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The Integrating Model of the Project Independence Evaluation System

Volume III — User's Guide

March 1979

Prepared for:
U.S. Department of Energy
Energy Information Administration
Assistant Administrator for Applied Analysis

Under Contract No. EC-77C-01-8558

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EIA Perspective

This contractor report was prepared by Logistics Management Institute and provides documentation of the version of the Project Independence Evaluation System (PIES) as it existed on January 1, 1978. Since that date, PIES has evolved into what is now called the Mid Range Energy Market Model (MEMM), a major component of the Mid Range Energy Forecasting System (MEFS). Major structural changes that have occurred between January 1, 1978 and January 1, 1979, are documented in the supplemental volume entitled, "Revisions to the Midterm Energy Market Model Relating to Natural Gas Regulation, Advanced Technologies, Coal Demand and Dynamics." Together, the six volume set of documentation, plus the supplemental volume on revisions, form the most comprehensive and up-to-date version of MEMM documentation currently available, documentation which significantly surpasses in both form and content the single volume published in January, 1977.

Although this documentation has not gone through the appropriate review process and clearance procedures to be published as an EIA endorsed report, it is currently being made available in its present form as an interim measure to satisfy many outstanding requests for MEMM documentation. As this report has not been submitted to comprehensive review, EIA does not endorse any information contained herein. The documentation is presently being subjected to comprehensive review both inside and outside the Department of Energy. A contract is currently in process to update it to the version used for the 1978 Annual Report to Congress (published in July 1979). This new version of the documentation report is intended to bring the MEMM documentation into conformity with EIA's documentation standards and to respond to any issues raised as a result of the review process. The results of the latter effort will result in a set of MEMM documentation fully cleared and endorsed by EIA, available in 1980.

PREFACE

This documentation describes the PIES (Project Independence Evaluation System) Integrating Model as it existed on January 1, 1978. The complete documentation consists of six volumes describing the various aspects of the Integrating Model as follows:

- Volume I is an executive summary, providing a simple, nontechnical overview of PIES.
- Volume II is a primer, describing and illustrating the basic inputs to the PIES algorithm.
- Volume III is a user's guide, describing scenario specification and the operational procedures for running the Integrating Model.
- Volume IV is the main model documentation, describing the theoretical basis of the Integrating Model and each of the supply submodels.
- Volume V is a code documentation, describing the data processing aspects of PIES: the data flow through the PIES programs, the functions performed by each program, the data inputs and outputs, and the PIES naming conventions.
- Volume VI is data documentation, containing the standard table used for the April 1978 Administrator's Annual Report, along with primary data sources and the office responsible. It also contains a copy of a PIES Integrating Model Report with a description of its contents.

The data and scenarios used in these volumes are those used in the 1972 EIA Annual Report to Congress, prepared by the Energy Information Administration. In all volumes, we refer to this report as the Administrator's Annual Report (AAR).

ACKNOWLEDGEMENT

This volume draws upon the PIES User's Guide prepared by Elizabeth Chase MacRae of the Energy Information Administration, Department of Energy and published as Volume XIV of the Project Independence Evaluation System (PIES) Documentation (FEA/N-77/115) by the Federal Energy Administration in June, 1977. .

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I. INTRODUCTION

PURPOSE OF THIS DOCUMENT

This is Volume III of a six-volume series documenting the Integrating Model of the Project Independence Evaluation System (PIES). Its purpose is to provide a potential PIES user with a description of how PIES operates with particular emphasis on the possible variations in assumptions and data that can be made in specifying alternative scenarios. Since PIES is an extremely complex system and is constantly evolving, actual operation of PIES is carried out with the assistance of a technical systems staff who are thoroughly familiar with the operational details of PIES. Consequently, this document does not include extensive listings of either computer programs or data bases, but provides instead a discussion of the basic operating concepts of PIES. More details on the structure and parameters of PIES may be found in the other volumes of this documentation series.

SCOPE OF THIS VOLUME

PIES provides the Department of Energy with its major mid-term energy forecasting and analysis capability. It consists of a number of complex inter-related computer models and associated data bases which can be used to project the state of the energy market in 1985 and 1990. By varying assumptions and data, the user can define alternative scenarios for the analysis of alternative energy issues.

PIES forecasts for the United States include detail on market equilibrium supply and demand for major fuels by region and sector. Also included are projections of domestic production, refining, and electric generation by region, import levels, and regional energy prices in each sector. The

International Energy Evaluation System (IEES), which is the international component of PIES, provides the capability for extending energy market analysis to the rest of the world. Finally, there is an economic impacts component of PIES which permits analysis of the impacts of energy market changes on variables such as gross national product (GNP), investment, personal income, and unemployment.

Section II of this document is an overview of the structure and components of PIES, with particular attention given to the PIES Integrating Model which forms the core of the system. It describes in general terms the assumptions and data that may be varied in producing alternative PIES forecasts and indicates the specific components of PIES where particular scenarios are implemented.

Section III discusses each of the PIES components in greater detail. The equilibrating mechanism, one of the three major components of the PIES Integrating Model, implements market equilibrium conditions including such variations as price regulation and taxes. Since energy market conditions are such an important component of PIES, several alternative market pricing schemes, such as natural gas regulation and crude oil entitlements, are discussed in some detail.

The Demand Model, another major component of PIES, is also described in Section III. The discussion covers not only the structure of the Demand Model itself and its interface with the PIES Integrating Model, but also the details of the macroeconomic forecast which is a major determinant of demand. There is also a discussion of the off-line models used to calculate savings from conservation programs and the penetration of solar/geothermal energy sources. These auxiliary models provide inputs to the Demand Model.

Section III also contains a description of the models, assumptions, and data which provide supply side inputs to the PIES Integrating Model. Oil and gas drilling and supply is described along with the assumptions and data which characterize oil and gas imports. The implementation of coal production and supply and the two major conversion activities, refining and electric generation, are also discussed. The refineries submodel converts crude oil into various refined petroleum products and establishes the relative magnitude of petroleum product prices. The electric utilities submodel forecasts capacity additions as well as electricity generation; its assumptions and data sources are described in some detail. The transportation system, which models the movement of energy products about the country, is also described in this section.

Section III concludes with a discussion of those aspects of PIES which extend the scope of the analysis beyond the national energy market. This discussion includes a description of IEES which produces equilibrium energy market forecasts for the world as a whole, taking into account productive capacity and international energy transportation costs. The methodology currently used to derive economic impacts of alternative energy policies and some of the caveats associated with these analyses is also discussed.

PIES produces a number of different reports as output from its various components. Section IV discusses two reports produced by the PIES Integrating Model: the PIES Integrating Model Report, and the Coal Transportation Report. This section also provides an interpretive guide to some of the more useful PIES satellite model reports.

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II. PIES OVERVIEW

INTRODUCTION

PIES is a system which can be used to produce forecasts of the state of energy markets and analyses of alternative energy issues. This section presents the major components of the system both in terms of their conceptual linkages and in terms of the actual processing procedure by which a scenario is implemented. Next follows a more detailed discussion of the PIES Integrating Model, which forms the nucleus of the system. Finally, there is a description of assumptions and data that may be varied to form alternative scenarios, along with references to other subsections in this document which provide the explicit details.

PIES STRUCTURE

PIES consists of a number of interrelated models and data sets. The central component of the system is the PIES Integrating Model which is a representation of the national energy system in which production, conversion, transportation, distribution, and consumption of energy takes place. Inputs to the PIES Integrating Model are generated by separate models of demand, oil and gas supply, coal supply, and refinery operation, each of which in turn requires inputs of data and assumptions. The separate demand and supply satellite models typically produce specialized output reports which contain background information which is more detailed and extensive than that which the PIES Integrating Model produces as its output.

In addition to forecasts of the national energy market which PIES produces, international energy forecasts are produced by means of the International Energy Evaluation System (IEES). This component is structured in a

manner similar to PIES and has associated models of demand and supply which provide inputs. IEES can be run in two modes: either the U.S. energy market is held fixed at some level and projections are made for the rest of the world; or the PIES Integrating Model itself is included in IEES to represent the U.S. component of the world energy picture.

Finally, the impacts of various energy market situations on the rest of the economy are projected using a variety of models and methodologies. These models permit analysis of energy market impacts on economic variables such as GNP, income, unemployment, household energy expenditures, and tax burdens. Inputs to the impacts models include not only forecasts of the state of the energy market, but also additional inputs on investment, costs, and expenditures which are either contained in the original assumptions or can be extracted from the output of the preliminary demand and supply models which feed the PIES Integrating Model.

The Components of the PIES Integrating Model

There are three principal components:

- A demand function, derived from an econometric demand model, which relates fuel quantities demanded to fuel prices. The demand function is represented by a mathematical equation which is linear in the logs of quantities and prices.
- An integrated supply function, derived from fuel-specific supply and conversion models, which shows the prices at which the energy market would be willing to produce and deliver specific fuel quantities. The integrated supply function is characterized by a linear program (LP).
- An equilibrating mechanism, which determines the energy market conditions which must be satisfied by demand and supply, and which controls the iterative process by which a market equilibrium is reached.

The PIES Integrating Model Framework is depicted in Figure II-1.

Final demand for a particular fuel, as characterized by the PIES demand function, depends upon the price of that fuel and the prices of alternative

FIGURE II - I
FRAMEWORK OF THE PIES INTEGRATING MODEL

fuels. The shape and position of the demand curves is governed by the general level of economic activity, the nature and extent of conservation programs, and by other demand-related scenario assumptions. The demand function involves demands for petroleum products, natural gas, coal, and electricity in each of 10 DOE regions, and in the major consuming sectors--residential, commercial, industrial, transportation, and raw material.

The energy production, conversion, and transportation activities, which constitute the integrated supply function, depend upon energy prices as well as upon assumptions about the resource base and technological costs and capacities. The integrated supply function deals with individual fuels in production, refining, and electric utility regions, and with the transportation of these fuels between regions. The linear programming (LP) framework simulates profit-maximizing market behavior by choosing the least costly methods and locations for producing basic fuel supplies, of refining petroleum into products, of generating electricity, and transporting final commodities to meet demand. Thus the LP methodology represents an integrated supply function by calculating the supply prices for any given set of quantities.

The equilibrating mechanism specifies the market conditions which are to be met. The market conditions typically deal with the implementation of price regulation, particularly average cost pricing for electricity, oil price control and entitlements, and natural gas regulation and allocation. The equilibrating mechanism then adjusts prices and quantities in the demand and integrated supply function until the market conditions are satisfied and quantities supplied equal quantities demanded of each fuel in each region.

Fuels, Sectors, and Regions

Figure II-2 depicts the flow of materials through the energy system as modeled in the PIES Integrating Model. Materials are disaggregated at

FIGURE II-2

SIMPLIFIED FLOW OF MATERIALS IN THE PIES
INTEGRATING MODEL

various points in the system in order to model important characteristics of the energy market. For example, crude oil is characterized by its place of origin (Indonesian, Alaskan North Slope, Louisiana Offshore, etc.) as a proxy for its specific attributes. The attributes of a crude oil determine the relative product yields and costs associated with refining. Coal supply is also disaggregated into 12 types, distinguished by their Btu and sulfur contents. Electric utilities are assumed to produce electricity from base load, cycling, and peaking (daily and seasonal) plants; the capital and other costs, and hence electricity prices, depend upon the choices for the four types of capacity. Finally, energy demand for each fuel is broken out by sectors (residential, commercial, industrial, transportation, and raw material) since different sectors respond in different ways to fuel prices.

The regional detail in the PIES Integrating Model is shown in Figures II-3 through II-6. The choice of regional breakout for each type of activity was determined both by the desire for useful regional distinctions, and by the availability of relevant data. Thus the choice of demand regions was based on a notion of geographical homogeneity since patterns of fuel consumption tend to depend upon climate. Supply regions for oil, gas, and coal are centered around major producing areas, and refinery regions are based on the distribution of refineries across the country. Using separate regional definitions for demand, supply, and refining helps to provide homogeneity and to ensure that transportation costs, which are calculated for region-to-region movements, are reasonable approximations to reality.

Price Trajectories and Dynamics

The PIES Integrating Model itself does not contain any explicit representation of the dynamics of energy market behavior. It produces forecasts of an equilibrium state of the market in 1985 and 1990, assuming that all

FIGURE II-3
DEMAND AND UTILITY REGIONS

FIGURE II-4
OIL AND GAS REGIONS
(NATIONAL PETROLEUM COUNCIL REGIONS)

FIGURE II-5
PIES COAL REGIONS

FIGURE II-6
PIES REFINERY REGIONS
(PADD REGIONS)

exogenous shocks and changes have been accommodated. There are, however, two ways in which energy market dynamics affect the PIES forecasts.

First, to provide some level of intertemporal consistency across 1985 and 1990, linkages are established between the forecasts with respect to electric utility capacity construction and costs. The 1985 forecast is used as a starting point for the linkages since that is the planning horizon on which interest is most often focused. For 1990, plants operational in the 1985 forecasts are treated as existing plants from an investment point of view.

The second way that dynamics are incorporated into the PIES Integrating Model is implicitly, through the shape of the demand and supply functions, and through the time dependence inherent in the demand elasticities computed. For energy demands, and for oil and gas supply, the trajectory of prices over time determines the quantity that will be demanded or produced in a particular target year. The demand and supply curves are based on a family of similarly shaped price trajectories, all of which start at historical values and fan out from there to different price levels in subsequent years. The characterization of the demand and supply curves in a particular year, say 1985, is in terms of the 1985 quantities and prices associated with each of the possible trajectories. PIES then equilibrates prices and quantities in 1985; no attempt is made to insure that earlier demand and supply prices (those lying along the trajectory which leads to the 1985 equilibrium prices) are compatible or that the implied quantities demanded and supplied are equal. In general, the 1990 equilibrium forecast will not lie along exactly the same price trajectories as the 1985 forecasts.

The PIES Processing Stream

Several distinct processing steps produce a PIES energy market forecast for a specific scenario. A schematic of the PIES Integrating Model is given in Figure II-7.

FIGURE II-7
PROCESS SCHEMATIC OF PIES

- * THERE ARE ACTUALLY TWO PREPROCESSORS FOR MODELING NATURAL GAS AND UTILITY DATA.
- ** THE DEMAND MODEL IS A SATELLITE MODEL TO PIES.

The first step is the determination and specification of the scenario assumptions and the development of the necessary supporting data if they do not already exist. On the demand side, the raw data developed in this initial step pass through one of several preprocessors to produce files in a standard format for use by the Demand Model itself. The second step on the demand side is to run the Demand Model to produce the data files containing the specification of the demand function.

On the supply side, the process is more complicated because there are more types of raw data and more preprocessors. Some initial information on scenario specification is passed to special supply models (e.g., the Mid-term Oil and Gas Supply Models) which produce transformed raw data. These data, along with information directly specified, are converted by a set of specialized preprocessors into standard tables. There are preprocessors and standard tables for each of the major supply side modules of PIES. The final step on the supply side is to run the matrix generator to combine all the standard tables into a single comprehensive LP matrix which characterizes the integrated supply function for the scenario.

The model structure which characterizes market equilibrium conditions can be constructed directly from the original assumptions. Model structure already exists for many special features such as average cost pricing of electricity, natural gas regulation, and oil entitlements.

The preliminary processing steps described above create the inputs to the PIES Integrating Model. A special subprogram called REVISE sometimes makes minor modifications to the LP matrix or to the demand function.

After PIES has produced its forecast, a report writer distills the resulting mass of numbers into a single coherent and useful report. Typically the report writer runs in conjunction with the PIES Integrating Model so there

is no lag between the creation of the solution file and the completion of the output report. A more detailed description of the processing stream is given in Section V, Operational Procedures for Running PIES.

SCENARIO SPECIFICATIONS

A variety of variables can be specified to define scenarios for the analysis of alternative national and international energy issues in PIES. This subsection describes the major variables briefly and indicates the subsections in Section III which discusses implementation in detail.

Import Prices and Availabilities (Oil and Gas Supply). The user may specify prices of imported crude oil, petroleum products, natural gas, liquefied natural gas (LNG) and import limitations.

Resource Base (Oil and Gas Supply, Coal Supply). Uncertainty regarding the extent and location of fossil fuel reserves is an important factor in energy market forecasts. Variations in the assumed resource base create alternative optimistic and pessimistic forecasts.

Production Costs and Constraints (Oil and Gas Supply, Coal Supply). Extra costs and production limitations represent the impact of environmental or other constraints.

Macroeconomic Forecasts (Demand, Economic Impacts). The economic forecast that drives energy demand specifies regional population, personal disposable income, value added in manufacturing, GNP and unemployment.

Conservation Programs (Demand). The effects of conservation programs can be incorporated into PIES forecasts through preliminary partial analysis done off-line, the results of which modify projected demand.

Price Regulations (Equilibrating Mechanism, Oil and Gas Supply). Average cost pricing of electricity, oil price controls, oil entitlements, natural gas regulation and allocation, and pricing assumptions for LNG and synthetic

natural gas (SNG) can all be part of the specification of market equilibrium conditions. In general, the implementation of oil or gas price regulation is carried out partly by the equilibrating mechanism and partly in the specification of oil and gas supply curves.

Taxes (Equilibrating Mechanism, Demand). Taxes can be applied to any fuels at any point in the system.

Electric Generation Costs and Capacities (Utilities). Items specified in the electric utility sector, include construction limitations for new plants, restrictions on the fuels used for electricity generation, load factors, and capital and operating costs.

Transportation Costs and Capacities (Transportation). Costs and capacities of transportation links can reflect environmental or other constraints.

Emerging Technologies (Demand, Utilities). Alternative assumptions can be made concerning the availability, cost, and penetration of solar and geothermal energy, both for direct use and in electric generation.

Most of the variables listed above can also be specified for the international energy market and used to define scenarios for IEES forecasts. The subsection in section III on International Energy Markets contains a more extensive discussion of the differences between PIES and IEES.

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III. PIES COMPONENTS

INTRODUCTION

This section discusses each of the three PIES Integrating Model Components in greater detail and, in the case of the supply component, each major energy sector. Included in this discussion are descriptions of the PIES satellite models which produce the raw data that is input to the PIES Integrating Model. Figure III-1 depicts these satellite models. This discussion is oriented to data and scenario specifications and also includes a description of IEES and a discussion of economic impacts.

THE EQUILIBRATING MECHANISM

The equilibrating mechanism forms the core of the PIES Integrating Model. Its particular usefulness, from a modeling point of view, arises from the fact that it permits the combination of distinctly different behavioral specifications into a single coherent model. On the supply side, the linear programming framework provides an appropriate structure for the large number of interrelated activities and processes which are involved in production, conversion, and transportation; the optimization inherent in the concept of an LP simulates the cost minimizing behavior of a competitive market system. This same LP framework, however, would not adequately represent the structure of energy demand and its joint nonlinear dependence on many price variables. Conversely, the use of nonlinear equations to characterize the integrated supply function would produce an impossibly complex system. Hence the demand and supply sides of PIES can best be characterized in quite different ways. The major purpose of the equilibrating mechanism is to tie the two different model structures together in order to

FIGURE III-1
PIES SATELLITE MODELS

produce an equilibrium forecast. In addition to its main purpose, special market conditions are specified and implemented in the equilibrating mechanism.

The equilibrium forecast produced by PIES projects quantities and prices which are consistent with one another from production, through conversion and transportation, to ultimate consumption. In equilibrium, quantities consumed equal quantities produced, minus any losses in conversion and transportation. Forecasted prices are consistent throughout the system and represent competitive market responses to costs, market conditions, and regulatory structure.

The steps in the equilibration are:

(1) Given a set of quantities demanded, the integrated supply function computes the regional marginal prices at which these demands could be satisfied.

(2) Regional, fuel specific supply-demand equilibria define regional market prices. In the absence of price distortions such as price regulations on fuel use taxes, the market prices are equal to the marginal prices computed in Step 1.

(3) The demand function is used to compute regional sectoral demand quantities for each product at these market prices.

(4) A test is made for convergence, i.e., the prices calculated in this iteration are compared against those from the previous iteration to see if they are within some specified tolerance. If so, convergence is attained. If not, proceed to Step 5.

(5) The old prices are averaged with the prices from the current iteration and the associated demand quantities are calculated. This averaging reduces changes between iterations.

(6) Return to Step 1.

Average Cost Pricing for Electricity

To model electric utilities as a regulated industry, the market price of electricity is set equal to the average cost of production, including a return on investment, instead of to the marginal price. The electric utilities sub-model, however, still makes capacity construction and operating choices on the basis of long-run marginal costs, after subtracting sunk costs of partially or wholly completed plants.

The computation of average cost begins with variable costs - the sum of fuel costs, nonfuel operating and maintenance costs for generating capacity and for transmission and distribution facilities, and general administrative and sales charges. Capital charges are derived by allocating the total cost of facility construction across the years the facility will operate such that the present discounted value of the allocation schedule is equal to the total capital cost. The sum of the annualized capital charge and the variable costs yields the total annual cost of electricity production. This figure is then divided by the quantity of electricity actually consumed to obtain the average cost of electricity.

Oil Price Controls and Entitlements

Controls on the price of oil restrict the oil supply curves in PIES to a single point--the quantity which will be supplied at the controlled price. Multi-tier pricing schemes are implemented by individual supply curves (or points) for production from each of the tiers.

Congress designed the oil entitlements program to compensate for inequities resulting from not all refiners having the same access to domestic crude oil at the low controlled price. Under the program, entitlements corresponding to the quantity of controlled domestic oil are issued to users of

imported crude in proportion to their use. The entitlements are sold to users of domestic crude who are required to have entitlements to purchase the lower priced domestic oil. The program equalizes the effective price of imported and domestic crude oil.

The entitlements program produces price differentials between the domestic supply or import prices and the prices perceived by refiners. Two considerations govern the size of these differentials. First, the perceived price for a barrel of controlled oil (the supply price plus the cost of the entitlement) must equal the perceived price for a barrel of imported oil (the import price minus the value of the entitlements sold). Second, the revenues paid and received for entitlements must be equal.

Once the price differentials for domestic crude and imported crude (positive and negative numbers, respectively) are computed, they are included in the model by adjusting the transportation costs for domestic and imported crude oil on the links which lead to refinery regions. Thus, refiners see a crude oil price which includes both transportation charges and the effect of the entitlements program.

Natural Gas Regulation

At present, natural gas is sold at a regulated price in the interstate market. Supply curves for interstate gas consist of a single point corresponding to the quantity that would be supplied at the regulated price.

Since the supply of interstate gas at the regulated price is not generally sufficient to meet demand, an allocation scheme distributes the available supply. Available supplies of interstate gas are allocated to regions based on their historical shares (to represent existing contract commitments), and then to the residential, commercial, raw material, and industrial sectors within each region (representing the FERC priority structure). After the interstate

allocations are determined, imported Canadian gas, SNG, Alaskan gas, and LNG are rolled in to region-specific interstate supply. Remaining unsatisfied demands in each region are met either by intrastate gas at its marginal price, or by a mix of substitute fuels whose composition depends upon existing fuel switching capabilities and relative inefficiencies.

Taxes

The equilibrating mechanism models taxes by adjusting the costs on appropriate transportation links in the integrated supply function or by adjusting the sectoral markups from wholesale to retail prices. By choosing the appropriate transportation links or markups, taxes are applied differentially to each fuel and sector. For example, a tax on utility consumption of distillate would be applied on the transportation links from refineries to utility regions and on the links which bring imported distillate to utility regions. A similar tax on industrial distillate would be added to the markups which convert demand region prices into sectoral retail prices.

DEMAND

A major component of PIES is the Regional Demand Forecasting model (RDFOR) which generates the demand functions used by the PIES Integrating Model. This behavioral model consists of equations derived econometrically from historical data. The forecasting program of RDFOR uses these equations to produce annual forecasts of energy demand by fuel, sector, and region from the present through 1990. The inputs to RDFOR forecasts include:

- The path of fuel prices by sector and region from the present to 1990.
- Forecasts of population, income, and industrial activity through 1990.
- Impacts of conservation programs.
- Forecasts of dispersed solar/geothermal consumption.

This subsection describes the interface between the RDFOR model and the PIES Integrating Model, the structure and operation of RDFOR itself, and the scenario variations that can be implemented.

RDFOR/PIES Interface

RDFOR is a dynamic model; quantities forecasted in any particular year depend upon the values of the input variables not only in that year, but also upon the values in earlier years. For example, a price path with gradually rising prices over time will produce a 1985 quantity forecast which is quite different from that produced by a price path on which prices take a sudden upward leap, even if both price paths show the same price level in 1985.

Since the PIES Integrating Model uses static demand functions, i.e., relations between prices and quantities in a single year, certain established conventions move the dynamic forecasts of RDFOR to static demand curves.

The first step is to consider a family of price paths which start at the actual 1975 price and which have similar shapes, shown in Figure III-2. The next step in developing the demand curves for PIES is to produce the forecasted quantities associated with each price path. The demand curves for, say, 1985 then consist of the prices in 1985 and the 1985 quantities associated with that price path as shown in Figure III-2.

FIGURE III-2
PRICE PATHS AND STATIC DEMAND CURVES

In actual practice, RDFOR does not produce forecasts for each price path. Instead, the demand curve in each year is approximated by a constant elasticity function such as

$$Q = Q_0 (P/P_0)^\epsilon$$

where (Q_0, P_0) is a particular quantity-price point on the demand curve (see Figure III-2), and ϵ is the elasticity.¹ The RDFOR model produces the forecasted quantity Q_0 associated with the price P_0 on a particular price path, and calculates the elasticity at that particular point on the demand curve. This information (prices, quantities, and elasticities, for 1985 and 1990) characterizes the demand function used by PIES.

In general, the "real" demand curves (those constructed from actual forecasts for each price path in the family of related paths) will not be constant elasticity curves. To make the approximation as accurate as possible, the price path about which the elasticities are calculated is chosen close to the anticipated equilibrium price solution from PIES.

RDFOR Model Structure

Figure III-3 depicts the major components of the RDFOR Model. Although they do not appear explicitly in the figure, salient features of the model include regionality of forecasts, price-sensitive fuel choice and fuel substitution, and dynamic adjustment of fuel demands to changing prices and economic conditions.

The preprocessors shown at the top of Figure III-3 take regionally specific raw data for price paths, macroeconomic forecasts, and some conservation program details affecting the transportation sector, and transform

¹"Elasticity" is the percent change in quantity demanded brought about by a 1 percent change in price. A "constant elasticity" demand curve has the same elasticity at each point on the curve.

FIGURE III - 3
STRUCTURE OF THE
REGIONAL DEMAND FORECASTING (RDFOR) MODEL

these data into standard format files which can be directly read by RDFOR. These inputs vary across different scenarios. Regional parameter values, which determine how responsive each equation is to prices and economic conditions, are also input to the model through a preprocessor. Parameters are estimated from historical information and remain invariant across scenarios.

The RDFOR model itself consists of groups of equations for each sector. Within each sector, the demand for each fuel is modeled jointly with the demands for other fuels, so that demands for fuels depend upon all prices. The majority of energy demand is modeled in this framework of joint fuel choice and substitution, and much of the rest of demand is assumed to depend upon at least some prices.

The energy demands which are modeled in RDFOR include energy used in the residential and commercial sectors, and most of the energy used in the industrial and transportation sectors. Consumption of primary energy by electric utilities, refineries, and natural gas pipelines is not part of the RDFOR model forecasts, but is modeled explicitly in the integrated supply function of PIES.

The immediate output of RDFOR is a set of annual demand forecasts and elasticities through 1990. These are then modified in an interface program which incorporates shifts in demand curves as a result of conservation programs, solar/geothermal energy consumption, and possibly other kinds of shifts (mandated boiler conversions, for example). This program finally produces the files containing the prices, quantities, and elasticities which specify the demand function for PIES.

Scenario Variations

The major areas for alternative assumptions in RDFOR are the macro-economic forecast, conservation programs, solar/geothermal use, and taxes.

The implementation of scenarios in each of these areas is discussed in the subsections below.

Macroeconomic Forecasts. Population, personal disposable income, and value added in manufacturing (total manufacturing, primary metals, and chemicals) are the primary macroeconomic inputs to the RDFOR model. Forecasts of these variables are needed at the regional level from 1976 to 1990. In addition, forecasts of certain variables are needed at the national level as input to the transportation sector. These variables include GNP, the unemployment rate, average wages per manhour, several Federal Reserve Board (FRB) production indices, and special transportation variables such as future driving speeds, proportion of multiple truck rigs and so forth.

Typically, forecasts of these variables (except for some of those used in the transportation sector) are obtained from the current forecasts produced by one of the standard large-scale macroeconomic model. Analyses of the sensitivity of energy market forecasts to macroeconomic assumptions are usually performed by parametrically adjusting growth rates of variables.

Conservation Programs. With the exception of conservation programs aimed at the transportation sector (efficiency standards, new car excise taxes, etc.) the fuel savings from conservation programs are calculated offline and are then incorporated into the RDFOR model as shifts to the demand curves.

The transportation sector can take into account new car efficiency standards and can produce forecasts either for the case where the standards (in terms of average new car Miles Per Gallon (MPG)) are assumed to be met or exceeded, or for the case where the manufacturers are assumed to be profit maximizers and respond to the combination of standards and civil penalties in their production, pricing, and sales. The latter case does not necessarily lead to the standards being met. Both the efficiency standards

themselves and the schedule of penalties for noncompliance can be specified for all years from the present to 1990. Excise taxes and rebates on new cars which are designed to penalize less efficient cars can also be simulated in the transportation sector.

The transportation sector produces forecasts of vehicles miles, new car purchases, total fleet size, average new car efficiency, average fleet efficiency, and the level of gasoline and diesel fuel consumption. The forecasts are calculated initially at the national level then are shared out to regions.

Conservation programs in other sectors are modeled outside of RDFOR, usually at the national level. In the residential and commercial sector there are fairly well developed auxiliary models of energy use which explicitly take into account appliance purchases, efficiencies, and utilization as well as thermal integrity of homes and buildings. These models which are driven by the same macroeconomic forecast and price paths used as inputs to RDFOR, permit specification of standards for new buildings, retrofit tax credits for existing buildings, subsidized weatherization programs, and efficiency standards for residential appliances. The residential/commercial energy use models project consumer behavior in terms of purchases and utilization of appliances and insulation, and the associated fuel consumption. The differences in fuel consumption between a base case with no conservation programs in effect and the case with specific programs implemented are the conservation savings, by fuel, attributable to the programs. The demand curves generated by the RDFOR Model are shifted by the amount of the savings so that the curves show less quantity demanded at each price.

In the industrial sectors, the end results of conservation programs are still fuel specific savings which are then applied to the demand curves generated by RDFOR.

For all the conservation shifts, the assumption of constant elasticity demand functions is retained. This means that, as shown in Figure III-4 the demand curve is shifted by the same percentage at each price. At the point (P_0, Q_0) , this percentage is equal to the specified amounts of conservation savings, so that the new demand curve passes through the point Q'_0 , where the difference between Q_0 and Q'_0 is the savings amount. The elasticity of the new curve is assumed to be the same as that of the old. This percentage shifting of the demand curve is compatible with the idea that there will be less effect of conservation programs at higher prices; the higher prices themselves will have induced some reduction in demand.

FIGURE III-4
DEMAND CURVE SHIFTS FROM CONSERVATION PROGRAMS

Dispersed Solar/Geothermal Energy. The extent of the displacement of traditional fuels by dispersed solar and geothermal energy is also calculated off-line by sector, fuel and region (use of solar and geothermal energy in the generation of electricity is modeled in the electric utility module of the integrated supply function). Since RDFOR does not represent fuel categories called "solar" or "geothermal," the use of these alternative energy sources does not appear in RDFOR forecasts except implicitly to the extent that demand for other fuels is reduced. Consequently, in order for the PIES Integrating Model report writer to produce a correct output report with dispersed solar/geothermal energy explicitly represented, the data on solar/geothermal displacements is provided not only to RDFOR but also directly to the PIES Integrating Model. In the future, PIES will be modified so that this data will be passed from the demand model.

Taxes. Since taxes on end-use energy represent a difference between the prices that consumers pay for fuels and the prices that suppliers receive, they are implemented only in the equilibrating mechanism of PIES where both supply and demand prices appear. From a theoretical point of view, there is no point to applying the tax in the RDFOR Model. Changing the price paths to include the amount of the tax merely causes the same demand curve to be specified in terms of a different point on the curve; the curve itself is the same and will result in the same PIES solution. However, since constant elasticity demand curves are approximations to the true RDFOR demand curves, it is better to develop the approximation about a point which is as close to the anticipated PIESIM solution as possible. Thus, in the tax case, the demand curves should be developed about a price path which includes the tax. Furthermore, if the tax is applied suddenly, then the shape of the

price paths change, so an accurate representation of the demand curve can only be made by using price paths with the tax applied.

OIL AND GAS SUPPLY

Oil and gas supply curves for PIES are constructed using two different methodologies. For the well-established producing areas of the lower '48 States (onshore and offshore) and portions of south Alaska, supply curves are derived using a detailed off-line oil and gas supply model. For more speculative sources, the supply curves are based on careful engineering analysis, judgment, and similar techniques.

This subsection describes the major features of the Mid-term Oil and Gas Model and the resulting domestic supply curves. It also covers the representation of oil and gas imports.

Projections of domestic oil and gas supplies are based on engineering and economic factors which affect production decisions. Unlike coal, oil and gas production both involve a mix of coproducts. Associated natural gas is often produced in conjunction with oil, while gas liquids often occur with natural gas. The model represents all these separate products whose proportion depends jointly on oil and gas prices. The model also maintains a distinction among primary, secondary, and tertiary or enhanced recovery oil production in each supply region.

The Mid-term Oil and Gas Supply Models are driven by a number of data inputs of which the more important are described below.

Resource Base. These data consist of regional estimates of potentially available oil and gas, both in old fields and in new fields, and stratified by recovery method--primary, secondary, and tertiary. Estimates of reserves, coupled with an expected market price, yield a schedule of exploratory drilling activity over time. Assumptions regarding the extent and location of

the resources may be specified by the user to define alternative scenarios.

Finding Rates. These factors are functions of cumulative production and drilling activity and help to project the amount of oil or gas which is located by exploratory and developmental drilling. Variations in assumptions regarding the undiscovered portion of the resource base affect these finding rate curves.

Recovery Factors. These regional factors determine how much of the oil or gas located will ultimately be produced by primary, secondary and tertiary recovery methods. When combined with regional lead times, these factors provide an allocation of oil and gas to proven reserves over time.

Decline Rates. These are based on regional information and affect the rate at which production occurs out of proven reserves.

Costs. These data include both investment costs needed to find oil or gas and convert it to proven reserves, and operating and maintenance costs necessary for actual production.

Price Trajectories. The pattern of oil and gas prices over time affects the annual production schedule and hence the production level in any given year. Supply curves are constructed from a family of related trajectories; the prices and associated quantities in a particular year then constitute the supply curve. Variations in the shape of price trajectories define price regulation scenarios.

These major data inputs plus other factors allow the model to derive regional supply curves for oil and gas in each year through projections of drilling schedules, reserve additions, and production profiles. Under price controls, there will typically be only a single possible price trajectory, which represents the controlled price. In this case, the supply curve reduces to a single point which shows the quantity supplied at the controlled price.

In the Federal Outer Continental Shelf (OCS), leasing constraints limit the resource base that can be developed. Therefore, drilling schedules for the offshore regions are derived from leasing rate instead of directly from an assessment of the resource base. Assumptions regarding lease sales and acreage leased can be varied for alternative scenarios.

Supply From Special Regions

Supply curves for special regions such as Alaskan North Slope, Beaufort Sea, the Naval Petroleum Reserves, and for shale oil, were constructed from detailed engineering analyses, taking into account the geological structure believed to underlie the region, and the most likely development program and its cost. For many of the special regions, especially north Alaska, the economics of production are closely related to the economics of the transportation systems which must be constructed. For example, although natural gas production may be economically attractive in Prudhoe Bay, it cannot be carried out until a pipeline is constructed to transport the gas to the lower-48. The gas must therefore be reinjected until the transportation capability is available. Eventually, gas reinjection limits the production of oil or gas liquids from the same site.

Imports

Imports of crude oil, petroleum products, Canadian natural gas, and LNG are also included in the integrated supply model. Imports of crude oil are made to refinery regions, imports of petroleum products and natural gas are made to demand regions, and imports of distillate, residual fuel oil and natural gas are made to utility regions. In each case, the price as delivered to the region includes all relevant transportation costs.

The price of imported crude oil is one of the key scenario variables in PIES. The usual assumption is that unlimited imports are available at whatever price is specified. The prices of imported petroleum products are tied to the crude oil price through constant markups. Natural gas and LNG imports are typically bounded in the model to represent an assessment of real world availabilities, but the bounds may be varied in response to alternative assumptions.

COAL SUPPLY

Coal supply curves in PIES are provided for several varieties of coal differentiated by two factors which are important in determining prices - Btu and sulfur content. Since both production and transportation costs depend on tonnage, energy from low Btu coal is proportionately more expensive than energy from higher Btu coal. The sulfur content also influences costs since it determines whether or not scrubbers are needed to meet environmental standards.

Coal supply functions are constructed for each coal supply region shown in Figure II-5. The functions consist of steps, each one of which represents coal from a different mine type, some mines already being in existence, and others yet to be opened. The price associated with each step is the price at which that mine will just keep operating, if it is an existing mine, or at which a new mine will open. The quantities along each step are estimates of the annual level of production which can be obtained from that mine at a given price.

The coal supply functions for each region result from a process of reserve allocation and mine costing. First, Bureau of Mines' estimates of the demonstrated coal reserve base are allocated to regions and coal types. Next, a variety of mine types are assigned to coal deposits in each region,

using historical data on regional mine types and geological information. The mine types include both deep and surface mines of varying sizes and geological configurations. Production estimates are then assigned to mine types, both existing and potential, and minimum acceptable selling prices per ton of coal are estimated. The selling price estimates depend on capital investment, labor costs, other operating costs, and miscellaneous factors such as reclamation costs and severance taxes. A regional coal supply curve for a particular coal type consists of all the production levels from different mine types arranged in order of increasing minimum selling price. Unlike oil and gas supply curves, the methodology for constructing coal supply curves does not depend upon price trajectories. It is implicitly assumed that a mine will operate in a particular year if the coal price in that year is at least as high as the minimum acceptable selling price associated with that mine.

Scenario variations for coal supply could involve changes in resource base assumptions and mining costs. In particular, environmental constraints on surface mining are modeled through appropriate respecification of costs.

REFINERIES

In the refineries submodel of PIES, each crude type is classified by its major attributes. These attributes determine the basic slate of petroleum products which a barrel of a particular crude will yield, and the cost of refining. A very detailed off-line model, the Refinery and Petrochemical Modeling System (RPMS), is issued to develop the characterization of base yields for each crude type. In addition, RPMS is also run in a number of other configurations to determine the cost and yields of further complex refinery operations which can convert one product into another. The results of this off-line analysis are used to approximate RPMS, with appropriate yields, costs of modifying yields, and refining capacity needs.

Product yields from refinery operations are specified in terms of gross output. However, certain amounts of the refined products are used by the refinery as fuel for its operations. This fuel use is subtracted from the gross refinery yields to obtain net saleable products. In some regions, natural gas may be used as a refinery fuel, substituting for residual fuel oil on a Btu equivalent basis.

Refining operations are limited by the available refinery capacity in each region. Therefore, in addition to operating existing refineries, PIES allows for the construction and operation of new facilities and new capacity at existing facilities. This means that the cost of refining crude oil into products increases with increasing volume since the costs of the new refinery capacity must be absorbed.

ELECTRIC UTILITIES

The electric utilities submodel of PIES characterizes the operation of existing facilities and the construction of new facilities so as to satisfy the demand for electricity at minimum cost in each region. Generating capacity is characterized by status (existing or new) by type (e.g., steam turbine), and by energy source (oil, gas, coal, nuclear, hydro, solar, geothermal). The mix of generating capacity in each region is chosen so as to minimize overall costs.

The electric utility sector of PIES requires considerable data input to describe the physical and financial characteristics of the electric utility industry. The structure and data requirements of the utilities sector are discussed in general terms below.

Since electricity cannot readily be stored, sufficient capacity must be provided to meet any likely peak demand. The average amount of capacity in use, however, is typically well below the peak. Since different types of

generating plants have different capital and operating costs, an electric utility will typically choose to have several different types of plants to make up its total capacity. Plants with high capital costs and low operating costs (such as nuclear and coal) are most effectively utilized as continuously operating base load plants. At the other extreme, plants with low capital costs and high operating costs are suited for occasional operation to meet peak load demand. In the middle are plants which are operated during periods when electricity demand is greater than can be satisfied by base load plants.

In PIES, electricity demand is not differentiated as base, cycling or peak. Therefore an assumption is made for each region as to how much of total annual electricity demand belongs to each category. Generation capacity is built and operated in four separate modes, base, cycling, daily peak, and seasonal peak loads, so as to satisfy each component of total electricity demand.

Generating Capacity

In PIES, electricity is generated in the least costly manner subject to constraints on capacity. Existing fossil fuel capacity is retired at prescribed rates based on announced utility plans, and mandated conversions (as assumed in each scenario) from oil and gas to coal are implemented. Other allowable fuel conversions built into the model are chosen based on economic considerations. For plants with long construction lead times or other construction limitations, upper bounds are placed on the capacity that can be built by a given year. The plant types typically constrained are nuclear, coal, hydro, solar, and geothermal. Scenario variations may specify alternative bounds on capacity construction.

For purposes of computing capital costs, discussed in a later section, new plant capacity is divided into two categories: committed and deferrable.

Committed plants are those which are close enough to completion to make delay or cancellation uneconomic, while the deferrable category includes plants which are less far along in planning and construction so that delay or cancellation is costly but possible. All committed plants must be completed; deferrable plants can be completed at a capital cost equal to the remaining investment needed.

Physical Operating Characteristics

The operating characteristics of electrical generation plants in each mode of service determine the efficiency with which fuels are converted to electrical energy and, hence, affect the cost of electricity. The "heat-rate" is the number of Btus of fossil fuel required to produce one kilowatt-hour of electrical energy. Heat-rates for all types of fossil fuel plants, with and without desulfurization equipment, and in each mode of service, characterize the fossil fuel to electricity conversion process in PIES. These heat-rate data change over time due to technological advances. Heat-rates for other types of plants (nuclear, hydro, solar, and geothermal) do not play a role in the PIES forecasts since there is no explicit representation of supply for these alternative energy sources. Scenarios which restrict the use of certain plant types in certain modes are typically implemented by specifying enormous heat-rates which make the plants prohibitively expensive to operate.

Plant capacity factors specify the amount of generating capacity needed to produce a certain number of kilowatt-hours of electricity in each service mode. Capacity factors, defined as $(\text{Actual Output})/(\text{Generating Capacity})$, are developed for each of the four modes in each region, based on the shape of the load duration curve for that region. The capacity factor associated with cycling plants, for example, depends on whether the electricity load is very high for short periods of time, or somewhat lower for longer periods.

The number of kilowatt hours may be the same in both cases, but the required generation capacity is not.

Capital and Operating Costs

Costs for existing and new plants affect the price of electricity generated. Construction costs for different kinds of plants vary by region and by the year of expected completion. Other capital costs are for transmission and distribution capacity, desulfurization facilities, and for plant conversions to other fuels.

Regional operation and maintenance costs (excluding fuel costs) for each plant type are constructed from historical data and discussion with manufacturers of electrical generating equipment. Fuel costs for fossil fuels are determined within PIES as part of the general supply-demand equilibrating process. Nuclear fuel costs are explicitly represented by nuclear fuel supply curves, developed from careful examination of the costs and constraints in all segments of the nuclear fuel cycle. The costs include those for mining and milling, conversion and enrichment, spent fuel shipping, reprocessing, and waste fuel disposal. For hydro, solar, and geothermal, fuel costs are assumed to be zero.

TRANSPORTATION)

The costs and capacity constraints on the transportation of energy materials from one region to another have important effects on regional demand and supply patterns especially for coal where the transportation costs per Btu are relatively high.

In the PIES Integrating Model, the transportation network for oil and gas is modeled as simple direct links between supply, refinery, and demand regions. Separate links are provided for each fuel type and transport mode: natural gas by pipeline, crude oil and petroleum products by pipeline,

tanker, and barge, and residual oil by tanker and barge. Since costs for coal transportation are relatively high, a more detailed transshipment network for coal by rail and barge is modeled.

Coal Transportation

Coal by rail moves between nodes on a rail network which interconnects most of the country's largest metropolitan areas. A waterways network also follows the major water routes available for coal shipment. Additional links connect coal supply regions to particular rail or waterway nodes, rail nodes and waterway nodes (thus allowing coal to be transferred from rail to barge), and rail nodes to utility and demand regions.

Costs of moving a ton of coal between nodes are associated with each link in the network. These costs include a fixed handling charge plus a mileage charge. In the case of links between two rail nodes or two waterway nodes, the handling charge is zero since there is no transfer of coal from one form of transport to another. Similarly, for links representing rail-to-barge or barge-to-rail transfers, there is only a fixed charge.

There are no capacity constraints on any of the coal transportation links, nor provisions for the construction of new links or additional capacity. These features, along with additional costs to represent congestion, could be part of alternative transportation scenarios.

Oil and Gas Transportation

The networks for movement of oil and gas are less complex than those for coal and involve direct links between supply, refinery, and demand or utility regions. These networks include links for shipping natural gas, crude oil, and petroleum products (except residual) by pipeline and for shipping crude oil, products, and residual fuel oil by barge or truck, since residual fuel oil will not flow through a pipeline system. Costs for moving crude oil

and products through existing pipelines are based on ICC tariffs. This tariff structure is also used to estimate the costs of new pipelines. For natural gas pipelines, not only are there dollar costs associated with gas transportation, but there is also a loss of natural gas itself used in running the pipeline pumps. Except for oil and gas shipments from Alaska, there are no constraints on quantities that move through the transportation network.

INTERNATIONAL ENERGY MARKETS

World production, consumption, and trade in energy commodities is forecasted by IEES,² a collection of models similar to the domestic portion of PIES but oriented toward international energy considerations. IEES can be run in conjunction with PIES to produce world equilibrium forecasts, or IEES can use an approximation to project PIES import demand as a function of world oil prices. The latter case is simpler and suffices for analyses dealing primarily with world oil trade.

The IEES Model Structure

IEES projects world energy balances and equilibrium prices for 1985 and 1990. International energy markets are assumed to be competitive markets involving oil, coal, natural gas, nuclear fuel, and hydro and geothermal energy, subject to distortions caused by national policies. The geographical detail in IEES consists of 33 regions which can be grouped in the following major blocks: United States; OECD³ countries (excluding the U.S.); OPEC;⁴ Non-OPEC LDC's;⁵ and another region category.

²For a more detailed documentation of IEES, see: The International Energy Evaluation System, Logistics Management Institute, Washington, D.C., Volume I, Executive Summary, May, 1978, Volume II, Technical Documentation, forthcoming.

³Organization for Economic Cooperation and Development.

⁴Organization of Petroleum Exporting Countries.

⁵Lesser Developed Countries.

IEES and PIES share a common methodology and differ primarily in the level of detail. Outside the United States, data on energy are often unreliable or missing so that a careful modeling of energy markets is often not possible. Most of the detail in IEES appears in the modeling of OECD energy consumption, which equals approximately 80 percent of world consumption.

The characterization of energy demand in IEES is in the form of a constant elasticity demand function derived from an econometric demand model involving energy prices and fuel substitutions, just as in PIES. Demand in each major OECD country is modeled separately in this manner. In the less developed countries (LDC's), only a simple ratio of energy demand to gross domestic product (GDP) is used. The demand sectors for the OECD countries are similar to those used for the United States, except that the iron and steel production, which is a major determinant of trade in metallurgical coal, is broken out from the rest of the industrial sector. Unlike the U.S. version, the transportation sector of the OECD demand model does not have a detailed characterization of automobile use for projecting gasoline demand.

In each region, supply curves for the various fuels are based on national forecasts and are thus simple point estimates rather than complete supply curves. In the case of OECD oil, a very low elasticity of supply is assumed. In the case of the OPEC nations, and particularly the "swing" group headed by Saudi Arabi and Kuwait, the concept of a supply curve is not entirely relevant. Due to oil revenues well in excess of current economic requirements, the Saudi group of oil suppliers determine world oil prices by

accepting production levels below their productive capacities; these suppliers are modeled in IEES as having perfectly elastic oil supply curves. In all other countries, production levels are assumed to equal productive capacity.

IEES can be run with an exogenously specified world oil price to derive the implied demand for oil from the Saudi group, or it can be run with a limit to production from the Saudi group in order to calculate the implied world oil price. In the former case, the exogenous world oil price can be calibrated within IEES so as to yield a given East Coast landed price of oil in the United States. This calibration feature is needed so as to allow IEES to be compatible with assumed import prices in PIES.

Electricity generation and crude oil refining are modeled explicitly only in the OECD countries. Unlike the U.S. model, IEES uses a three-mode approximation to each country's load duration curve. The form of the IEES refinery model is identical to that used in the United States.

The transportation components of IEES allow movements of raw materials and products between regions via tankers, bulk carriers, and pipelines. The important physical and technological limitations on the international distribution of energy set capacity limitations on transportation links. In IEES, the expansion of transportation capacities is permitted.

Scenario Variations

Many of the factors which can be varied to define scenarios for the U.S. energy market can also be varied for IEES scenarios. On the supply side, assumptions about the extent and location of world energy resources can be varied, as well as the characterization of the productive capacities and market shares of the swing OPEC oil suppliers. Macroeconomic assumptions can be varied to derive alternative demand patterns, and impacts of conservation programs can be incorporated as shifts to national or regional demand curves.

Since the electric generation and refining modules of IEES are basically the same as in PIESIM, the same sorts of variations on capacity and costs may be implemented. Unlike the U.S. version, the IEES equilibrating mechanism does not have the capability to model price regulation.

ECONOMIC IMPACTS

The forecasts produced by PIES do not include the effects of feedbacks between the energy sector and the rest of the economy. This means that the macroeconomic forecast driving PIES may not be compatible with the state of the energy market as forecast by PIES, i.e., the energy quantities and prices from PIES may imply a different level of economic activity than that expressed in the macroeconomic forecast. Ideally, a joint forecast of the macroeconomy and the details of the energy market should be made in PIES by iterating through the PIES Integrating Model, deriving the energy market implications for the macroeconomic forecast, using the revised forecast to develop new PIES forecasts and so forth until convergence is achieved. Ideally, the iterative process should also include international considerations as reflected in IEES.

Since the iterative process described above is time-consuming, it is usually not carried beyond the step at which the first macroeconomic forecast is derived from a PIES forecast. The analysis of economic impacts is then done in terms of comparisons between these first-order macroeconomic forecasts derived from alternative energy market assumptions. In addition to PIES forecasts, economic impact analysis requires additional data or assumptions concerning investment, tax revenues and rebates, and the like. Much of this information can be developed from the preliminary models which drive PIES.

None of the major macroeconomic models which are currently available can accommodate all of the energy sector data from PIES in a satisfactory manner. Since the variables in macroeconomic models are typically national aggregates, none of the regional detail from PIESIM can be incorporated. Moreover, there are conceptual differences between PIES and the usual macroeconomic models which preclude any direct substitution of PIES variables. The differences include both the level of aggregation at which variables are defined and a more fundamental difference in accounting frameworks; PIES deals in product prices and quantities while macroeconomic models forecast components of GNP.

The problems inherent in establishing linkages from PIES to the macroeconomic models are not present for linkages in the other direction primarily because the demand model component of PIES was explicitly designed to be driven by economic variables which are readily available in typical macroeconomic models. In contrast, the standard macroeconomic models were not designed with any idea of interfacing with PIES.

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IV. PIES OUTPUT REPORTS

INTRODUCTION

Several components of PIES produce output reports which may be of interest to the user. The principal one of these is the report which presents the PIES Integrating Model forecasts and is affectionately known as "Wonder Cookie" for reasons which have long since become obscure. The other output report which can be obtained from the PIES Integrating Model is the Coal Transportation Report. These reports are discussed below.

Besides these reports, the PIES satellite models also have their own reports. There is an output report from IEES which shows forecasted international energy balances, production, and trade. In addition, both the Demand Model and the Mid-term Oil and Gas Supply Models produce reports containing a considerable amount of background data, particularly about the time patterns of demand and production, which are not used directly in the PIES Integrating Model. Brief descriptions of these output reports are also given.

THE PIES INTEGRATING MODEL REPORT

This report displays the important features of the PIES Integrating Model forecast in terms of consumption, production, conversion, and transportation at both the national and regional levels. The title pages show which inputs were used for the integrated supply function and which demand files (characterized by date and time of creation) specified the demand function. There is also an indication of the version of the equilibrating mechanism that was used, and a summary of the important scenario assumptions.

The tables in the report are of several different types:

- Summaries of national levels of production, consumption, and imports by fuel and sector;
- Regional details of oil and gas production and distribution, and the allocation of natural gas shortages under price regulation;
- Regional details of coal production and distribution;
- Sectoral/regional energy consumption by fuel;
- Regional refinery fuel consumption;
- Regional electric utility fuel consumption and generating characteristics;
- Regional prices, including retail fuel prices in final demand sectors, and wholesale prices in demand regions, utility regions, refinery regions, and oil and gas supply regions.

The PIES Integrating Model Report (PIES Report) can be produced for each target year, each assumed oil price, and each scenario specification. Included in this subsection are four tables, with descriptions, from the PIES Integrating Model Report for the 1985 mid-range/TRENDLONG scenario, which assumes a normal rate of growth for the economy, natural gas regulation and an oil import price of \$15.32/barrel. Throughout this section, computer tables will be denoted by full capitals (e.g., TABLE 1) and internal tables within the volume will be denoted by initial capitals (e.g., Table 1).

TABLE 1: Executive Data Summary (Standard Physical Units)

TABLE 1 of the PIES Report summarizes energy production, consumption and import projections for 1985. The columns are fuel types, and the rows show distribution of energy fuel among imports, domestic consumption and domestic supply. The units are standard physical units per year, as listed in Table IV-1. Physical units for coal are million short tons (MMST) where a short ton is 2,000 pounds. The volume of oil imports in millions of barrels per calendar day (MMB/CD) is given in a footnote.

TABLE 1

1995 MID-RANGE/REFINING SCENARIO (SERIES C)
WITH NATURAL GAS REGULATION

OIL IMPORT PRICE: 15.32
RUN DATE: 1.14

EXECUTIVE DATA SUMMARY

UNITED STATES TOTAL GROSS SUPPLY/CONSUMPTION OF ENERGY RESOURCES
(ENERGY SOURCES IN STANDARD PHYSICAL UNITS PER YEAR)

SECTOR	COAL (MMST)	OIL (MMB)	GAS (BCF)	NUCLEAR (MMKWH)	HYDRO, SOLAR, GEOTHERMAL (MMKWH)	SOLAR/GEO FOSSIL GUST. (TRTU)	TOTAL ELEC. DISTRIBUTED (MMKWH)
DOMESTIC SUPPLY:	1033.98	1735.42	16725.86	565.62	410.02	119.86	3042.54
(COAL, GAS, ELEC.)	1033.98		11594.54	565.62	395.67		3042.54
(CRUDE)		1262.15					
(CO-PRODUCTS/ASSOC. GAS)		456.11	1221.32				
(SYNTHETICS)							
(SHALE)		17.15					
(DIRECT SOLAR/GEO)					14.35	119.96	
IMPORTS:	74.00-	4021.28	1848.07				
(CRUDE)		2829.99					
(PRODUCTS)		1192.29					
(LNG)			942.07				
(CANADIAN/MEXICAN)			905.00				
(COAL)	74.00-						
TOTAL SUPPLY	959.98	7756.69	18573.93	565.62	410.02	119.86	3042.54
GAINS (+) /LOSSES (-)		203.61		16.11-	15.70-		254.14-
CONSUMPTION:							
RESIDENTIAL	1.03	707.45	5251.75		4.46	43.39	341.10
COMMERCIAL	.56	596.96	1841.34		5.03	20.41	635.80
INDUSTRIAL	206.21	2044.22	9840.85		4.90	56.06	1225.84
TRANSPORTATION	.02	1901.61	194.50				4.05
ELECTRICAL GENERATION	745.50	541.31	2035.61				2766.43-
SYNTHETICS	13.66	169.11	472.16-				
TOTAL DOMESTIC CONSUMPTION	960.98	7960.65	18547.89		14.35	119.86	.00

NOTE: OIL IMPORTS IN MMBOB = 11.02

GAS CONSUMPTION IN THE TRANSPORTATION SECTOR INCLUDES NATURAL GAS TRANSPORTATION LOSSES.

INDUSTRIAL CONSUMPTION INCLUDES REFINERY FUEL CONSUMPTION.

GAINS ARE REFINERY GAINS. LOSSES ARE TRANSMISSION LOSSES.

SUPPLY/DEMAND IMBALANCES MAY BE DUE TO ERRORS WITHIN THE EQUILIBRATION CONVERGENCE TOLERANCE.

TABLE IV-1. PHYSICAL UNITS IN THE PIES REPORT

B	Barrel
BCF	Billion cubic feet
BCF/YR	Billion cubic feet per year
M	Thousand
MB/CD	Thousand barrels per calendar day
MCF	Thousand cubic feet
M.E. Ton	Material equivalent ton of 22.5 million Btu
MKWH	Thousand kilowatt hours
MM	Million (Thousand thousand)
MMB	Million barrels
MMB/CD	Million barrels per calendar day
MMB/YR	Million barrels per year
MMCF/CD	Million cubic feet per calendar day
MMMKWH/YR	Billion kilowatt hours per year
MMST	Million short tons (a short ton is 2000 pounds)
MMST/YR	Million short tons per year
MM\$/YR	Million dollars per year
ST	Short ton
T	Ton
TBTU	Trillion Btu
\$/BBL	(1978) Dollars per barrel
\$/MCF	(1978) Dollars per thousand cubic feet
\$/M.E. Ton	(1978) Dollars per material equivalent ton
MILS/KWH	(1978) Mils per kilowatt hour

The first column summarizes coal data. Indigeneous coal supply is given as 1,033.98 MMST/YR, and coal imports are noted as -74.00 MMST/YR. Negatively signed imports represent exports; thus, 74.00 MMST/YR of coal are exported, reducing the amount of coal available for domestic uses to 959.98 MMST/YR, as given in the total supply row.

Oil supply derives from several different sources; 3262.15 MMB/YR of crude is produced within the U.S. Co-products associated with crude oil production account for 456.11 MMB/YR and shale oil for 17.15 MMB/YR of indigenous OIL supply. Total imports for OIL amount to 4021.28 MMB/YR, of which 2828.99 MMB/YR are crude imports, and 1192.28 MMB/YR are refined petroleum product imports. Total oil supply is thus 7756.69 MMB/YR, which is total indigenous supply plus total imports. The 203.61 MMB/YR volumetric gain indicated in TABLE 1 occurs because the volume of petroleum products produced is greater than the volume of crude entering the refinery.

Indigenous gas supply is derived from gas wells that produce no oil (non-associated gas) and from oil wells that produce both liquid hydrocarbons and gas. The non-associated gas production entry, 13,504.54 BCF/YR is in the COAL, GAS, ELEC. row. The entry for associated and dissolved gas is found in the CO-PRODUCTS/ASSOC. GAS row. Total associated and dissolved gas production is given as 3,221.32 BCF/YR.

There are two columns with solar and geothermal references. The column labeled HYDRO, SOLAR, GEOTHERMAL relates to the generation of electrical power by utilities from these sources, which amounts to 395.67 MMMKWH/YR. The 14.35 entry in the DIRECT SOLAR/GEO row represents electricity demand reduction due to the substitution of solar and geothermal resources for electricity. For example, the use of solar heating in a residence to reduce the use of electricity would be represented in this category. The standard transmission line loss of electricity supply from the 410.02 MMMKWH/YR of electricity from HYDRO, SOLAR, GEOTHERMAL sources is 35.70 MMMKWH/YR. There is no loss associated with direct substitution of solar and geothermal sources for electricity. The SOLAR/GEO FOSSIL SUBSTITUTION column similarly reflects the reduction of fossil fuel demand resulting

from direct solar and geothermal substitution. A sectoral breakout of these numbers appears in the consumption portion of the Table.

Fuel consumption by sector is shown in the lower portion of TABLE 1. These consumption, or demand, sectors include residential, commercial, industrial, transportation, synthetics and electrical generation. To find the amount of coal consumed in the residential sector, we find the entry corresponding to the fuel type column, COAL, and the sector row, RESIDENTIAL; thus 1.03 MMST/YR of coal are consumed in the residential sector. Similarly, .56 MMST/YR of coal are consumed in the commercial sector, and 745.50 MMST/YR are consumed in the generation of electricity. Sectoral consumption amounts for the other fuel types are also obtained by looking down the fuel type column and across the sector row.

Total supply should equal total domestic consumption for each fuel type. A note at the bottom of TABLE 1 explains that slight imbalances between net supply and demand may be due to the convergence criteria used in the equilibration process.

TABLE 2: Executive Data Summary (Trillion Btu)

TABLE 2 is basically a repetition of TABLE 1 in which each entry is reported according to its Btu value thus allowing direct comparisons between fuel types. A number of summation columns have also been incorporated to aggregate across fuel types.

The SOLAR/GEO FOSSIL SUBST. column of TABLE 1 is not given as a separate column in TABLE 2 because of space limitations. It has been combined with the hydro, solar and geothermal entries, and a footnote gives the fossil fuel substitution amount as 119.86 TBTU. The amount of solar and geothermal substitution is given as 143.50 TBTU.

TABLE 2

1985 MID-RANGE/TERMOLOG SCENARIO (SERIES C)
WITH NATURAL GAS REGULATION

OIL IMPORT PRICE: 15.32
RUM DATE: 1.19

EXECUTIVE DATA SUMMARY

UNITED STATES TOTAL GROSS SUPPLY/CONSUMPTION OF ENERGY RESOURCES
ENERGY SOURCES IN TRILLIONS OF BTU'S PER YEAR

SECTOR	COAL	OIL	GAS	TOTAL FOSSIL FUEL	NUCLEAR	HYDRO SOLAR GEO.	TOTAL 6 SECTOR INPUTS	GROSS ELECT. INPUTS	TOTAL 4 SECTOR INPUTS	UTILITY ELECTRIC DISTRIB.	NET FOUR SECTOR INPUTS
DOMESTIC SUPPLY:	23062	21029	17261	61352	6222	4220				10381	
(COAL, GAS, ELEC.)	23062		13937	16999	6222	3957				10381	
(CRUDE)		18996		18986							
(CO-PRODUCTS/ASSOC. GAS)		1944	3324	5268							
(SYNTHETICS)											
(SHALE)		100		100							
(DIRECT SOLAR/GEO)						263					
IMPORTS:	1918-	21190	1907	23179							
(CRUDE)		16465		16465							
(PRODUCTS)		6725		6725							
(LNG)			972	972							
(CANADIAN/MEXICAN)			935	935							
(COAL)	1918-			1918-							
TOTAL SUPPLY	21144	44219	19168	84531	6222	4220	94973			10381	
GAINS (+) / LOSSES (-)		362-								867-	
CONSUMPTION:											
RESIDENTIAL	24	3026	5422	9272		89	9360	9656	19016	2870	12230
COMMERCIAL	13	3560	1900	5473		71	5544	7988	11532	2374	7919
INDUSTRIAL	5016	11302	10156	26474		104	26578	18069	40647	4181	30759
TRANSPORTATION		20954	411	21366			21366	46	21412	14	21380
ELECTRICAL GENERATION	15904	3328	2152	21385	6222	3957	31563			9439-	
SYNTHETICS	208	983	900-	196			196				
TOTAL CONSUMPTION	21166	43657	19141	84164	6222	4220	94606	31759	94606		72287

NOTE: GAS CONSUMPTION IN THE TRANSPORTATION SECTOR INCLUDES NATURAL GAS TRANSPORTATION LOSSES.

INDUSTRIAL CONSUMPTION INCLUDES REFINERY FUEL CONSUMPTION.

LOSSES ARE REFINERY CRACKING LOSSES AND ELECTRICITY TRANSMISSION LOSSES.

NUCLEAR AND HYD/SOL/GEO ENTERING ESTIMATE BTU CONSUMPTION FOR AN EQUIVALENT FOSSIL FUEL PLANT AT 10000 BTU/KWH.

SUPPLY/DEMAND IMBALANCES MAY BE DUE TO ERRORS WITHIN THE EQUILIBRATION CONVERGENCE TOLERANCE

OR AVERAGE BTU CONVERSION OF AGGREGATES.

DIRECT SOLAR/GEO SUPPLY INCLUDES FOSSIL FUEL DEMAND REPLACEMENT IN TBtus OF 119.96

AND ELECTRICITY DEMAND REPLACEMENT AT 16000 BTUS/KWH OF DEMAND IN TBtus OF 143.50

TOTAL SUPPLY QUADS NET OF REFINERY CRACKING LOSS: 94.61

TOTAL GROSS QUADS CONSUMED: 94.61

TABLE IV-2. CONVERSION FACTORS

<u>Item</u>	<u>Millions of Btus per Indicated Unit</u>
Crude Oil (all) (B)	5.800
Gas Liquids (B)	5.248
Butane (B)	4.010
Coal - High Btu, Medium Sulfur (ST)	23.800
Coal - Medium Btu, Medium Sulfur (ST)	21.800
Coal - High Btu, High Sulfur (ST)	23.800
Coal - Medium Btu, High Sulfur (ST)	21.800
Coal - Low Btu, Low Sulfur (ST)	18.330
Coal - Very Low Btu, Low Sulfur (ST)	13.000
Coal - High Btu, Low Sulfur (ST)	23.800
Coal - Very Low Btu, Medium Sulfur (ST)	13.000
Coal - Low Btu, Medium Sulfur (ST)	18.330
Coal - Medium Btu, Low Sulfur (ST)	21.800
Coal - Metallurgical (ST)	27.000
Electricity (MKWH)	3.412
Gasoline (B)	5.248
Distillate (B)	5.825
Residual (B)	6.287
Other Refined Petroleum (B)	5.000
Natural Gas (MCF)	1.032
Liquid Petroleum Gases (B)	4.010
Jet Fuel (B)	5.318

The fossil fuels (oil, gas and coal) and electricity represent the actual BTU contents of the fuels (see Table IV-2 for conversion factors). Entries for the HYDRO, SOLAR, GEO columns do not represent the actual BTU content but estimate the BTU consumption of an equivalent fossil fuel plant with a heat rate of 10,000 BTU/ KWH. This conversion factor is not used for the entries in the DIRECT SOLAR/GEOTHERMAL row. Nuclear entries assume heat rates of 11,000 BTU/ KWH.

GROSS ELECT. INPUTS represents a distribution of the electrical generation (31563 TBTU/YR) and the synthetics fuel (196 TBTU/YR) consumption volumes among the remaining four sectors on the basis of end-use proportions. For example, if the residential sector is assumed to use 60 percent of the electricity generated, the entry under this column and

across the RESIDENTIAL row would represent 60 percent of the total inputs consumed in electrical generation and synthetic fuel production (31,759 TBTU/YR). The first four sectors are chosen because they are end-use consumption sectors. The electrical generation and synthetics sectors provide energy to the remaining four consumption sectors and the GROSS ELECT. INPUTS column shows the distribution of the fuel consumed in generating this energy to the four sectors based on sectoral consumption of electricity.

TOTAL FOUR SECTOR INPUTS in the consumption portion of the table represents both direct fuel consumption and consumption of fuel for the purposes of producing electricity and synthetic fuels and is thus the sum of TOTAL 6 SECTOR INPUTS and GROSS ELECT. INPUTS for the first four sectors. NET 4 SECTOR INPUTS represents both direct fuel consumption and the direct consumption of electricity and thus is the sum of UTILITY ELECTRIC DISTRIB. and TOTAL 6 SECTOR INPUTS for the first four sectors only.

TABLE 3: Price Summary in 1978 \$/Standard Physical Units

TABLE 3 contains the retail prices of the energy products. These prices are given by sector (residential, commercial, raw material, industrial and transportation) and by region (the ten DOE regions). Retail prices are obtained by applying sectoral markups to the delivered prices. The retail price markups are based on historical data. Entries in the TOTAL column are quantity-weighted averages of the regional prices.

TABLE 4: Regional Price Summary in 1978 \$/Million BTU

TABLE 4 is the same as TABLE 3 with all prices converted to 1978 dollars per million BTU.

TABLE 3

1985 MID-RANGE/TRENDLONG SCENARIO (SERIES C)
WITH NATURAL GAS REGULATION

OIL IMPORT PRICE: 15.32

RUN DATE: 1.14

DEMAND REGION RETAIL PRICE SUMMARY IN 1978 \$/ STANDARD PHYSICAL UNIT

SECTOR (FUEL)	DEMAND REGIONS										TOTAL
	NW-ENG.	NY/NJ	MID-ATL	S.-ATL	MIDWEST	S.-WEST	CENTRAL	N-CENTRAL	WEST	N.-WEST	
RESIDENTIAL											
(ELECT.)	45.42	54.27	47.39	37.69	40.96	40.50	43.32	32.92	43.21	19.91	39.97
(DIST.)	22.64	23.11	24.21	24.63	22.08	22.73	21.44	22.54	22.40	22.40	22.46
(LG)	15.62	16.08	17.33	17.33	15.99	15.73	15.69	16.32	15.80	15.40	16.21
(COAL)	46.56	43.89	41.32	44.29	39.48	36.59	37.79	30.84	39.39	39.68	40.13
(NG)	4.68	4.27	3.69	3.25	1.21	2.47	2.17	2.33	3.46	3.76	3.19
COMMERCIAL											
(ELECT.)	45.10	60.37	45.40	39.14	40.87	38.42	42.41	30.01	39.77	19.82	40.98
(DIST.)	21.21	21.61	21.90	21.92	20.99	21.22	20.45	21.18	20.77	20.77	21.10
(RESID.)	18.01	18.61	20.55	18.22	19.64	18.66	19.49	18.95	18.35	17.91	18.11
(LG)	13.10	13.10	13.10	13.10	13.99	13.10	13.80	13.93	13.10	13.10	13.50
(COAL)	46.56	43.89	41.32	44.29	39.48	36.59	37.79	30.84	39.39	39.68	40.13
(ASPHALT)	19.08	19.08	19.08	19.00	19.19	18.75	18.88	19.13	19.42	18.42	18.33
(NG)	3.98	3.64	3.21	2.72	2.86	2.54	3.57	3.23	2.92	3.15	3.04
RAW MATERIAL*											
(LG)	18.96	18.96	18.94	18.81	19.92	18.56	18.48	19.67	18.08	18.08	18.59
(OIL)	19.08	19.08	19.08	19.00	19.19	18.75	18.83	19.13	18.42	18.42	18.91
(NG)	3.39	2.92	2.77	2.26	2.52	2.23	3.20	2.73	2.52	2.44	2.41
INDUSTRIAL***											
(ELECT.)	37.42	32.30	37.44	32.07	31.95	32.64	36.00	24.91	31.99	13.16	31.70
(DIST.)	21.20	21.51	22.46	22.40	20.97	21.12	20.40	21.41	20.77	20.77	21.15
(RESID.)	18.37	19.26	20.04	19.01	19.49	18.60	19.30	18.61	18.33	18.68	18.79
(LG)	14.67	15.01	15.92	15.89	15.31	14.85	15.07	15.46	14.81	14.81	15.20
(COAL)	46.56	43.89	41.32	44.29	39.48	36.59	37.79	30.84	39.39	39.68	39.51
(NET COAL**)	58.90	56.06	53.30	56.66	54.43	57.25	52.73	59.63	69.80	73.02	54.85
(NAPHTHA)	18.96	18.96	18.94	18.81	19.82	18.56	18.44	18.67	18.08	18.08	18.58
(NG)	3.39	2.92	2.77	2.31	2.52	2.23	3.20	2.73	2.52	2.44	2.39
TRANSPORTATION											
(ELECT.)	42.43	48.63	42.13	35.26	36.19	36.29	40.05	29.30	34.80	16.91	45.10
(DIST.)	27.68	28.19	29.14	29.08	27.65	27.40	27.08	28.09	27.45	27.45	28.07
(RESID.)	18.37	19.26	20.04	19.01	19.49	18.60	19.30	18.61	18.33	18.68	18.80
(LG)	13.10	13.10	13.10	13.10	14.97	14.10	13.84	13.93	13.10	13.10	13.27
(GASOLINE)	31.76	32.92	31.63	31.19	31.30	30.07	30.59	30.83	31.54	31.61	31.30
(JET FUEL)	22.08	21.57	25.04	25.29	22.55	23.19	21.91	21.19	22.95	22.85	23.51

*LIGHT GAS IN THE RAW MATERIAL SECTOR INCLUDES LIGHT GAS FEEDSTOCK.

**NET COAL INCLUDES 70% PREMIUM COAL AND 30% BITUMINOUS LOW SULFUR COAL.

***INDUSTRIAL SECTOR HERE DOES NOT INCLUDE REFINERIES.

TABLE 4

1995 MID-RANGE/TRENDLONG SCENARIO (SERIES C)
WITH NATURAL GAS REGULATION

OIL IMPORT PRICE: 15.42

PDN DATE: 1.14

DEMAND REGION AVERAGE RETAIL PRICE SUMMARY IN 1978 \$/MILLION BTUS

SECTOR (FUEL)	DEMAND REGIONS										TOTAL
	NW-ENG.	NY/NJ	MID-ATL	S.-ATL	MIDWEST	S.-WEST	CENTRAL	N-CENTRAL	WEST	N.-WEST	
RESIDENTIAL	5.11	5.66	6.14	7.87	4.56	5.20	4.41	4.10	5.59	4.82	5.39
(ELECT.)	13.11	15.91	13.39	11.05	12.00	11.37	12.70	9.65	12.66	5.83	11.71
(DIST.)	3.99	3.97	4.16	4.23	3.79	3.90	3.69	3.87	3.95	3.85	3.93
(LG)	3.90	4.01	4.32	4.32	3.99	3.92	3.91	4.07	3.94	3.94	4.04
(COAL)	2.07	1.95	1.84	1.97	1.75	1.63	1.68	1.37	1.75	1.76	1.82
(NG)	4.53	4.13	3.58	3.15	3.11	2.39	2.11	2.26	3.35	3.65	3.09
COMMERCIAL	4.74	6.45	6.45	6.65	5.15	6.02	6.05	5.26	5.85	4.22	5.35
(ELECT.)	13.22	17.69	13.31	11.14	11.98	11.26	12.43	8.80	11.71	5.81	12.11
(DIST.)	3.64	3.71	3.76	3.76	3.60	3.64	3.51	3.64	3.56	3.56	3.66
(RESID.)	2.97	2.96	3.27	2.90	3.12	2.97	3.10	3.01	2.92	2.85	2.99
(LG)	3.27	3.27	3.27	3.27	3.49	3.27	3.46	3.47	3.27	3.27	3.19
(COAL)	2.07	1.95	1.84	1.97	1.75	1.63	1.68	1.37	1.75	1.76	1.82
(ASPHALT)	3.14	3.18	3.18	3.17	3.20	3.13	3.15	3.19	3.07	3.07	3.15
(NG)	3.86	3.53	3.11	2.63	2.78	2.46	3.46	3.13	2.83	3.05	2.94
RAW MATERIAL*	3.43	3.35	3.14	2.92	3.25	3.27	3.28	3.20	3.08	2.92	3.12
(LG)	3.61	3.61	3.61	3.58	3.59	3.54	3.52	3.56	3.44	3.44	3.54
(OIL)	3.18	3.18	3.18	3.17	3.20	3.13	3.15	3.19	3.07	3.07	3.15
(NG)	3.29	2.83	2.69	2.19	2.44	2.16	3.10	2.65	2.44	2.37	2.33
INDUSTRIAL***	4.86	4.54	3.92	4.98	3.88	2.98	4.79	3.16	3.95	3.28	3.79
(ELECT.)	10.97	9.47	10.97	9.40	9.37	9.57	10.55	7.30	9.96	3.96	9.29
(DIST.)	3.64	3.69	3.86	3.85	3.60	3.63	3.50	3.69	3.56	3.56	3.67
(RESID.)	2.92	3.06	3.19	2.97	3.10	2.96	3.07	2.96	2.92	2.97	2.99
(LG)	3.66	3.74	3.95	3.96	3.92	3.70	3.76	3.85	3.69	3.69	3.79
(COAL)	2.07	1.95	1.84	1.97	1.75	1.63	1.68	1.37	1.75	1.76	1.82
(NET COAL**)	2.18	2.08	1.97	2.10	2.02	2.12	1.95	2.21	2.59	2.70	2.43
(NAPHTHA)	3.61	3.61	3.61	3.58	3.59	3.54	3.52	3.56	3.44	3.44	3.54
(NG)	3.29	2.83	2.69	2.24	2.44	2.16	3.10	2.65	2.44	2.37	2.33
TRANSPORTATION	5.74	5.79	5.67	5.63	5.67	5.22	5.52	5.49	5.39	5.42	5.55
(ELECT.)	12.44	14.25	12.35	10.33	10.61	10.64	11.74	8.59	11.17	4.96	13.22
(DIST.)	4.79	4.94	5.00	4.99	4.75	4.77	4.65	4.82	4.71	4.71	4.82
(RESID.)	2.92	3.06	3.19	2.97	3.10	2.96	3.07	2.96	2.92	2.97	2.99
(LG)	3.27	3.27	3.27	3.27	3.49	3.27	3.46	3.47	3.27	3.27	3.19
(GASOLINE)	6.05	6.27	6.03	5.94	5.96	5.73	5.83	5.87	6.01	6.02	5.96
(JET FUEL)	4.12	4.23	4.49	4.54	4.05	4.16	3.93	4.16	4.10	4.10	4.22
AVERAGE PRICE	5.16	5.62	5.68	5.76	4.67	3.93	5.21	4.40	5.11	4.42	4.82

*LIQUID GAS IN THE RAW MATERIAL SECTOR INCLUDES LIQUID GAS FEEDSTOCK.

**NET COAL INCLUDES 70% PREMIUM COAL AND 30% ALUMINUM LOW SULFUR COAL.

***INDUSTRIAL SECTOR HERE DOES NOT INCLUDE PETROLEUMS.

THE COAL TRANSPORTATION REPORT

The Coal Transportation Report details the regional distribution of coal throughout the United States. It consists of two parts. The first part contains tables for each coal region giving the distribution of each coal type by transshipment node¹ (i.e., major coal distribution and shipment points).

An example of this first part of the report is illustrated by TABLE 5. The scenario under which the data was developed is described in the upper right corner of each report page. There is a page for each coal supply region, as indicated by the page heading. Each coal type is listed in the first column with the various destinations in the second column.

The amount of coal shipped in a year is detailed in millions of short tons in column three. The regional total appears at the bottom of the column. The fourth column lists the marginal supply price for each coal type delivered to each destination. The cost of transportation (column five) is then added to determine the delivered price in column six. The last column is a ratio of transportation cost to delivered price, providing a reference for determining the transportation impact on the price of various coal types to regions as they compare with others in the same region, or in different regions.

The second part of the report details the transportation of coal between eastern and western coal supply regions. As illustrated in TABLE 6, the scenario is specified for these report pages in the upper right corner. The report heading is self-descriptive. The report details the annual coal transportation between supply region (western in the example) and the transshipment nodes (eastern in the example). The entries in the table indicate

¹Coal transportation is described in detail, including the transshipment network, in Chapters III and IX of Volume IV, Model Documentation, of this documentation series.

TABLE 5

WITH NATURAL GAS REGULATION

OIL IMPORT PRICE: 15.00

RUN DATE: 1.14

COAL REGIONAL DISTRIBUTION SUMMARY IN MILLIONS OF SHORT TONS PER YEAR

SUPPLY REGION: MIDWEST

COAL TYPE	DESTINATION	AMOUNT	MARGINAL SUPPLY PRICE (\$/TON)	COST OF TRANSPORT (\$/TON)	DELIVERED PRICE (\$/TON)	TRANSPORT COST/DELIVERED PRICE RATIO
MI-BTU,MED-S	CINN	1.99	20.09	3.02	23.11	.13
MI-BTU,MED-S	TOTAL S.-ATL	1.99				
MI-BTU,MED-S	CHICAGO	11.53	20.09	3.70	23.79	.16
MI-BTU,MED-S	ST.LOU	.80	20.09	2.01	22.10	.09
MI-BTU,MED-S	TOTAL MIDWEST	12.33				
MI-BTU,MED-S	NEW ORLEANS	.42	20.09	2.47	22.56	.11
MI-BTU,MED-S	TOTAL S.-WENT	.42				
MI-BTU,MED-S	MIAMI	34.65	20.01	11.66	31.67	.37
MI-BTU,MED-S	TOTAL S.-ATL	34.65				
MEU-BTU,MED-S	ST.LOU	1.91	17.94	2.01	19.95	.10
MEU-BTU,MED-S	TOTAL MIDWEST	1.91				
MEU-BTU,MED-S	MIAMI	3.13	17.34	11.66	29.00	.10
MEU-BTU,MED-S	CINN	45.94	17.34	3.02	20.36	.15
MEU-BTU,MED-S	TOTAL S.-ATL	49.07				
MEU-BTU,MED-S	CHICAGO	67.96	17.34	3.70	21.04	.18
MEU-BTU,MED-S	ST.LOU	15.10	17.34	2.01	19.35	.10
MEU-BTU,MED-S	TOTAL MIDWEST	83.06				
TOTAL MIDWEST		185.42				

TABLE 6

WITH NATURAL GAS REGULATION

GIL IMPORT PRICE: 13.00

RLN DATE: 1.14

SHIPMENTS FROM WESTERN COAL SUPPLY REGIONS TO EASTERN TRANSHIPMENT NODES
IN MILLIONS OF SHORT TONS PER YEAR

TRANSHIPMENT NODES											
SUPPLY REGIONS	BOSTON	NY	BLT/PHL	MIAMI	PTSRG	ATLANTA	CINN	DETROIT	CHICAGO	ST. LOU	ST. PAUL
CENTRAL WEST											
METALLURGICAL HI-BTU, LO-S							.08				.10
TOTAL CENTRAL WEST							.08				.10
N.W. GREAT PLAINS											
HI-BTU, LO-S						5.00	7.92	9.08	.66		
MED-BTU, LO-S								5.40	2.71	3.46	
MED-BTU, MED-S										17.64	
LO-BTU, LO-S							11.38	20.48	4.55	4.55	
TOTAL N.W. GREAT PLAINS						5.00	19.30	34.97	7.91	25.66	
TOTAL FROM WEST											
						5.08	19.30	34.97	7.91	25.95	

millions of short tons of each coal type shipped. Total shipments are detailed at the bottom of each transshipment node column.

THE INTERNATIONAL ENERGY EVALUATION SYSTEM REPORT

The executive summary report of the IEES model present supply, demand, and trade forecasts for each of the eight foreign regions of the world and the net trade statistics for the United States as derived from PIES.

TABLE 7 summary forecasts for oil, gas, coal, nuclear, and hydro/geothermal power for each region along with the assumed price of world oil. The average landed price of crude oil on the U.S. east coast appear in the table. The OPEC price is adjusted by the model to achieve a U.S. landed price consistent with that assumed in the corresponding PIES run.

THE REGIONAL DEMAND FORECASTING MODEL REPORT

The RDFOR model report show quantities of different kinds of fuels demanded at exogenously specified prices for the years 1973 through 1990. There are separate reports for each of the demand regions and for the total United States.

The first page of each report is primarily concerned with internal debugging information, and allows the analyst to relate this particular RDFOR run to specific input assumptions concerning macro-economic forecasts, price forecasts, and model parameters. Also, the date and time of the run appear (and are the same as the date and time information for demand file generation listed in the PIES Integrating Model Report.)

The body of each report lists the forecasts of fuel demands and their associated prices. Tables for quantities demanded in the residential, commercial, industrial, transportation, and aggregate sectors appear in turn. Each set of tables is accompanied by a growth rate table. Next the exogenously specified prices for the major fuels (the only ones which are

TABLE 7

EXECUTIVE SUMMARY

WORLD OIL PRICE 13.00

	USA	CANADA	JAPAN	OECD-EU	MEA	OECD	LOC	IOPEC	IOPE	WORLD
ALL OIL										
PRODUCTION (MM/D)	10,234	1,300	10	4,462	14,986	16,275	7,056	41,055	15,295	80,081
IMPORTS	11,017	1,101	8,414	12,730	13,125	30,311	4,430	-37,751	-990	
CONSUMPTION	21,251	2,401	8,024	17,201	28,112	50,586	11,486	3,304	14,305	80,081
NATURAL GAS										
PRODUCTION (BCF/Y)	16,726	3,376	305	7,043	27,065	20,325	3,120	7,205	21,900	60,590
IMPORTS	1,408	-869	902	1,525	3,251	3,006	-600	-3,131	329	
CONSUMPTION	18,134	2,507	1,207	8,568	31,316	23,331	2,520	4,074	22,229	60,590
ALL COAL										
PRODUCTION (MMST/Y)	1,030	67	0	466	1,374	1,718	908	6	3,071	5,203
IMPORTS	-74	-20	125	151	177	97	-42		-55	
CONSUMPTION	956	47	125	617	1,551	1,815	866	6	3,016	5,203
NUCLEAR										
GENERATION (TWH/Y)	566	64	94	453	1,160	1,179	180	19	230	1,836
CAPACITY (GW)	99	10	17	77	200	207	32	3	45	207
HYDRO, SOLAR, GEOTHERMAL										
GENERATION (TWH/Y)	400	299	117	475	1,270	1,166	401	0	506	2,273
TOTAL PRIMARY ENERGY										
(QUADS)	95	12	20	66	197	203	43	12	111	360
TOTAL FINAL CONSUMPTION										
(QUADS)	80	0	10	53	163	168	39	12	106	325

NOTES

UNITED STATES DATA WAS OBTAINED FROM THE CORRESPONDING PIES FORECAST.
WORLD PRICE IS THE AVERAGE LABORED PRICE OF IMPORTED CRUDE ON THE EAST COAST, UNITED STATES.

modeled as being price-sensitive) appear accompanied by their own growth rates.

In addition to the formal regional quantity and price tables, there are separate reports which list the fuel/sector demand elasticities for each region and for the United States as a whole.

THE MID-TERM OIL AND GAS MODEL REPORTS

The Mid-term Oil and Gas Models produce supply curves for PIES which are snapshots in time of oil and gas production and the associated levels of investment and drilling activity at various marginal prices. PIES uses these supply curves in computing its forecast.

Stand-alone reports are produced by region by year and display the supply curves for oil and gas and their co-products, as well as the investment and drilling profiles mentioned above. In addition, reserve addition and vintage information over time is available along with a detailed financial balance sheet for the oil and gas industry. Special computer graphics software is linked to the model to allow display of the above tabular information as bar charts, maps, and graphs.

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