvious implications for spending for education and other youth-related items. The growth in the over-65 category, in contrast, is very strong, with a bulge in the growth to 2.2% from 1970 to 1980 followed by some moderation to 1.8% from 1980 to 1990, still well above the 0.9% growth of the total population. In 1990 there will be about 7.4 million more people over 65 than there were in 1975, which will require more government outlays for housing for the elderly, medical care, and social security.

The dichotomy between the growth rates for the elderly and for the working age population has produced the financing crisis of the social security fund, and will continue to pose problems over the coming years. Fortunately, rising labor force participation rates are keeping the ratio of population outside the labor force to labor force participants declining. This decline in the number of dependents per worker is shown in Chart 1.5. The ratio reached a postwar peak of 1.544 in 1962, and has declined to 1.183 in 1977. The trend forecast shows a further decline to 1.020 in 1990. Another measure of economic dependency is the ratio of total population not holding jobs to total employment. This figure has dropped from 1.689 in 1963 to 1.346 in 1977. By 1990 the average number of nonworking persons supported by each job-holder will drop to 1.116.

Forecast Summary

CHART 1.5

Economic Dependency: Ratio of Population not in Labor Force to Labor Force, including Military

Economic Dependency: Ratio of Non-working Population of All Ages to Employment, including Military

Growth of various age groups within the working age population category is also important. The boxed-in area in Table 1.2 shows that the baby-boom generation will be boosting the growth of the population aged 25-44 most strongly over the forecast interval. These groups comprise the younger, although experienced, workers and the strong growth here bodes well for productivity gains. Further, these age groups include consumers in the prime home-buying and accompanying consumer-durable-purchasing age brackets. In contrast, the oldest group of workers, those aged 55 to 64, will grow slowly through 1985 and then decline, and the 45-54 age group will decline until the first of the baby-boom children start moving into this bracket at the end of the decade.

THE FIVE-YEAR OUTLOOK

As policy parameters come into focus, the outline of the business cycle over the next five years becomes somewhat clearer. It is now evident that a substantial tax reduction will be enacted in 1978. The long-term forecast assumes that a Federal tax cut of \$20 billion

TABLE 1.2

*Population by Age Class Levels and Annual Rates of Change**

Age Class	1950	1955	1960	1965	1970	1975	1980	1985	1990
Total	152.3	165.9	180.7	194.3	204.9	213.5	221.1	232.9	243.5
%		1.7	1.7	1.5	1.1	0.8	0.8	0.9	0.9
18 - 64	92.6	95.7	99.5	106.1	115.1	124.9	135.2	143.3	148.9
%		0.6	0.8	1.3	1.6	1.6	1.6	1.2	0.8
Under 20	51.7	60.0	69.5	76.3	77.2	74.6	70.5	69.6	72.0
%		3.0	3.0	1.9	0.2	-0.7	-1.1	-0.2	0.7
20 - 24	11.7	10.7	11.0	13.7	17.2	19.2	20.9	20.5	17.9
%		-1.7	0.8	4.3	4.6	2.3	1.7	-0.4	-2.6
25 - 29	12.4	11.8	10.9	11.3	13.7	16.9	18.9	20.6	20.2
%		-0.9	-1.6	0.7	3.9	4.3	2.3	1.7	-0.4
30 - 34	11.7	12.4	12.0	11.1	11.6	14.0	17.2	19.3	20.9
%		1.3	-0.8	-1.5	0.8	3.8	4.3	2.3	1.6
35 - 44	21.6	22.9	24.2	24.4	23.1	22.8	25.7	31.4	36.6
%		1.1	1.1	0.2	-1.1	-0.3	2.4	4.0	3.1
45 - 54	17.4	18.9	20.6	21.8	23.3	23.8	22.7	22.4	25.3
%		1.6	1.7	1.2	1.3	0.4	-0.9	-0.2	2.4
55 - 64	13.4	14.6	15.6	17.1	18.7	19.8	21.2	21.7	20.8
%		1.8	1.3	1.8	1.8	1.2	1.4	0.5	-0.9
Over 65	12.4	14.5	16.7	18.4	20.1	22.4	24.9	27.3	29.8
%		3.2	2.8	2.0	1.7	2.2	2.2	1.8	1.8

*The rates of change are calculated for prior 5-year intervals.

The boxed area highlights the impact of the postwar baby boom.

Forecast Summary

takes effect in late 1978, with one-third going to businesses. The anticipated fiscal stimulus reduces the probability of a growth recession in 1979. Real GNP growth is projected at 4.4% over the 1977-1980 period, with capital spending maintaining the expansion's momentum at the end of the decade.

The odds of escaping a mild growth recession over the next five years are small. The tax package will stimulate the economy in 1979 and the election year, but not without costs in later years. By 1981 fiscal and monetary policies could be working in opposition. The Federal budget is projected to show deficits of \$20 billion in 1981 and 1982, requiring a high volume of Treasury borrowing. Rising energy prices, uncomfortably high manufacturing capacity utilization rates, and higher labor costs are likely to push the inflation rate to 6% in 1981. With the burden of controlling inflation thrust on the Federal Reserve, some monetary tightening is anticipated. The trend forecast envisions rising short-term interest rates in 1981, causing a mild setback in homebuilding and other interest-sensitive markets.

The outcome is a hesitation in the growth pace during 1981 and 1982, with real GNP advancing 3.9% in 1981 and 3.5% in 1982. The interlude of slower growth dampens inflationary pressures, allowing capacity to adjust to a higher level of demand, and permitting monetary policy to become more accommodating. This sets the stage for a rebound in the economy's growth pace in late 1982 and 1983.

LONG-TERM SIMULATIONS

The DRI Long-Term Trend Forecast

The presence of uncertainty in the long-range outlook makes flexibility a requisite in long-range planning. DRI has developed two alternative forecast simulations which present planners with very different economic scenarios and serve different purposes.

TRENDLONG1277 is a stable-growth, long-range simulation of the 1977 DRI Quarterly Model. Projections through 1980 are based on the short-term forecast, CONTROL125.

TABLE 1.3

*Capsule Summary of the DRI
Long-Term Forecast Alternatives*

	History		TRENDLONG1277		CYCLELONG1277	
	56-65	66-75	76-83	84-90	76-83	84-90
Rates of Change						
=====						
GNP-Current Dollars	5.7	8.4	10.3	7.7	11.1	11.5
-Constant Dollars	3.6	2.6	4.4	2.9	3.8	2.8
GNP Deflator	2.0	5.7	5.6	4.6	7.1	8.5
Consumer Price Index	1.7	5.7	5.6	4.6	6.9	8.1
Wholesale Price Index	1.0	6.3	5.9	4.6	7.6	9.9
Adj. Avg. Hourly Earnings	3.6	6.7	7.2	6.6	9.0	10.3
Shares of Real GNP (%)						
=====						
Consumption	63.5	62.4	63.2	61.7	63.1	60.5
Business Fixed Investment	14.6	14.4	14.9	15.7	14.9	14.4
(Excl. Pollution Control)	14.6	14.2	14.5	15.3	14.5	14.0
Residential Construction	4.9	4.1	4.6	4.2	4.6	4.1
Government Purchases	20.3	21.9	21.1	21.7	21.7	24.7
Key Indicators of Activity						
=====						
Unemployment Rate (%)	5.4	5.0	6.2	4.6	6.5	6.9
Retail Car Sales (Mil.)	6.8	9.5	11.3	12.1	11.0	10.8
Housing Starts (Mil. Units)	1.40	1.58	1.91	2.10	1.84	1.81
Savings Rate (%)	5.9	7.0	5.4	5.8	5.7	6.6
Federal Funds Rate	2.93	6.45	6.23	5.81	6.56	7.33
Prime Rate	4.36	7.10	7.50	6.88	7.90	8.25
New High-Grade Corp Bond Rate	4.34	7.40	8.41	7.60	8.87	10.01

Forecast Summary

TRENDLONG1277 departs from the mold of previous long-term trend simulations by incorporating DRI's forecast of the business cycle through 1982, as outlined above. Beyond 1982 the trend projections abstract from cyclical variations in the economy. The magnitudes of the trend forecast should be interpreted as averages of a range of possible outcomes, keeping in mind that it is extremely difficult to anticipate the timing of business cycles more than a few years ahead. Fluctuations will occur, but most can be absorbed without shifting the economy's potential growth path.

In TRENDLONG1277 the gap between potential and actual GNP is nearly closed by 1984. Thereafter, the growth of real GNP is assumed to parallel the growth of potential output, as determined by the growth of labor, capital and energy inputs, adjusted for technological change. Monetary policies are assumed to promote stable credit market conditions, while fiscal restraint in the 1980s brings the Federal budget into near-balance in the middle of the decade. The trend simulation optimistically assumes there are no destabilizing shocks to the macroeconomy.

CHART 1.6

Real Gross National Product
(Billions of 1972 Dollars)

A Pessimistic Cyclical Alternative

The long-range cyclical simulation, CYCLELONG1277, is a pessimistic alternative to the trend forecast. Like its precursor, CYCLELONG0977, it assumes that the problems of inflation, energy, and policy mistakes worsen rather than improve. The result is an economy of increasing volatility, upward-spiralling inflation, periodic clashes between fiscal and monetary policies, and lower real investment in housing and business plant and equipment. As a result, the growth of potential real GNP is reduced by 0.2 percentage point. The growth paths of the trend and cycle alternatives are traced in Chart 1.7. In the cyclical solution, the expansion peaks in the first quarter of 1982. Then, real GNP falls by 2.3% over four quarters. This first cycle is typical of the postwar cycles up to 1973. The next cycle reaches a peak in the first quarter of 1986 and bottoms out in the second quarter of 1987, with a peak-to-trough decline of 5.3%. This later cycle almost rivals the 1973-1975 recession in severity.

CHART 1.7

Real GNP Growth
(Percent)

Nominal magnitudes are deceptive in the inflationary climate of CYCLELONG1277, and underlying economic relationships are better

Forecast Summary

understood by examining constant dollar magnitudes. The timing of economic fluctuations is somewhat arbitrary in the cyclical alternative. The simulation should be used to assess the vulnerability of particular sectors of the economy to a more volatile, uncertain climate.

FORECAST HIGHLIGHTS

The highlights of the trend forecast, in comparison with the cycle alternative, can be summarized as follows:

Real GNP

The trend projections envision real GNP growth of 4.4% from 1977 to 1980, 3.6% from 1980 to 1985, and 3.0% from 1985 to 1990. The more volatile economic environment of the cycle alternative contributes to lower average economic activity, with real GNP growing 4.2% over the next three years, 3.3% from 1980 to 1985, and 2.2% from 1985 to 1990.

CHART 1.8

Unemployment Rate
(Percent)

Unemployment

The unemployment rate falls gradually from a 7.1% average in 1977 to 5.9% in 1980 and to 4.9% in 1983, before stabilizing in the 4.6 to 4.7% range. Employment increases at a 2.3% rate over the 1977-1983 period and at a 1.2% pace over the balance of the forecast interval as the economy follows a steady growth path.

In the cyclical alternative, the unemployment rate fluctuates between 4.6% and a peak of 8.8% in mid-1987. The average unemployment rate is 6.6% in the 1981-1990 period, well above the 4.8% average in the trend solution. Employment growth averages 1.9% in 1977-1983 and 1.1% in 1983-1990.

Prices and Wages

Inflation is projected to continue near its current pace over the next six years before decelerating. The consumer price index rises at rates of 5.5% over the 1977-1983 period and 4.6% from 1983 to 1990 in the trend alternative. Wage inflation, measured by the average hourly earnings index for production workers, slows from 7.2% in the 1977-1983 period to 6.7% in the later period. Compensation per hour in the private nonfarm economy increases 1 percentage point per year faster than wages as a result of increased Social Security payroll taxes and the trend toward greater fringe benefits. Productivity gains hold the average rise in unit labor costs to 4.8% over the forecast interval. Inflation is exacerbated by sharp increases in energy prices over the next few years, as petroleum and natural gas prices are brought up to free market levels. The increase in wholesale fuel prices is projected at 11.1% in 1977-1983 and 6.9% in 1983-1990.

An assumption of the pessimistic cyclical alternative is an explosive wage-price spiral, set off by the interaction of frequent commodity price shocks with inflation expectations. Average CPI inflation is 7.6% from 1977 to 1990, although it reaches 10% in 1986. Wage gains average 9.9%, while unit labor costs show an average growth of 8.2% over the forecast period. Wholesale prices rise 9.1%, compared to 5.3% in the more optimistic trend simulation.

Forecast Summary

CHART 1.9

Consumer Price Index
(Percent Change)

trend projections. With the growth of the population aged 16 to 64 slowing from 1.6% in 1975-1980 to 0.8% in 1985-1990, the volume of car sales will be held to 11.9 million units annually in the first half of the 1980s and 12.1 million units in the remainder of the decade. The stock of cars per person aged 18 to 64, which has increased from 0.49 in 1955 to 0.79 in 1977, will advance to 0.88 by 1990, assuming an annual depreciation fluctuating around 8%.

In the cyclical alternative, real consumer spending growth is 3.3% from 1980 to 1985 and 2.6% from 1985 to 1990. Increased uncertainty, reflected in lower consumer sentiment, causes consumers to channel a larger share of incomes into savings to protect the real value of financial assets. Discretionary purchases are curtailed to a disproportionate extent. By 1990 real durable consumption is 15.5% below the trend projection, while nondurables and services are reduced by 3%.

Wholesale Price Index
(Percent Change)

CHART 1.10

Retail Car Sales
(Millions of Units)

Consumer Spending

Real personal consumption expenditures are projected to grow at compound annual rates of 3.7% from 1980 to 1985 and 3.3% from 1985 to 1990, paralleling the growth of real disposable income. The savings rate approaches 6% in the

Housing

Housing starts and mobile home shipments average 2.5 million units per year in the trend forecast, peaking at 2.8 million units in 1983.

Forecast Summary

As the impact of the postwar baby boom passes, the annual change in the adult population (22 years and older) will drop from 2.6 million persons in 1979 to an average of 2.4 million

CHART 1.11

Housing Unit Starts and the
Change in Adult Population
(Millions)

persons in 1981-1985 and 1.9 million persons in 1986-1990. The implication is a slight reduction in the housing construction by the end of the next decade. The housing outlook is strengthened by the existence of pent-up demand from the recession, evidenced by low vacancy rates.

The cycle alternative illustrates the sensitivity of the housing industry to financial conditions. In periods of high interest rates and restricted mortgage credit, housing starts and mobile home shipments sink as low as 1.5 million units, and average 2.2 million units over the forecast horizon. By 1990 the housing stock is 3.5 million units below the trend projection.

Business Fixed Investment

An increasing share of real GNP will be devoted to business investment over the next decade. In the trend forecast, the growth of real business fixed investment averages 5.9% from 1977 to 1983 and 3.8% from 1983 to 1990. The strength of investment demand is predicated on new tax incentives, including liberalization of the investment tax credit, sustained output growth combined with relatively high capacity utilization rates by the end of this decade, and replacement demands that were postponed during the recession.

CHART 1.12

Housing Starts and
Mobile Home Shipments
(Millions of Units)

CHART 1.13

Business Fixed Investment as a
Percentage of Real GNP

Forecast Summary

The cyclical alternative offers a more pessimistic view of the long-term investment outlook. The growth of real business fixed investment averages 4.4% from 1977 to 1983, and only 2.3% over the balance of the forecast period. Cyclical fluctuations in product markets are amplified in the investment sector, with real investment declines of 6.6% in 1983 and 12.7% in 1987.

Government

The Federal budget is projected to return to near-balance (annual deficits less than \$10 billion) by the mid-1980s, a few years behind the current Administration's timetable. Compared to the previous long-term forecast, the budget gap is larger due to the added assumption of permanent tax cuts in mid-1978 and the projected slower economic growth in 1981 and 1982. The long-range forecasts incorporate Social Security financing reforms, a wellhead tax on crude oil, and limited taxes on industrial use of petroleum and natural gas. Federal government purchases in 1972 dollars are assumed to grow 2.7% annually from 1977 to 1983 and 2.2% annually from 1983 to 1990.

State and local government purchases are projected to increase. Chart 1.14 illustrates the cyclical nature of the Federal budget balance in the alternative. Real expenditure policy is identical in the alternative forecasts, although higher unemployment in the cyclical simulation triggers countercyclical transfers and shrinks revenues.

Financial Markets

Monetary policies are assumed to promote stable credit growth over the long-run in the trend forecast. Following an episode of monetary tightening in 1981, the Federal funds rate falls from a peak of 7.3% to 5.8% in 1984 and is stable over the remainder of the solution interval. Long-term interest rates decline steadily over the 1982-1986 period in response to diminished inflation expectations. Measured against the current period's inflation rate, the real yield on high-grade corporate bonds is 3% in the late 1980s, when the economy is on a steady growth path. The prime rate peaks at 8.2% in 1981, edging down to 6.8% by 1987.

Growth in the narrowly-defined money supply averages 4.7% over the forecast horizon,

CHART 1.14

Federal Government Budget Surplus
Or Deficit (-) as a Percent of GNP

CHART 1.15

Prime Rate on
Short-Term Business Loans

Forecast Summary

restrained by advances in money-saving technology. M2 growth is substantially higher, averaging 8.3% from 1977 to 1990.

A key assumption of CYCLELONG1277 is cycle-intensifying shifts in monetary policies between accommodation and extreme restriction. The result is credit crunches of increasing severity in the 1980s. The prime rate surpasses 10% on two occasions, as depicted in Chart 1.15. Against the backdrop of acute inflation and volatile credit policies, money (M1) averages 7.8% over the forecast interval.

CONCLUSION

DRI is optimistic that the economy can achieve sustained growth at a moderate pace over the next decade. Real GNP is projected to grow 4.2% annually over the period to 1983, closing the gap between potential and actual output. From 1983 to 1990, the economy will achieve 3% annual growth, based on the growth of potential GNP. Slower population growth will dictate a slower expansion of markets; however, the growth of real per capita incomes will match historical trends.

TABLE 1.4
Long-Term Forecasts of the U.S. Economy: December 1977

Forecast Summary

TRENDLONG1277	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
GNP and Its Components---Billions of Dollars															
Total Consumption.....	1093.9	1208.5	1331.5	1461.5	1603.2	1753.7	1913.8	2097.3	2276.0	2454.4	2641.4	2842.2	3055.8	3280.3	3517.4
Nonres. Fixed Investment.....	161.9	184.6	206.3	232.2	262.7	297.2	326.8	365.2	406.1	443.7	487.2	536.4	577.1	621.1	673.2
Res. Fixed Investment.....	68.0	89.9	100.4	108.9	126.1	135.3	140.3	165.5	175.9	181.3	187.2	190.9	198.7	207.6	216.7
Inventory Investment.....	13.3	18.2	18.4	13.8	20.2	25.5	25.4	32.6	31.4	32.8	34.6	37.9	41.4	45.0	46.7
Net Exports.....	7.8	-7.8	-5.4	-4.5	-3.4	-1.1	5.9	5.7	4.0	3.2	0.7	-1.2	1.6	2.2	2.6
Federal Purchases.....	130.1	146.4	163.0	176.8	191.8	210.4	230.8	251.7	273.6	296.6	321.0	346.4	373.6	402.9	433.7
State and Local.....	231.2	250.5	281.7	310.0	342.9	381.3	420.1	460.1	503.6	549.6	598.1	650.3	708.0	770.3	835.3
Gross National Product.....	1706.4	1890.3	2095.8	2298.8	2543.5	2802.2	3063.2	3378.1	3670.6	3961.6	4270.1	4602.9	4956.2	5329.4	5725.5
Real GNP (1972 Dollars).....	1274.7	1336.8	1397.5	1451.7	1519.2	1578.8	1633.9	1707.0	1763.8	1815.0	1868.9	1925.8	1982.4	2040.2	2100.5
Prices and Wages --- Rates of Change															
Implicit Price Deflator.....	5.3	5.6	6.1	5.6	5.7	6.0	5.6	5.6	5.2	4.9	4.7	4.6	4.6	4.5	4.4
Fixed Weight Deflator.....	5.6	5.9	6.1	5.6	5.7	6.1	5.7	5.8	5.4	5.1	4.9	4.9	4.9	4.8	4.6
Consumer Price Index.....	5.7	6.6	6.2	5.6	5.4	5.4	5.3	5.2	4.9	4.9	4.7	4.5	4.4	4.3	4.3
Wholesale Price Index.....	4.6	6.2	6.3	5.9	6.4	6.2	5.6	6.3	5.2	4.8	4.6	4.6	4.5	4.3	4.3
Compensation per Hour.....	8.6	8.7	8.4	7.9	8.0	8.5	8.4	8.3	8.3	8.1	7.8	7.6	7.4	7.3	7.2
Production and Other Key Measures															
Industrial Production (67=1).....	1.298	1.372	1.443	1.510	1.613	1.702	1.774	1.888	1.966	2.030	2.112	2.202	2.285	2.374	2.476
Rate of Change.....	10.1	5.7	5.2	4.6	6.8	5.5	4.2	6.4	4.2	3.2	4.0	4.3	3.8	3.9	4.3
Housing Starts (Mil. Units).....	1.541	1.958	1.837	1.817	1.988	1.921	1.959	2.291	2.270	2.217	2.137	2.073	2.049	2.005	1.965
Retail Unit Car Sales (Mil. Units).....	10.1	11.2	11.0	11.2	11.4	11.5	11.7	12.3	12.3	11.9	11.9	12.0	12.1	12.3	12.3
Unemployment Rate (%).....	7.7	7.1	6.6	6.3	5.9	5.5	5.4	4.9	4.7	4.7	4.6	4.6	4.6	4.6	4.6
Federal Budget Surplus (NIA).....	-54.0	-49.7	-51.0	-50.1	-29.4	-20.2	-19.5	-10.5	-8.0	-8.8	-8.3	-5.4	-4.0	-5.3	-6.8
Money and Interest Rates															
Money Supply (M1).....	311.1	334.4	352.8	375.5	401.8	424.1	444.6	469.2	488.5	507.8	527.2	546.9	568.3	588.7	608.5
Rate of Change.....	5.6	7.5	5.5	6.4	7.0	5.6	4.8	5.6	4.1	3.9	3.8	3.7	3.9	3.6	3.4
New AA Corp. Utility Rate (%).....	8.67	8.34	8.02	8.66	8.84	8.93	8.96	8.64	8.30	7.97	7.74	7.84	7.70	7.84	7.80
New High-Grade Corp. Bond Rate (%).....	8.33	8.06	8.50	8.33	8.52	8.60	8.63	8.32	7.99	7.68	7.47	7.55	7.47	7.53	7.48
Federal Funds Rate (%).....	5.05	5.56	6.83	6.15	6.53	7.24	6.59	5.89	5.83	5.81	5.80	5.80	5.79	5.79	5.83
Prime Rate (%).....	6.84	6.83	7.98	7.56	7.73	8.17	7.68	7.21	7.10	6.95	6.89	6.82	6.79	6.80	6.81
Incomes---Billions of Dollars															
Personal Income.....	1382.7	1533.3	1690.2	1849.1	2037.9	2239.6	2455.5	2690.7	2927.5	3156.3	3400.4	3664.5	3946.8	4244.9	4562.4
Real Disposable Income (%Ch).....	3.9	4.1	4.4	3.7	4.0	4.0	4.1	4.7	3.4	2.9	3.0	3.3	3.4	3.5	3.5
Saving Rate (%).....	5.6	5.1	5.4	5.3	5.2	5.3	5.6	5.9	5.8	5.7	5.7	5.7	5.8	6.0	6.1
Profits Before Tax.....	156.8	170.9	184.9	199.7	225.1	242.6	257.0	286.6	303.8	325.0	351.7	380.1	406.8	435.3	464.4
Profits After Tax.....	92.1	102.9	113.8	125.8	143.6	155.6	166.1	186.3	198.9	213.9	232.7	252.9	272.1	292.6	314.0
Percent Change.....	25.5	11.7	10.5	10.6	14.2	8.3	6.7	12.2	6.8	7.5	8.8	8.7	7.6	7.5	7.3
Composition Of Real GNP --- Rates of Change															
Gross National Product.....	6.0	4.9	4.5	3.9	4.6	3.9	3.5	4.5	3.3	2.9	3.0	3.0	2.9	2.9	3.0
Final Sales.....	4.5	4.6	4.6	4.2	4.4	3.8	3.6	4.3	3.4	2.9	3.0	3.0	2.9	2.9	3.0
Total Consumption.....	6.0	4.5	4.0	4.1	4.1	3.8	3.8	4.4	3.6	3.1	3.2	3.3	3.4	3.3	3.3
Nonres. Fixed Investment.....	3.6	8.4	5.4	6.9	7.4	6.2	3.9	5.4	5.2	3.9	4.5	4.7	2.3	2.5	3.4
Equipment.....	4.2	10.8	5.2	7.0	7.1	6.8	4.0	5.5	5.2	4.0	4.7	5.0	2.6	2.8	3.6
Nonres. Construction.....	2.2	3.3	5.7	6.7	7.9	5.0	3.6	5.1	5.0	3.7	3.9	4.0	1.6	1.9	2.7
Res. Fixed Investment.....	23.1	18.4	3.9	1.4	8.3	-0.1	-2.5	10.6	0.2	-2.5	-2.0	-3.0	-0.9	-0.3	-0.3
Exports.....	6.5	3.4	7.0	6.5	5.0	4.2	3.9	4.8	4.5	5.1	4.3	4.3	4.3	4.4	4.4
Imports.....	18.4	10.2	3.9	4.7	4.0	3.7	2.3	6.9	5.9	5.2	5.2	6.0	5.3	5.9	5.9
Federal Government.....	-0.1	5.7	4.7	2.1	1.9	2.7	2.8	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
State and Local.....	1.0	1.4	5.1	3.5	3.5	3.6	3.7	3.5	3.6	3.4	3.2	3.1	3.0	2.9	2.8

Forecast Summary

TABLE 1.5

Composition of Gross National Product

TRENDLON1277	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990
Billions of Dollars															
Gross National Product...	1706.4	1890.3	2095.8	2298.8	2543.5	2802.2	3063.2	3378.1	3670.6	3961.6	4270.1	4602.9	4956.2	5329.4	5725.5
Consumption.....	1093.9	1208.5	1331.5	1461.5	1603.2	1753.7	1913.8	2097.3	2276.0	2454.4	2641.4	2842.2	3055.8	3280.3	3517.4
Durables.....	158.9	179.5	193.6	208.1	224.8	243.7	269.6	304.3	334.7	362.9	394.2	428.7	466.8	507.4	550.8
Motor Vehicles & Parts	71.9	84.3	90.2	96.5	104.8	113.6	124.5	139.7	151.7	161.8	173.2	186.1	201.3	217.5	234.6
Furniture & Appliances	63.9	70.1	76.0	82.1	88.4	96.0	107.0	121.2	134.4	147.5	161.6	176.1	191.1	205.9	224.6
Other Durables.....	23.1	25.1	27.4	29.5	31.6	34.1	38.1	43.4	48.5	53.6	59.4	66.5	74.5	83.0	92.7
Nondurables.....	442.8	477.4	521.5	569.7	623.5	677.7	731.0	790.4	844.8	899.0	955.6	1016.9	1083.4	1153.1	1225.8
Clothing & Shoes.....	76.3	82.1	90.2	99.1	108.6	119.1	129.8	143.0	153.8	164.2	176.5	189.8	203.8	218.6	234.4
Food & Beverages.....	225.6	245.1	267.7	291.6	318.2	344.9	369.0	394.4	418.2	442.7	467.0	493.7	522.9	553.1	584.3
Gasoline & Oil.....	41.4	44.4	48.5	52.8	58.1	61.9	66.0	70.2	74.6	79.0	83.3	87.5	92.1	96.8	101.9
Other Nondurables.....	99.6	105.8	115.1	126.1	138.6	151.8	166.3	182.8	198.2	213.1	228.9	245.9	264.6	284.5	305.3
Services.....	492.3	551.7	616.4	683.7	754.9	832.3	913.3	1002.6	1096.6	1192.5	1291.6	1396.6	1505.6	1619.8	1740.8
Household Operation...	73.0	83.5	93.7	103.4	113.5	123.5	133.7	144.9	156.7	169.5	182.6	196.2	209.8	223.6	238.8
Housing.....	168.0	184.5	204.0	224.1	245.7	268.9	293.4	319.7	347.1	375.2	404.7	434.5	464.5	495.5	526.1
Transportation.....	36.9	41.5	46.3	51.0	56.1	62.4	69.4	77.0	84.1	91.4	98.9	107.0	115.3	123.8	132.9
Other Services.....	214.6	242.2	272.4	305.3	339.6	377.5	416.8	460.9	508.7	556.5	605.4	656.9	716.0	776.9	841.0
Investment.....	243.3	292.7	325.1	354.9	409.0	457.9	492.5	563.3	613.4	657.7	709.0	765.2	817.1	873.7	936.5
Fixed.....	230.0	274.5	306.7	341.1	388.8	432.4	467.1	530.7	582.0	625.0	674.3	727.3	775.7	828.7	889.9
Nonresidential.....	161.9	184.6	206.3	232.2	262.7	297.2	326.8	365.2	406.1	443.7	487.2	536.4	577.1	621.1	673.2
Equipment.....	106.1	123.3	137.6	154.7	173.6	195.9	214.4	238.2	262.9	285.9	313.3	344.5	370.0	397.4	429.5
Structures.....	55.9	61.3	68.7	77.5	89.1	101.2	112.4	127.0	143.1	157.7	173.9	191.9	207.1	223.7	243.7
Residential.....	68.0	89.9	100.4	108.9	126.1	135.3	140.3	165.5	175.9	181.3	187.2	190.9	198.7	207.6	216.7
Structures.....	66.8	88.5	98.9	107.3	124.3	133.4	138.3	163.3	173.5	178.7	184.4	188.0	195.6	204.4	213.4
Equipment.....	1.3	1.4	1.6	1.6	1.8	1.9	2.0	2.2	2.4	2.6	2.7	2.9	3.0	3.2	3.3
Change in Inventories..	13.3	18.2	18.4	13.8	20.2	25.5	25.4	32.6	31.4	32.8	34.6	37.9	41.4	45.0	46.7
Exports.....	162.8	178.5	200.3	225.6	253.7	283.5	313.3	351.4	390.6	432.2	475.1	525.7	582.0	643.5	710.5
Imports.....	155.1	186.4	205.8	230.1	257.1	284.6	307.4	345.7	386.6	429.0	474.5	526.8	580.4	641.3	707.9
Government.....	361.4	396.9	444.7	486.8	534.7	591.7	650.9	711.8	777.2	846.2	919.1	996.7	1081.7	1173.2	1269.0
Federal.....	130.1	146.4	163.0	176.8	191.8	210.4	230.8	251.7	273.6	296.6	321.0	346.4	373.6	402.9	433.7
National Defense.....	86.8	94.9	104.5	113.3	122.8	134.3	146.6	159.2	172.7	186.9	201.9	217.5	234.1	252.0	270.8
Nondefense.....	43.3	51.5	58.5	63.5	69.1	76.1	84.2	92.6	100.9	109.8	119.1	128.9	139.5	150.9	162.9
State & Local.....	231.2	250.5	281.7	310.0	342.9	381.3	420.1	460.1	503.6	549.6	598.1	650.3	708.0	770.3	835.3
Billions of 1972 Dollars															
Gross National Product...	1274.7	1336.8	1397.5	1451.7	1519.2	1578.8	1633.9	1707.0	1763.8	1815.0	1868.9	1925.8	1982.4	2040.2	2100.5
Consumption.....	821.3	858.3	893.0	929.4	967.7	1004.4	1042.7	1088.5	1127.4	1162.0	1198.6	1238.4	1280.2	1323.1	1367.3
Durables.....	127.5	137.7	142.7	147.8	153.7	159.8	170.0	184.3	195.2	204.7	215.2	226.7	239.1	252.0	265.7
Motor Vehicles & Parts	55.7	61.3	62.5	64.3	66.9	69.1	72.2	77.1	80.0	81.6	83.5	85.8	88.7	91.7	95.0
Furniture & Appliances	52.8	56.4	59.2	61.8	64.4	67.5	73.0	79.9	86.0	92.0	98.5	104.9	111.5	118.2	125.7
Other Durables.....	19.0	20.0	20.9	21.7	22.4	23.2	24.8	27.2	29.2	31.1	33.3	36.0	39.0	42.0	45.0
Nondurables.....	321.6	330.9	342.8	356.8	371.9	384.9	395.6	408.5	417.8	424.8	432.5	441.0	450.4	460.2	470.1
Clothing & Shoes.....	64.7	66.9	70.2	73.7	77.2	80.5	83.7	88.0	90.1	91.9	94.4	97.1	99.8	102.5	105.4
Food & Beverages.....	159.7	166.3	172.2	179.4	187.1	193.2	196.7	201.4	205.3	208.0	210.7	213.8	217.6	221.5	225.5
Gasoline & Oil.....	25.1	25.6	26.1	26.5	27.3	27.8	28.1	28.4	28.6	28.8	28.9	29.0	29.0	29.1	29.2
Other Nondurables.....	72.0	72.1	74.3	77.1	80.3	83.4	87.0	90.7	93.7	96.1	98.5	101.1	104.0	107.1	110.1
Services.....	372.2	389.7	407.6	424.8	442.2	459.7	477.1	495.7	514.4	532.5	550.9	570.7	590.7	610.9	631.5
Household Operation...	52.7	56.5	59.4	61.6	63.7	65.6	67.3	69.2	71.3	73.8	76.1	78.6	80.7	82.8	85.1
Housing.....	136.3	141.2	147.4	153.1	159.3	166.2	173.6	181.0	188.7	196.7	205.4	214.2	223.0	231.8	240.6
Transportation.....	28.9	29.6	30.7	31.9	33.2	34.8	36.6	38.5	39.8	41.0	42.2	43.6	45.0	46.3	47.8
Other Services.....	154.3	162.4	170.1	178.2	185.9	193.1	199.6	207.0	214.5	221.0	227.2	234.4	242.0	250.0	257.9
Investment.....	173.0	195.2	204.1	210.9	229.7	241.5	245.4	264.2	272.2	277.7	285.2	293.6	298.7	304.7	312.0
Fixed.....	164.5	183.2	192.2	202.3	217.8	227.3	232.0	247.8	257.1	262.7	270.0	277.6	281.9	287.2	294.6
Nonresidential.....	116.8	126.6	133.4	142.7	153.2	162.8	169.1	178.2	187.4	194.7	203.3	212.9	217.9	223.4	230.9
Equipment.....	79.7	88.3	92.9	99.5	106.6	113.8	118.4	124.9	131.4	136.6	143.0	150.2	154.1	158.5	164.2
Structures.....	37.1	38.3	40.5	43.2	46.6	48.9	50.7	53.3	56.0	58.0	60.3	62.7	63.7	64.9	66.7
Residential.....	47.8	56.6	58.8	59.6	64.5	64.5	62.9	69.6	69.7	68.0	66.6	64.6	64.1	63.9	63.7
Structures.....	46.7	55.4	57.6	58.4	63.3	63.2	61.5	68.1	68.2	66.4	65.0	63.0	62.3	62.1	61.9
Equipment.....	1.0	1.1	1.2	1.2	1.3	1.3	1.3	1.4	1.5	1.6	1.6	1.7	1.7	1.8	1.8
Change in Inventories..	8.4	12.0	12.0	8.6	11.9	14.2	13.5	16.4	15.1	15.0	15.2	16.0	16.7	17.5	17.4
Exports.....	95.8	99.0	106.0	112.9	118.6	123.6	128.4	134.6	140.7	147.9	154.3	160.9	167.8	175.2	182.9
Imports.....	79.8	87.9	91.4	95.7	99.6	103.3	105.7	113.0	119.7	126.0	132.5	140.4	147.9	156.6	165.8
Government.....	264.4	272.3	285.7	294.3	302.7	312.6	323.1	332.9	343.2	353.4	363.3	373.4	383.6	393.9	404.2
Federal.....	96.6	102.1	106.9	109.1	111.1	114.1	117.3	119.9	122.5	125.2	128.0	130.8	133.6	136.6	139.6
National Defense.....	64.4	66.2	68.5	69.9	71.1	72.8	74.5	75.8	77.3	78.9	80.5	82.1	83.7	85.4	87.2
Nondefense.....	32.2	35.9	38.4	39.2	40.0	41.3	42.8	44.1	45.2	46.3	47.5	48.7	49.9	51.1	52.4
State & Local.....	167.8	170.2	178.8	185.2	191.6	198.5	205.8	213.0	220.6	228.1	235.3	242.6	250.0	257.3	

The projected business capital stock was based on the assumption of a rise in the real investment-to-GNP ratio from 11.1% in 1991 to 12.8% in 2002. Energy input was assumed to grow at a rate .5 percentage points below potential GNP. Labor force estimates for eight demographic groups were derived from an econometric model of labor force participation described below. The projections for inputs and potential output were reached by an iterative procedure.

Actual GNP growth was assumed to parallel the growth of potential output. The unemployment rate is projected to fall from its steady state value of 4.6% in the late 1980's to 4.4% in the 1990's as the result of a decline in share of teenagers in the labor force.

Labor Force

Labor force projections through 1990 were based on the findings published in the study "The Labor Force Input to Potential Growth" in the Summer 1977 Data Resources U.S. Long-Term Review. In this study, a model for labor force participation rates through 1990 were estimated with eight separate age-sex groups. Explanatory variables in different groups included military employment, real wages, the unemployment rate, unemployment benefit payments, aid-to-dependent children payments, the ratio of small children to women in the childbearing age group, and the married male unemployment rate. Departing from the more exploratory spirit of the published study, judgmental assumptions were imposed on the growth in the participation rates of women in the two younger categories, restraining their rise. For this reason, and because the Census Bureau has provided revised population forecasts, the labor force projections for 1977-1990 differ in detail from those in the published study.

The equations of this model, after these adjustments, were solved through 1999, the last year for which the Census Bureau has provided annual population forecasts. These projections are displayed in Table 2. Labor force estimates for the years 2000-2002 were made by extrapolation.

Housing

Housing starts, residential investment, and the stock of residential capital were projected by estimating headship rates for seven age groups. The headship rate is defined as the number of households as a percentage of population. The change in the housing stock was assumed to equal the change in occupied units, or households, implying no change in vacancies.

TABLE 3

Projected Headship Rates by Age Group*

	1980	1985	1990	1995	2000
Age Group					
20-24	30.0	31.3	32.5	33.8	35.2
25-29	48.0	50.0	51.3	52.5	53.7
30-34	52.0	54.0	56.0	58.0	60.2
34-44	52.5	53.5	54.3	55.0	55.4
45-54	54.0	54.3	54.6	54.8	55.2
55-64	58.0	58.5	59.0	59.5	60.0
65 and Over	66.0	68.5	71.0	73.0	75.0
20 and Over	51.9	53.6	55.3	56.7	57.7

*For historical plots, refer to The Data Resources U.S. Long-Term Review, Winter 1977, pp. 1.22-23.

THE EXTENDED DRI LONG-TERM PROJECTIONS, 1990-2002

by Sara Johnson and Douglas C. Rice

DRI has extended its June 1977 long-range projections for the U.S. economy to encompass a 25-year planning horizon. Projections through 1990 were developed in the simulation "TRENDLONG0677" of the DRI Quarterly Model. Due to the complexity, costs, and diminishing reliability of large-scale model simulations beyond 1990, alternative econometric methods were used to derive projections for 1990-2002 for a subset of approximately 100 variables.

Potential GNP

The framework for predicting the economy's growth path is a model of potential GNP reported in the Summer 1977 Data Resources U.S. Long-Term Review.¹ This model translates assumptions about the growth of labor supply, capital, and energy input into estimates of potential output based on historical productivity trends. For the years 1990-2002, potential real growth is projected to slow to a 2.8% to 2.9% annual rate. The principal explanation for the deceleration is the slowdown in labor force growth as retirement ages fall, participation rates of women rise at a more gradual pace, and the age structure shifts. The growth of productive inputs and their contribution to potential GNP is summarized in Table 1.

TABLE 1

Determinants of Potential GNP Growth, 1975-2002

	1975-1980	1980-1985	1985-1990	1990-1995	1995-2000	2000-2002
Compound Annual Growth Rates						
Labor Force	1.81	1.57	1.41	.97	1.12	1.35
Nonresidential Capital	2.56	3.49	3.47	4.26	4.00	3.57
Residential Capital	3.03	3.58	3.29	2.66	2.55	2.55
Energy	3.75	2.43	2.38	2.33	2.33	2.33
Contributions to Potential GNP Growth*						
Labor Force	1.14	.99	.89	.61	.71	.85
Nonresidential Capital	.59	.80	.80	.98	.92	.82
Residential Capital	.28	.34	.31	.25	.24	.24
Energy	.16	.10	.10	.10	.10	.10
Input Productivity	1.19	.89	.89	.89	.89	.89
Potential Output Growth	3.36	3.14	3.01	2.82	2.86	2.90

*The contribution to growth is equal to the input's rate of growth multiplied by its average share in total factor costs. Input productivity can be broken down into three components: research and development effort (.12); an age of equipment effect (.10); and the residual (.67).

¹Brinner, Roger E., "Potential GNP Projections," The Data Resources U.S. Long-Term Review, June 1977, pp. II.31-39.

TABLE 2

Full-Employment Labor Force Projections, 1976-1999

	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989
Male Participation Rates (1)														
Total.....	74.4	74.4	74.2	74.0	73.9	73.9	73.9	73.9	74.0	74.0	74.1	74.1	74.1	74.1
Ages 16 to 24.....	71.4	71.2	72.0	72.3	72.6	72.8	73.1	73.4	73.7	74.0	74.3	74.6	74.8	75.0
Ages 25 to 54.....	89.4	89.3	89.0	88.9	88.8	88.7	88.6	88.6	88.6	88.6	88.6	88.6	88.6	88.6
Ages 55 to 64.....	73.6	72.9	72.0	71.3	70.6	70.0	69.4	68.9	68.5	68.0	67.6	67.1	66.7	66.3
Ages 65 and over.....	19.5	19.1	18.6	18.2	17.8	17.6	17.3	17.1	16.9	16.8	16.7	16.5	16.3	16.1
Male Civilian Labor Force														
Total.....	56.5	57.3	58.0	58.7	59.4	60.1	60.7	61.3	61.9	62.5	63.1	63.7	64.2	64.6
Ages 16 to 24.....	13.2	13.4	13.6	13.7	13.8	13.7	13.6	13.4	13.2	13.0	12.8	12.7	12.5	12.4
Ages 25 to 54.....	34.5	35.1	35.6	36.2	36.9	37.6	38.3	39.2	40.0	40.8	41.6	42.5	43.3	44.1
Ages 55 to 64.....	7.0	7.0	7.0	7.0	7.0	7.0	7.0	7.0	6.9	6.9	6.9	6.7	6.6	6.5
Ages 65 and over.....	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Male Population														
Total, Ages 16 and over.....	75.9	77.0	78.2	79.3	80.3	81.3	82.1	82.9	83.7	84.4	85.2	86.0	86.7	87.4
Ages 16 to 24.....	18.5	18.7	18.9	18.9	19.0	19.0	18.6	18.3	17.9	17.6	17.3	17.0	16.7	16.5
Ages 25 to 54.....	38.6	39.3	40.0	40.7	41.5	42.4	43.3	44.2	45.1	46.0	47.0	48.0	48.9	49.7
Ages 55 to 64.....	9.5	9.6	9.7	9.8	9.9	10.0	10.1	10.1	10.1	10.1	10.1	10.0	9.9	9.8
Ages 65 and over.....	9.4	9.4	9.6	9.8	9.9	10.1	10.2	10.3	10.5	10.7	10.9	11.1	11.2	11.4
Female Participation Rates (1)														
Total.....	47.4	47.7	48.1	48.5	48.9	49.5	50.1	50.7	51.3	52.0	52.6	53.1	53.6	54.1
Ages 16 to 24.....	60.3	61.0	61.9	63.0	64.2	65.7	67.1	68.6	70.2	71.8	73.6	74.2	75.3	76.0
Ages 25 to 54.....	56.3	56.8	57.3	57.8	58.3	59.0	59.9	60.8	62.0	63.2	64.3	65.5	66.6	67.7
Ages 55 to 64.....	49.7	49.9	50.1	50.2	50.4	50.5	50.6	50.7	50.8	50.9	51.0	51.1	51.2	51.3
Ages 65 and over.....	7.7	7.6	7.4	7.3	7.2	7.2	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.8
Female Civilian Labor Force														
Total.....	39.0	39.9	40.9	41.8	42.7	43.8	44.8	45.8	46.8	47.9	48.9	49.9	50.8	51.7
Ages 16 to 24.....	12.9	13.2	13.5	13.7	13.9	14.2	14.5	14.8	15.1	15.4	15.7	16.0	16.3	16.6
Ages 25 to 54.....	15.7	16.3	16.9	17.6	18.3	19.0	19.7	20.4	21.3	22.2	23.1	24.0	25.0	26.0
Ages 55 to 64.....	11.3	11.4	11.4	11.4	11.5	11.5	11.5	11.6	11.6	11.6	11.7	11.8	11.9	12.0
Ages 65 and over.....	1.0	1.0	1.0	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1	1.1
Female Population														
Total, Ages 16 and over.....	82.4	83.6	84.9	86.1	87.3	88.4	89.4	90.4	91.2	92.1	93.0	93.9	94.7	95.5
Ages 16 to 24.....	18.1	18.4	18.5	18.6	18.6	18.5	18.3	18.0	17.6	17.3	16.9	16.7	16.4	16.1
Ages 25 to 54.....	27.9	28.7	29.5	30.4	31.3	32.3	33.2	34.2	35.1	36.0	36.9	37.6	38.2	38.8
Ages 55 to 64.....	22.3	22.8	23.3	23.8	24.3	24.8	25.3	25.8	26.3	26.8	27.3	27.8	28.3	28.8
Ages 65 and over.....	13.6	13.8	14.1	14.3	14.6	14.9	15.1	15.4	15.6	15.8	16.0	16.3	16.5	16.7
Total Participation Rates (1)														
Ages 16 and over.....	60.3	60.5	60.6	60.7	60.9	61.2	61.5	61.8	62.2	62.5	62.8	63.2	63.4	63.7
Ages 16 to 24.....	65.7	66.4	67.3	67.7	68.4	69.3	70.2	71.0	72.0	72.8	73.6	74.4	75.1	75.8
Ages 25 to 54.....	69.7	69.5	69.5	69.6	69.7	69.9	70.2	70.5	70.9	71.3	71.5	72.2	72.6	72.9
Ages 65 and over.....	12.5	12.3	12.0	11.7	11.5	11.4	11.2	11.1	11.0	10.9	10.8	10.7	10.6	10.5
Total Civilian Labor Force														
Ages 16 and over.....	95.5	97.2	98.8	100.5	102.1	103.9	105.5	107.1	108.7	110.3	112.0	113.7	115.1	116.5
Ages 16 to 24.....	24.0	24.6	25.0	25.4	25.7	25.9	25.9	25.7	25.6	25.4	25.2	25.1	24.8	24.5
Ages 25 to 54.....	68.9	69.7	70.9	72.2	73.6	75.1	76.8	78.5	80.3	82.1	83.9	85.6	87.3	88.9
Ages 65 and over.....	2.9	2.8	2.8	2.8	2.8	2.8	2.8	2.8	2.7	2.7	2.7	2.6	2.6	2.5
Total Population														
Ages 16 and over.....	158.3	160.6	163.1	165.4	167.7	169.7	171.6	173.3	174.9	176.5	178.2	180.0	181.4	182.9
Ages 16 to 24.....	36.6	37.3	37.4	37.6	37.6	37.4	36.9	36.2	35.5	34.9	34.2	33.7	33.1	32.5
Ages 25 to 54.....	98.8	100.4	102.0	103.8	105.5	107.4	109.4	111.4	113.3	115.2	116.9	118.6	120.3	121.9
Ages 65 and over.....	22.9	23.2	23.7	24.1	24.5	24.9	25.3	25.7	26.1	26.7	27.1	27.6	28.1	28.5

(1) Civilian Labor Force divided by Total Population for the Age Group

i

i

Projected headship rates over time were extrapolated along a trend line. Despite the steady upward trend in headship rates, the growth of households is expected to slow during the 1990's due to the changing age composition of the population. Throughout the 1990-2002 period, the population in the household-forming age group (ages 21-28) will be declining. The total number of households is projected to increase by 14 million between 1990 and 2002.

Housing starts were derived from the change in demand plus stock of replacement, assuming (1) an average depreciation rate of .00642, (2) 95.7% of housing starts are completed, and (3) mobile homes comprise 5.45% of the housing stock. To project real fixed residential investment, an equation was estimated in logarithms annually over the 1960-1976 period, relating investment to housing starts and lagged real disposable income.

Inflation

The model simulation TRENDLONG0677 projects an inflation rate of 4.5% in the period 1983-1990, when the economy is expanding along its high employment growth path. Since similar macroeconomic conditions are assumed for the 1990's, a 4.5% trend inflation rate was extrapolated through 2002. Relative wage and price trends were established after considering (1) model simulation results for the 1983-1990 period, (2) average rates of change of individual wage and price indexes over history, and (3) plots of relative wage-price-productivity movements over history. Output per manhour in the private sector was assumed to grow at the historical trend rate of 2.2%. Compensation per manhour was projected to rise 6.7% annually, with unit labor costs rising at a 4.5% rate. Consumer goods, agricultural, and durable equipment prices show smaller increases than the GNP deflator, while the labor-intensive construction and government sectors continue to exhibit relatively high inflation. To ensure consistency with the aggregate inflation assumption, a weighted sum of individual price deflators was calculated, using projected real final demands as a share of real GNP as weights.

Incomes

The components of national income were analyzed as shares of GNP or shares of the appropriate aggregate. The projections of capital consumption allowances (CCA) were based on the model equation, using business fixed investment as the explanatory variable. Assuming indirect taxes (TX) claimed 9.2% of GNP, business transfers (VBUS) equal to 0.376% of GNP, government subsidies less current surplus (SUB@SRPG) equal to \$12.5 billion, and a statistical discrepancy (STAT) of zero; national income was derived from the identity

$$YN = GNP - CCA - TX - VBUS - STAT + SUB@SRPG$$

Historical trends in income composition were extended, adjusting for a rising capital-labor ratio during the 1990's. Profits and business interest as a share of GNP rise, while entrepreneurial and rental income decline relative to GNP. Wages, salaries, and supplements (WSS) was forecast using the equation

$$WSS = \exp(1.85 + 1.03 * \log(EEA) + 0.90 * \log(JRWSSNF))$$

where,

EEA = Nonagricultural employment

JRWSSNF = Compensation per manhour index, nonfarm business sector

Another equation relating contributions for social insurance to employment and compensation was estimated and used in the projections.

Corporate tax rates were assumed to decline by 0.4 percentage points per year, following a historical trend. The dividend payout ratio was projected to rise toward the 50% mark which survey evidence suggests as the most common target payout ratio.²

Personal income (YP) was calculated from the identity

$$YP = YN - ZBADJ - TW + VG + YINTPER + DIV + VBUS$$

where,

YN	= National income
ZBADJ	= Corporate profits before tax with inventory valuation and capital consumption adjustments
TW	= Contributions for social insurance
VG	= Government transfer payments to persons
YINTPER	= Personal interest income
DIV	= Dividends
VBUS	= Business transfer payments

Personal taxes were set at a level which would keep the government budgets near balance. The ratio of personal taxes to personal income rises by .002 per year.

Interest Rates

The interest rate projections of TRENDLONG0677 were extended through 2002, allowing for some covariation with relevant loan demands implied by the investment projections. Historical interest rate differentials were also considered in deriving the projection.

Production Index and Employment Projections

The projections for the two-digit and aggregated production indexes were developed from a study of the historical trend performances of individual industries relative to aggregate production.

The aggregate production index (JQIND) was forecast on the basis of a simple, statistically reliable relationship to gross national product. For each of the disaggregated categories and two-digit industries, historical relationships were plotted through time: specifically, the ratio of the individual production index to the aggregate measure. A majority of these relationships have exhibited an identifiable trend pattern over time. These relationships were extended or modified to reflect anticipated long-run constraints (e.g., the changing mix of

²Lintner, John, 1976, "Distribution of Incomes of Corporations Among Dividends, Retained Earnings, and Taxes," S.C. Myers, ed., Modern Developments in Financial Management (Praeger, New York), pp. 78-94.

energy sources). By examining each plot and measuring the slope of the trend relationship (s), the indexes were projected by applying the formula

$$JQINDx_t = JQIND_t \left(\frac{JQINDx_{t-1}}{JQIND_{t-1}} + s \right)$$

for each disaggregated industry x in each time period t.

Employment by industry was projected by examining historical plots of productivity trends as measured by the logarithm of the ratio of production to employment in each industry. Most industries showed a stable rate of productivity change, and the trends were again extended by measuring the slope of the relationship (s) and applying the formula for employment in industry x in time period t

$$Ex_t = \frac{JQINDx_t * Ex_{t-1}}{JQINDx_{t-1} * e^s}$$

The implied aggregate employment levels were then calculated and checked against the employment implied by labor force and unemployment rate projections to insure that the process had not produced any significant bias over time.

CHAPTER VII

GLOSSARY

This glossary briefly defines special terms used in the ISTUM documentation. Chapter references are to volume 1 unless otherwise noted.

1. Actual Market Share

The actual market share of a technology in a market segment is the fraction of all units sold in that market segment which will actually be of that technology. Usually expressed as a percentage. The actual market share includes the effect of behavioral lags, while the nominal market share is before lags are allowed for. (Chapter IV.C.)

2. Building Block

The basic unit from which technology costs are built up. Each technology is divided into its fundamental cost building blocks, such as site preparation and environmental controls. Also called a "cost component". (Chapter II.B.)

3. Behavioral Lags

The phenomenon where new technologies are adopted more slowly than their ostensible costs would indicate. (Chapter IV.C.)

4. Capital Charge Rate

The number which multiplies a one time capital expenditure to convert it into an equivalent annual amount. Its value depends

on the tax and financial characteristics of the firm making the capital expenditure. (Chapter IV.B.2.b.)

5. Capital Turnover

The phenomena by which old capital equipment is gradually replaced by new equipment, of the same or a different type. (Chapter IV.D.)

6. Cost Component

See "Building Block"

7. Cost Frequency Distribution

A diagram showing the fraction of the U.S. market which would experience each possible cost if it tried to install a technology. Each building block has its own cost frequency distribution; each technology also has one, constructed from the cost frequency distributions of the building blocks which constitute it. These are not probability distributions in the sense in which that term is usually used. (See "Technical Uncertainty") (Chapters II.B and IV.B.2.c.)

8. Combustor Size

The output of an individual energy combustor. It is measured in million Btu's of service demand per hour. For conservation technologies, it is the number of Btu's of service demand displaced per hour. (Chapter II; Volume 4.)

9. Date of Availability

The year in which the first commercially built unit of a technology could come on stream. (Chapter II.D.)

10. Efficiency

The ratio of service demand produced to fuel consumed. Depends on the technology. (Chapter II.D.)

11. Incremental Demand

The total demand for new equipment, of whatever type, in a particular market segment. Incremental demand = New demand (growth in total energy requirements) + retirement. (Chapter IV.D.)

12. Interdependencies

The phenomenon in which the costs or maximum fraction of one technology depends on those of another. Interdependencies will be greatest between technologies which are the most similar. The opposite of "interdependent technologies" is "independent technologies". (Chapter IV.B.)

13. Levelized Fuel Prices

Fuel prices adjusted for the fact that they will be rising in future years. A decision maker is indifferent between paying the levelized fuel price for the life of his combustor, or paying the actual price which applies in each successive year. Calculating levelized fuel prices requires a knowledge of the discount rate or the decision maker, and also a knowledge of what he thinks fuel prices will do in the future.

14. Load Factor

The fraction of full rated output that a combustor actually delivers in a year. Measured in hours per year (with 100% equalling 8760 hours per year). Load factor thus takes into account both the fact that combustors are completely shut down for part of the year, and the fact that when operating

they operate at less than full rated output. Sometimes also called capacity factor. The load factor a combustor is operated at is a property of the application, rather than of the technology used. It has a great effect on the cost per million Btu of capital intensive technologies. (Chapter III.C.6 and Volume 3 for estimating the load factors in different service sectors; Volume 4 for the effect of load factor on costs.)

15. Market Segment

A portion of the United States industrial energy market. Usually broken down by year, combustor size, combustor load factor, SIC, and service sector. The competitiveness of a technology depends greatly on what market segment it is in. (Chapter III for estimating the demand in each market segment.)

16. Maximum Fraction

An upper limit on the fraction of a market segment which could be captured by a technology. Usually expressed as a percentage. A technology could have maximum fraction less than one because of environmental restrictions, heterogeneity within a market segment (such as having some demands at temperatures higher than could be reached by that technology), etc. (Chapter II and Volume 4.)

17. MMBtu

Abbreviation for million (10^6) Btu. A unit of either fuel or service demand. See "quad" for conversion factors into physical units.

18. Non Boiler

The energy market is sometimes divided up into "boilers" and "non boilers". In ISTUM, service sectors 2 through 23 are non boilers.

19. Nominal Market Share

The fraction of a market segment which should theoretically be captured by a technology, when only equilibrium economics are considered. See also "actual market share". (Chapter IV.B.)

20. Quad

Unit of energy use. Equals a quadrillion (10^{15}) Btu's. The following physical amounts of fuel equal one quad of energy.

Coal: 42 million tons (depends on coal type and source)

Crude oil: 172 million barrels (470,000 barrels per day for one year)

Residual fuel oil: 159 million barrels

Natural gas: .97 trillion cubic feet

Steam: .9 trillion pounds of steam (depends on temperature and pressure)

Electricity: 293 billion kilowatt hours

21. Service Demand

The amount of demand for useful energy, i.e., energy delivered to the final use. All energy demands in ISTUM are measured in Btu's of service demand, rather than Btu's of fuel required to provide that service demand. This is done to allow for the fact that some technologies have higher efficiencies.

22. Service Sector

A type of energy consumption, roughly corresponding to functional use. There are 23 service sectors currently in ISTUM; technologies are competed in 11 of these. (Chapter III.)

23. SIC

Short for Standard Industrial Classification code.
Used to refer to particular industries. For example, SIC 29 is the petroleum refining industry.

24. Technical Uncertainty

Refers to the fact that technologies which are not presently (1978) commercialized may not behave as predicted in the ISTUM technology data base. Technical uncertainty is not considered during market share calculations or in the cost frequency distributions. (Chapter IV.B.2.d.)

25. Theoretical Market Share

See "nominal market share".