REPORT TO THE CONGRESS

BY THE COMPTROLLER GENERAL OF THE UNITED STATES

Review Of The 1974 Project Independence Evaluation System

Federal Energy Administration

The 1974 Project Independence Evaluation System is a complex evaluation, forecasting, and analysis system. It was developed by the Federal Energy Administration to use in preparing the Project Independence report of 1974.

This initial version of the Project Independence Evaluation System provided an innovative framework for evaluating energy policy, even though it contained limitations. The Federal Energy Administration is aware of these limitations and is implementing a plan for improving the system.

These changes are essential in order for the Project Independence Evaluation System to approach its full usefulness.

OPA-76-20 APRIL 21, 1976

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To the President of the Senate and the
Speaker of the House of Representatives

3500

At the request of the Chairman, House Committee on Science and Technology, we have reviewed the methodology used in the 1974 Project Independence Evaluation System. This report contains our review of the complex evaluation, forecasting, and analysis system developed by the Federal Energy Administration and used in preparing the November 1974 Project Independence report.

We made our review pursuant to the Budget and Accounting Act, 1921 (31 U.S.C. 53), and the Accounting and Auditing Act of 1950 (31 U.S.C. 67).

We are sending copies of this report to the Director, Office of Management and Budget, and the Administrator, Federal Energy Administration.

Thomas B. Staats

Comptroller General
of the United States

Contents

ABBREVIATIONS

AEC	Atomic Energy Commission (note a)
DIR	Data Resources, Inc.
FEA	Federal Energy Administration

ABBREVIATIONS

GAO	General Accounting Office
GNP	gross national product
INFORUM	Interindustry Forecasting Model of the University of Maryland
LTMAC	Long Term Macroeconomic Model
MIT	Massachusetts Institute of Technology
NPC	National Petroleum Council
PCE	personal consumption expenditures
PIES	Project Independence Evaluation System (note b)
PIES-74	1974 Project Independence Evaluation System (note c)
R&D	research and development

a/The Energy Reorganization Act of 1974, (Public Law 93-438; 88 Stat. 1233,) abolished the Atomic Energy Commission and in so doing distributed the regulatory functions of AEC to the newly created Nuclear Regulatory Commission. The nonregulatory functions of AEC were transferred to the newly created Energy Research and Development Administration. See 42 U.S.C. 5811 et. seq. and 42 U.S.C. 5841.

b/Refers to the Project Independence Evaluation System in general and not to the specific version used for the 1974 Project Independence report.

c/Refers to the specific version of the Project Independence Evaluation System which was used for the 1974 Project Independence report.

COMPTROLLER GENERAL'S REPORT TO THE CONGRESS

REVIEW OF THE 1974 PROJECT INDEPENDENCE EVALUATION SYSTEM

D I G E S T

GAO has reviewed the methodology used in the 1974 Project Independence Evaluation System--a complex evaluation, forecasting, and analysis system developed by the Federal Energy Administration to use in preparing the Project Independence report of November 1974.

The 1974 Project Independence Evaluation System is a set of interrelated models developed to represent the U.S. energy system. This major effort involved many Government employees and energy experts outside Government under the overall direction of the Federal Energy Administration. For the Project Independence report, the 1974 Project Independence Evaluation System was used to evaluate the state of the U.S. energy system in the years 1977, 1980, and 1985 for combinations of the following alternative situations:

--Two energy supply scenarios--business-as-usual and accelerated development. Business-as-usual assumed that existing Government policies would be continued (except that crude oil would be decontrolled and natural gas would be deregulated) with no new actions to stimulate supply or remove barriers limiting production. Accelerated development assumed the implementation of incentives and other programs that promote production.

--Two energy demand scenarios--one with and one without conservation initiatives. The former assumed implementation initiatives and other programs to promote energy conservation. The latter assumed that existing policies would be continued with no new programs to induce energy conservation.

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--Varying assumptions about the price of crude oil--$4, $7, $11, and $15 per barrel.

Initially, the 1974 Project Independence Evaluation System was constructed and used to support preparation of the November 1974 Project Independence report. After the report was completed, the Federal Energy Administration continued to use and refine the system as a policy analysis tool. This refined system, used to support the "National Energy Outlook" published by the Federal Energy Administration in February 1976, is not addressed in this report. (See ch. 4.)

CONCLUSIONS AND RECOMMENDATIONS

GAO believes that the 1974 Project Independence Evaluation System is a valuable attempt to provide an integrated framework for evaluating energy policy. Under severe time constraints, the Federal Energy Administration developed an innovative framework for analyzing the complex and interdependent sectors of the U.S. energy system. Nonetheless, the 1974 Project Independence Evaluation System contained serious problems. The 1974 Project Independence Evaluation System requires corrective action in order to approach its full usefulness and to assure that the results from subsequent versions will be reliable.

The Federal Energy Administration is aware of the limitations in the initial version of the Project Independence Evaluation System and is implementing a workplan for its improvement. According to the Federal Energy Administration much of this work has already been done. The Administrator, Federal Energy Administration, should give highest priority in implementing the plan to development of complete documentation for the system.

GAO also recommends that the Federal Energy Administration add to its plan:

--An analysis of problems resulting from the static nature of the system and the procedures which can be used to alleviate them.

--An analysis of the limitations in the environmental impact analysis and the procedures which can be applied to correct them.

--A comprehensive, well-documented verification, validation, and sensitivity testing effort.

GAO further recommends that in implementing the plan, priority be given to the following areas:

--The methodological approach used to estimate energy supply, in particular crude oil and natural gas.

--The energy demand estimation technique regarding calculating energy price elasticities.

--The representation of the relationship between the energy system and the economy.

--A more thorough assessment of the economic, environmental, and international impacts of alternative U.S. energy policies.

CHAPTER 1

INTRODUCTION

The Project Independence report, submitted by the Federal Energy Administration (FEA) to the President in November 1974, summarized the impact of different Government energy policies on energy supply and consumption. 1/ The major policy analysis tool used in developing the report was the 1974 Project Independence Evaluation System (PIES-74). PIES-74 is a complex evaluation, forecasting, and analysis system that attempts to represent the U.S. energy system. Because of the potential for its continued use in evaluating alternative energy options, the Chairman, House Committee on Science and Technology, asked that we review PIES-74.

PIES-74 is a set of interrelated models 2/ developed by FEA to portray the U.S. energy system and to provide a means to assess alternative energy policies. "System" refers to a group of parts that operate together for a common purpose. The U.S. energy system is a good example of a very complex, interrelated system. Its parts work together to produce, distribute, and consume energy. A model is used to capture the essence but not necessarily the detail of the system. It is an abstraction of reality and, for analytical purposes, can be regarded as a substitute for the real system. Thus, instead of investigating and experimenting with the real system, one can do the same with a model--usually with less time and money. To the extent that a particular model is an appropriate representation of the system, it can be a valuable aid in assessing alternative strategies associated with the system and in identifying the consequences of these strategies.

ORGANIZATION OF PROJECT INDEPENDENCE

Project Independence was an interagency effort involving several hundred Government employees and non-Government experts. FEA's Assistant Administrator for Policy and Analysis was project manager and the following working groups were established to perform indepth studies and analyses.

1/A subsequent report, "National Energy Outlook," was published by FEA in February 1976 but is not addressed in this report.

2/A "model" is defined as a representation of a system under study.

International Assessment
Research and Development
Conservation
Policy Evaluation
Quantitative Analysis
Resource Development

Four of the groups developed data used in selecting alternative energy strategies and assessing the output of PIES-74, as follows:

--The International Assessment working group assessed the cost of vulnerability to embargoes and forecast future world oil supply, demand, and prices.

--The Research and Development working group evaluated the impact of research and development on Project Independence goals.

--The Conservation working group developed estimates of the cost and impact of the various energy conservation options.

--The Policy Evaluation working group identified and analyzed various policy options.

The Resource Development working group was responsible for estimating various levels of energy production, as well as the requirements for water, transportation, manpower, equipment, materials, and construction needed to support these levels of production. This was accomplished by task forces staffed primarily by personnel from other Government agencies. The production data developed by the task forces was used in PIES-74 to represent domestic energy supply. (See ch. 2.)

The Quantitative Analysis working group, staffed by FEA, was responsible for

--developing estimates of energy demand,

--developing data on key resource constraints which would affect energy supply, and

--evaluating economic, social, and environmental impacts of alternative policy options.

A major task in fulfilling these responsibilities was to develop a model capable of balancing the estimated supply, demand, and resource constraint data.

SCOPE OF OUR REVIEW

We visited FEA headquarters in Washington, D.C., and interviewed a number of FEA personnel involved in the development of PIES-74.

Our investigation relied heavily on

--the 1974 Project Independence report,

--task force reports,

--documentation for nongovernmental proprietary models used in PIES-74,

--the limited available PIES-74 documentation from FEA, and

--reviews of PIES-74 by other organizations.

We did not test PIES-74 in developing our findings. We originally intended to test the model using a facility independent of FEA. However, because of the limited documentation available, the decentralized nature of the operation of the system (see app. I), and the fact that the system was being modified, we did not test the model independently. Consequently, we could not determine what effects FEA's data and methodological assumptions had on the model's results. In other words, we could not test the validity of the assumptions or the sensitivity of the model results to the assumptions or the input data.

Chapters 2, 3, and 4 of this report essentially describe

--how the energy data was developed for use in PIES-74 (ch. 2),

--how PIES-74 was structured and how it functioned in the preparation of the November 1974 report (ch. 3), and

--what modifications have been made or are planned for the system (ch. 4).

Chapter 5 contains an appraisal of PIES-74. Chapter 6 contains our conclusions and recommendations.

CHAPTER 2

SUPPLY DATA DEVELOPED FOR PIES-74

The usefulness of PIES-74 relies heavily upon the availability and quality of input. As with any model or set of models, development of this data is critical to its successful operation. Regardless of how close the model represents the real system, inaccurate input data undermines the accuracy of results. The House Committee on Science and Technology asked us to review the development of the data which was used in PIES-74. The Resource Development working group at FEA was responsible for the major effort in developing the supply data.

The group consisted of nine energy supply task forces--coal, oil, natural gas, synthetic fuels, oil shale, geothermal, solar, nuclear, and facilities. The facilities task force developed data on energy facilities, such as oil refineries, fossil-fueled electric power generation plants, hydroelectric power transmission and distribution systems. Each of the other energy supply task forces developed estimates of potential production levels for its resource, taking into account production lead times and institutional factors--such as labor contract terms and willingness of investors to invest in new mines--which could affect the rate of growth. All assumed there would be no change in production methods and no constraints on production. The supply task forces were asked to estimate what amounts of the various fuels could be produced rather than what they thought would be produced or could be used. That is, they were asked to estimate fuel availability, not market-determined demand and supply conditions. They provided production estimates based on different prices for a barrel of crude oil.

TWO ALTERNATIVE STRATEGIES

Because of economic conditions and government policies, each task force was asked to estimate production under two different circumstances--business-as-usual and accelerated development.

Business-as-usual was based on the following assumptions.

--Existing policies will be continued with no new actions to stimulate supply or to remove barriers that limit production, except that natural gas will be deregulated and crude oil decontrolled.

--Tax policies will remain the same.

--Price and allocation programs involving crude oil and petroleum products would be phased out in 1975.

--Current environmental regulations would be implemented.

--An $11 billion energy research and development program would be continued.

Accelerated development assumed the implementation of incentives and other programs that promote production.

To define and differentiate between alternate scenarios, a large number of assumptions were made. The following table compares the major assumptions used in business-as-usual and accelerated development. 1/

Energy source	Business-as-usual assumptions	Accelerated development assumptions
Oil	Outer continental shelf leasing programs of 1 to 3 million acres a year; Prudhoe Bay, Alaska, developed with one pipeline	Accelerated outer continental shelf leasing program including Atlantic and Gulf of Alaska; expanded Alaskan program assuming additional pipeline and authority to develop Naval Petroleum Reserve No. 4
Natural gas	Phased deregulation of new natural gas; liquefied natural gas facilties in Alaska	Deregulation of new natural gas; additional gas pipelines in Alaska; gas produced in tight formations
Coal	Some Federal coal land leasing; phased implementation of Clean Air Act with installation of effective stack gas control equipment; some strip-mining legislation	Same except additional leasing and larger new mines

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1/FEA Project Independence report, pp. 64-65, Nov. 1974.

Nuclear	No change in licensing or regulation; added enrichment and reprocessing capability	Streamlined siting and licensing to reduce lead-times; increased reliability; additional uranium availability; material allocation
Synthetic fuels	No change in licensing or incentives; no relaxation or postponement of environmental standards	Streamlined licensing and siting; financial incentives; increased water availability
Shale oil	No change in leasing or air quality standards; no financial incentives	Additional leasing of Federal lands; modification of air quality standards; financial incentives; increased water availability
Geo-thermal	Continued research and development (R&D) and Federal leasing programs	Leasing of Federal lands; streamlined licensing and regulatory procedures; financial incentives
Solar	Continued R&D program	Additional R&D expenditures and financial incentives

For both business-as-usual and accelerated development, the task forces were asked to provide, by region

--unconstrained production data; how much could be produced for the years 1977, 1980, and 1985;

--the estimated cost per unit as a function of production; and

--the requirements for various resources--water, transportation, manpower, equipment, material, and construction--needed to support the various levels of production.

<u>Summary of sources of data developed by the task forces</u>

The sources of data developed by task forces are summarized below.

<u>Coal</u> data came primarily from the Bureau of Mines, Department of the Interior, which compiles and publishes reserves estimates from data supplied by the mineral and energy materials industries and Government agencies.

Natural gas data came from a variety of both governmental and nongovernmental sources, including the Geological Survey, Department of the Interior, which, among other things, is responsible for appraising the mineral fuel resources of the United States, and the American Gas Association, a trade association of natural gas production and transmission companies.

Oil data sources included FEA; the Bureau of Mines; Petroleum Intelligence Weekly (a petroleum industry trade paper); and the National Petroleum Council, an advisory group to the Department of the Interior made up of petroleum industry representatives.

Nuclear data came primarily from the Atomic Energy Commission (AEC), which, before its reorganization, was the Federal agency responsible for nuclear research and development and industry regulation. The data was either new projections for the task force or existing AEC data.

Oil shale data came largely from the Geological Survey and the Bureau of Mines, with some cost and processing data being supplied by an oil company which was involved in a pilot project.

Synthetic fuels data was based on projected plant operations developed in conjunction with the Commerce Department Technical Advisory Board, a panel of private and Government experts which advises the Secretary of Commerce on technical matters.

Geothermal data came primarily from the Geological Survey as well as Government-supported research projects. Based on this data, the task force made the required projections and estimates.

Facilities data related primarily to electricity, which is a secondary fuel source and depends on other fuels for its generation. The task force made the required projections on the basis of both governmental and private data.

Solar data was not included because its short term role was considered minimal.

The task forces submitted their estimates to the Quantitative Analysis working group where the data was translated into computer format and entered into PIES-74.

TASK FORCE USE OF MODELS

Some of the task forces used computer models to develop the data provided to the Quantitative Analysis working group. The most extensive use of a model was made by the oil and natural gas task forces which used a National Petroleum Council model to develop their production data.

To a lesser extent, the coal, synthetic fuels, and oil shale task forces also used models to develop data for PIES-74. The coal task force used a model developed by TRW Systems Group, a private firm, to facilitate development of the coal data. The model integrated the assumed mix of new mines and mine cost data to arrive at average minimum acceptable selling prices for each coal supply region for the target years, as well as the needs for mining equipment, manpower, and supplies. Development of the synthetic fuel and oil shale projections was assisted by models developed by Battelle Memorial Institute. Synthetic fuel (coal gasification and liquefaction) and oil shale plant construction schedules were developed to conform to predetermined production estimates based on work done by or for the Department of the Interior. With these schedules and the estimated per plant construction operating and production requirements developed by the Bureau of Mines and contractors to the Office of Coal Research, the model calculated total current and cumulative construction, operating, and production requirements for any year in the schedule interval (1974-90).

Crude oil and natural gas task force efforts

The oil and natural gas task forces stated that, because of the short time allowed for completion of their work, they were unable to develop their own methodology and computer support for a state-of-the-art analysis of possible oil and gas supplies. Consequently, from the methodologies available, they selected the U.S. oil and gas supply computer program which was developed by the National Petroleum Council (NPC) and used in preparing NPC's "U.S. Energy Outlook" reports. This methodology allowed for automated handling of the voluminous data of possible national supply at the disaggregated level required by the Project Independence guidelines. The task forces stated that they critically examined the assumptions, structure, and data and, to the extent possible within the allowed time, altered those which were least desirable.

The analyses were made on the basis of the 14 NPC regions. However, manual procedures, similar to those in the NPC program, were used to project production from the Alaskan regions in the case of gas, the Alaskan North Slope region in the case of oil, military reservations, and special sources of gas and oil.

The NPC model in part consists of a series of linear relationships which project the amount of oil and natural gas to be discovered and produced. The model has oil, natural gas, and economic sections. The economic section was significantly modified by FEA to conform to the PIES method of pricing which employed the discounted cash flow technique.

Data required by NPC model

The NPC model requires a considerable amount of input data for 1974-88. This data includes projections of levels of drilling activity, estimates of discovery of reserves per foot drilled, probabilities of drilling success, rates of depletion of reserves, estimates of drilling and operating costs, a stipulated discount rate (rate of return) and, in the case of oil, secondary and tertiary recovery data for 1974-88. NPC provided historical data through 1970. This data was updated through 1973 and projected for the period 1974-88. The key production, discovery, and cost data projections were prepared by the task forces.

The oil and natural gas task forces cautioned that low reliability must be assigned to individual values resulting from the model because of great uncertainty attached to several factors that influence domestic production, such as potential oil and gas reserves for which there are a wide range of currently available estimates.

How the model estimates future oil and natural gas production

The NPC model used the input data to establish target production figures (maximum exploration and development and production estimates, etc.) for each region for each year. Then based on economic criteria, the model determines whether these target figures would be achieved at various prices for oil and natural gas. To estimate oil production, for example, the estimates of annual exploratory drilling footage for each region were multiplied by projected finding rates (barrels of oil per exploratory foot drilled) to estimate discoveries of oil-in-place. Estimated recovery factors were then applied to calculate the volume of oil recoverable by primary method. It was assumed that annual production from proven reserves would be a constant fraction of the remaining reserves. The total footage required to process and fully develop these reserves was calculated by applying appropriate ratios to the amount of exploratory footage drilled. All of these estimates varied by producing regions, taking into account the unique characteristics of each. Increments to the proven reserves were added at 5- and 10-year intervals to allow for secondary recovery. The extent of secondary recovery at each interval was estimated by considering the magnitude of the primary recovery, along with the ultimate recovery potential in each region. Tertiary recovery was similarly estimated, except that only one phase of tertiary recovery was included in the 15-year projection. For new fields, the first phase of the tertiary recovery was assumed to occur 10 years after the initial discovery of oil.

Once the oil and natural gas target (maximum potential) production projections were made, the economic implications of oil and gas production were analyzed to determine the degree to which these production estimates were realized. It was assumed that exploration and development projects in a particular region would be undertaken only if economical. This was determined by using the discounted cash flow method to calculate minimum acceptable prices per barrel of oil or thousand cubic feet of natural gas needed to attain a 10-percent rate of return.

In the case of oil, based on regional cost data, rate of return, depletion allowance, and assumed project life, the minimum acceptable price (the price that results in a net present value of zero using the discounted cash flow approach) for each year and region was determined. For example, for the $7 a barrel price for crude oil the results were examined and where the minimum acceptable price was less than or equal to $7 a barrel, all the drilling and discovery for that region were assumed to take place. Otherwise, no drilling or discovery was assumed to take place for that region and year. Discoveries were added across regions to give total reserves and, given stipulated production-reserve ratios for each region, total production.

For natural gas, a similar procedure was used. The output which resulted contained the maximum production possibilities by year and region at minimum acceptable price increments of 10 cents per thousand cubic feet for the last thousand cubic feet produced. The tables also showed the increase in production resulting from minimum acceptable price increases of 10 cent per thousand cubic feet and the increasing price of natural gas required to obtain additional production in future years.

Capital, material, and manpower requirements associated with these projections were also estimated. These projections included detailed capital requirements data, material requirements for 21 raw, semifinished, and fabricated material goods, and labor requirements grouped into 74 occupational skill categories.

Sensitivity testing of the NPC model

Sensitivity testing 1/ of the NPC model was performed by the oil and natural gas task forces. The oil task force found that, within a range of reasonable assumptions, different values regarding discount rates, financial costs, or finding rates could affect the quantities of oil produced at the various price levels by 10 to 40 percent. Other assumptions about drilling costs and effective depletion rates affected production levels by as much as 15 percent. The natural gas task force found that by increasing or decreasing the finding rate by 20 percent, discovery volume changed by about 20 percent. Also, as the rate of return was set at 7.5 and 15 percent, compared to the assumed 10-percent rate, the natural gas minimum acceptable prices dropped 13 to 18 percent in the former case and increased 28 to 33 percent in the latter.

In the case of both task forces, including lease bonuses and rental costs in the formula for minimum acceptable price (not initially considered in determining prices) increased prices considerably. For example, the price of natural gas obtained from offshore drilling increased between 36 and 265 percent, depending on the region and the year.

1/Sensitivity testing seeks to determine the extent to which a model's results are dependent upon certain data or combinations of data and the variability of the data.

CHAPTER 3

THE 1974 PROJECT INDEPENDENCE EVALUATION SYSTEM

This chapter describes the organization and structure of the 1974 Project Independence Evaluation System. The first section presents an overview of PIES-74, including the concept developed by the Federal Energy Administration to model the national energy system. The remaining sections describe the four subdivisions--the supply, demand, integrating, and assessment components.

CONCEPTUAL FRAMEWORK USED BY FEA TO DESCRIBE THE NATIONAL ENERGY SYSTEM

FEA viewed the national energy system as a multiregion network for producing, refining, processing, converting, distributing, transporting, and consuming energy. Production, refining, processing, conversion, and demand activities were conceived as separate segments of the network. Production represented the source of energy; refining, processing, and conversion represented the intermediate segments; and demand represented the end uses of energy. Transportation and distribution were represented as links between segments of the system.

Potential production was described by a set of supply curves that identified the prices that would be paid and the resources required (manpower, capital, etc.) for each possible production level.

Some important physical or technological limitations which could inhibit an increase in the energy supply were described within the transportation system. Capacities of the energy transportation systems (both present and future) were represented as maximum amounts shipped among regions. Expansion of these capacities was included as an activity governing energy production, and the resources required for expansion were compared with the resources required for the alternative uses in the energy system.

Refining and conversion were envisioned as intermediate sections of the network. As with the transportation system, operation or expansion of these facilities required various resources. A representation of the refining and conversion technologies should describe the conversion of one energy product into others and, in many cases, identify the competition among primary energy products for production inputs. Refining and conversion are linked to demand by transportation and distribution.

Demand for energy products occurs in different geographical regions. Demand in each region varies with energy prices in a systematic manner--the higher the price of a product, the lower the corresponding demand; the higher the prices of substitutes, generally, the higher the demand for the original product.

THE STRUCTURE OF PIES-74

For the November 1974 report, various parts of PIES-74 were run on different computer systems in several parts of the country. Data was generally communicated from one part of PIES-74 to another in tabular form, and modifications to the data were made manually at specified steps.

The chart on page 14 identifies the models which make up PIES-74 and indicates the direction of data flow. We have grouped the various parts of PIES-74 into four major components: supply, demand, integrating, and assessment. We have also identified on the chart the work accomplished by the supply task forces (including the models which were used) to develop data for the supply component, even though it is not considered part of PIES-74.

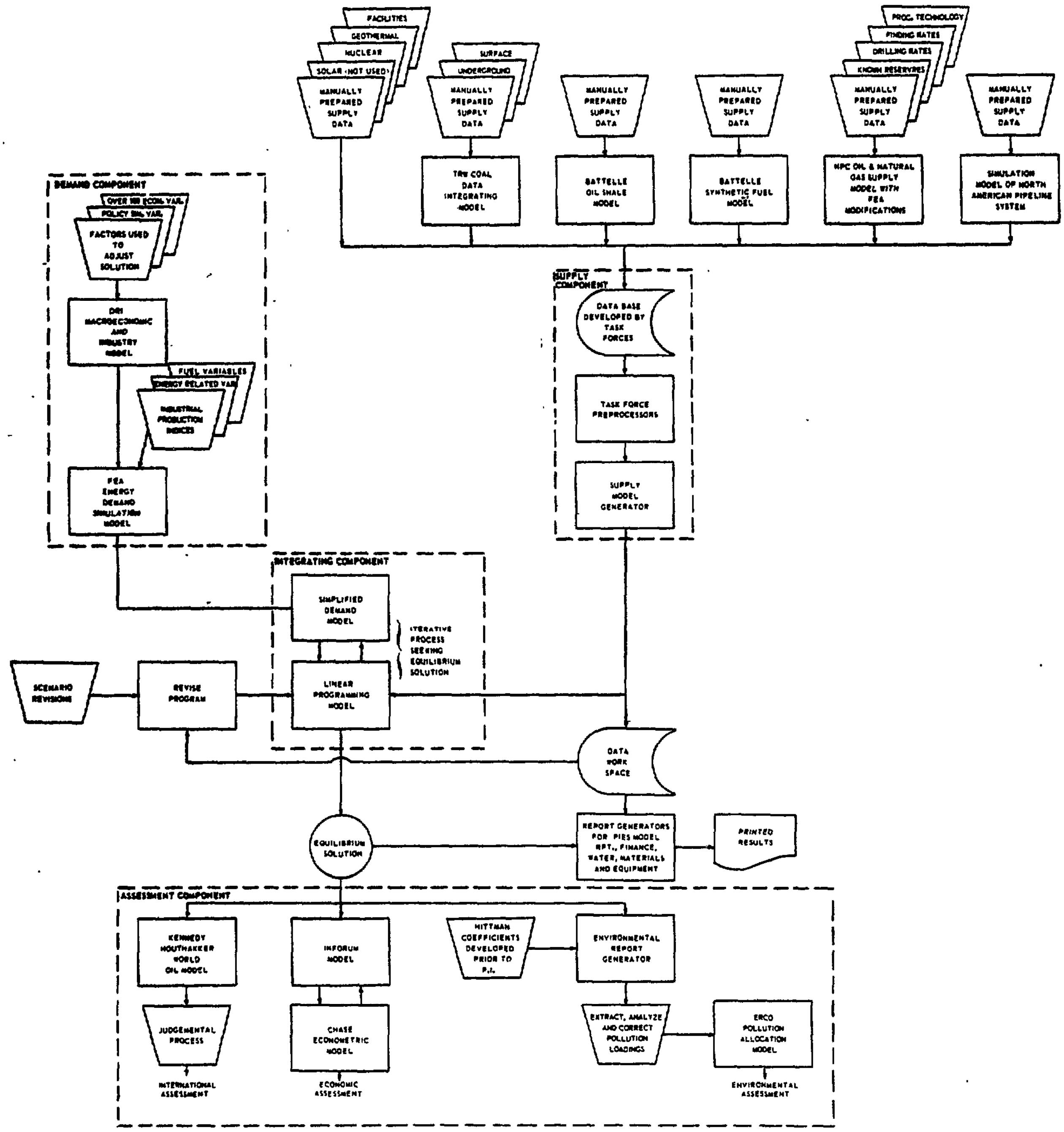
The supply component consists of the data base developed by the task forces and the computer programs developed by FEA to prepare this data for use in the integrating component. (See p. 15.)

In the demand component, initial estimates were projected by an econometric model called the energy demand simulation model. It used macroeconomic variables projected by the Data Resources, Inc. (DRI), macroeconomic and industry model to predict unconstrained demands for each energy product and energy-consuming sector. The energy demand simulation model was also used to predict how price changes would influence demand. (See p. 18.)

The integrating component, using a linear programming model and simplified demand model, equated demand and supply to produce an equilibrium price and quantity for each region. (See p. 24.)

Finally, in the assessment component, selected results from the equilibrium solution of the integrating component were incorporated into additional models to analyze the socioeconomic, environmental, and international impact. (See p. 27.)

1974 PROJECT INDEPENDENCE EVALUATION SYSTEM
OVERVIEW: MODELS AND DATA FLOW



SUPPLY COMPONENT

The data provided by the task forces can be summarized in three categories:

--Supply data specifies the potential production possibilities of various energy sources at various prices and the associated material, equipment, investment, and manpower requirements.

--Distribution data specifies the cost and capacity of shipping energy from its sources to distribution points. Other data specifies the associated requirements for material, equipment, investment, and manpower to meet these distribution needs. For example, one table provides cost data for coal transported by train from the seven coal supply regions to each of the nine demand regions. Another table provides cost data for coal transported by train from the seven coal supply regions to each of the nine utility regions. Additional tables describe other energy sources (e.g., oil), shipping modes (e.g., barges), capacities (e.g., pipeline capacity for natural gas), and associated requirements (e.g., oil pipeline investment required for expansion). 1/

--Energy conversion technology data specifies the capacity; inputs and outputs; and associated material, equipment, financial, and manpower required to operate a particular type of technology.

This data base has a considerable amount of product detail. Energy content of coal, major petroleum products, and generating capacity of electricity are differentiated.

PIES-74 was designed for regional as well as national analyses and different classifications were used for

--production of natural gas,

--production of oil,

--production of coal,

--operation of electric utilities,

1/The pipeline cost, capacity, and resource requirements data were developed by the transportation task force and based on a simulation model of the North American pipeline system.

--operation of refineries,

--foreign regions, and

--demand.

For example, the country was divided into 14 regions as defined by the National Petroleum Council for describing oil production. Refining operations in the United States were described in seven regions called Petroleum Administration for Defense Districts and demand for refined oil products was defined for the nine Census Bureau regions, different from both previous regional definitions.

The analysis did not take account of sulfur levels in coal, different crude oil types, and certain other fuels. FEA states that these differences are important and can cause conclusions which appear correct in the aggregate to become impractical in reality or subject to qualitative evaluation. In particular, they may overstate the ability of the supply system to shift to certain domestic fuel sources. For example, antipollution standards may preclude the use of coal with a high sulfur level.

Engineering cost estimates and assumptions about rates of return were used to develop production cost curves. It was assumed that at the margin the highest unit cost of production would set the market price. FEA stated that although this was consistent with economic principles, it might not be close to actual behavior. 1/ There are spot markets and long term contracts, as well as widely different rates of return, both between industries and within any given industry. Furthermore, in the regulated electric utility and natural gas industries, average prices are commonly used in rate setting. Moreover, the price for the marginal barrel of oil in the United States in recent years has generally been set by the Organization of Petroleum Exporting Countries cartel.

Preparation of data

Since the task forces developed the supply data in different formats, it was necessary to convert this data into a form usable by PIES-74. Computer programs called preprocessors were developed for the conversion of data of

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1/We did not run PIES-74 in our review. Consequently, we were not able to determine the effects of limitations associated with input data and/or methodological assumptions on the model results. (See p. 3.)

each task force, and each was designed for the units and assumptions submitted by that particular task force. Each preprocessor produced standardized data in consistent units for comparability, and the standardized data was organized in tabular form and referred to as "standard tables."

Each standard table is a description of a small component of the energy supply system. For example, a standard table describing the production of coal for a given scenario, and a given year, would include the maximum production, the minimum acceptable price, and the cumulative investment for each of four types of coal, in each of seven coal regions and for four types of mines.

The standard tables are combined by the supply model generator to produce a matrix. The matrix is the mechanism used by FEA to quantitatively describe the energy supply system. Simply defined, a matrix is a rectangular arrangement into rows and columns of a set of numbers.

The matrix combines many regions, fuel types, conversion technologies, and transportation alternatives. For example, in the production of conventional crude oil, the matrix allows for production in 14 regions at more than a dozen price and quantity levels. It may move by pipeline, barge, or tanker to any of seven refining centers. One of several refining technologies or yields must be selected in each refining center to determine the transformation of the crude oil into varying combinations of four types of refined products. These products, in turn, are shipped by varying modes of transportation to the nine demand centers for final consumption or conversion into electric power. At many stages, limited capacities for processing and transportation and limited key resources are recognized as constraints.

FEA developed a computer program to make revisions without repeating the preprocessor and supply model generator phases. This program was used extensively to make such changes as

--adjusting coal production prices to reflect increases due to new labor contracts,

--altering the price of natural gas imported from Canada, and

--limiting quantities of electricity that may be transported between a given utility region and a demand region to guarantee that regional patterns of supply are realistic.

DEMAND COMPONENT

The goal of energy demand forecasting was to develop price-sensitive regional demand forecasts for major energy sources and economic sectors. These forecasts reflected unconstrained demand and contained no restrictions on supply, financing, or imports. Another goal was to estimate and incorporate into the demand forecasts the effects of such non-price-induced energy conservation initiatives as establishing a 20 mile per gallon auto efficiency standard and increased insulation in homes.

Current macroeconomic models do not allow FEA to produce simultaneous solutions for both energy and economic alternatives. FEA recognized this as a limitation of the methodology since any energy forecast has significant economic implications and should be consistent with economic forecasts. However, an alternative approach, which could have been taken but wasn't, was to conduct additional analyses (feedback) to translate the economic impact of energy policy actions into revised demand estimates and to reassess the energy forecast. According to FEA, in an environment of increasing investment in domestic energy production, its methodology would understate the rise in energy prices and the difficulty of pursuing the necessary financial and resource commitments. 1/

FEA's approach is summarized as follows:

--Forecast the state of the U.S. economy to 1985.

--Make assumptions concerning the prices of primary energy sources, such as oil and gas, and generate four different price scenarios.

--Calculate national and regional energy demands by fuel and consuming sector (household/commercial, industrial, and transportation).

--Calculate energy price elasticities.

--Incorporate conservation and demand management strategies.

Data Resources, Inc., macroeconomic and industry model

The forecasts of energy demand generated by the demand component depend upon assumed values of economic and

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1/See note on p. 16.

demographic variables. The variables, projected to 1985, include the gross national product (GNP), the unemployment rate, the consumer price index, the wholesale price index, population, personal disposable income, nonfarm compensation, housing starts, and a number of the Federal Reserve Board industrial production indexes.

The long term projections of economic variables which were required were derived by means of the DRI macroeconomic and industry model (also called the DRI quarterly model). The DRI model is a large econometric model of the U.S. economy, which is updated annually (the 1974 version was used in PIES-74), based on new data and each year's forecasting experience. The model, excluding the industry section, consists of several hundred equations and about 100 input variables; the industry section also contains several hundred equations and requires additional input variables. Examples of these variables are certain tax rates, noninstitutional population data, and the amounts of State and local obligations outstanding. The sources of this data are primarily government and industry data collection sources (e.g., Bureau of Census, Department of Labor, trade associations).

The macroeconomic section of the model requires solving a large system of equations simultaneously to project economic indicators, including those used in developing the energy demand forecast. The industry section uses input-output analysis to project such variables as the Federal Reserve Board indexes of industrial production.

How the DRI model is used for long term forecasting

The DRI model is essentially a short term model used to make a series of quarterly forecasts covering a 2-year period. Periodically, long term forecasts (to 1990) are made using the model. The DRI procedure for long term forecasting involves making projections of the input data and adjusting some of the output variables over the forecast period. For this reason the long term forecast is said to be controlled. The projections of input data are based on forecasts by various Government agencies, universities, various DRI long term models of specific sectors of the economy, and the best judgments of DRI economic experts.

A number of options exist in operating the DRI model. The following examples illustrate how some of these options were used to control the long term forecast:

--The policy-simulation option of the DRI model permits establishment of upper and lower bounds on fiscal and monetary goals. For example, the unemployment rate in the latter years of the projection was limited to 4.6 to 4.7 percent.

--Another DRI model option permits using a changing growth-rate for variables. For example, the Hudson-Jorgenson growth model projection for potential GNP (growing initially at 3.8 percent annually and slowing to 3.5 percent by the end of the forecast) was used in this analysis.

--Another option permits adjusting the value of output variables. For example, this option was used to adjust consumer expenditures for gasoline, automobiles, household operations (utilities), and other nondurables (fuel oil) downward for higher energy costs.

Energy demand simulation model used to forecast energy demand

The energy demand simulation model was developed by FEA based upon the Verleger-DRI energy policy model and associated data base. The model provides two types of information relevant to analysis of energy markets: (1) energy quantities demanded (consistent with a given set of energy prices for each energy product by major consuming sector for a specified year) and (2) how price changes will influence demand in the specified year. Energy sources considered by the model are coal (bituminous and anthracite), natural gas, petroleum (broken down into eight fuel categories), and electricity distributed.

Three consuming sectors are modeled--household/commercial, industrial, and transportation. The demand for fuels by the electric utilities sector was determined within the integrating component. The model also estimates demand for energy products such as asphalt, naphtha, and petroleum coke, used as raw materials by industrial activities.

The model consists of four submodels which

--calculate energy prices,

--calculate a set of nonprice energy specific independent variables,

--predict national energy demands, and

--predict regional energy demands.

In addition to the data provided by the DRI macroeconomic and industry model, the energy demand simulation model requires assumptions about energy-related variables such as military consumption of jet fuel, energy price data, and housing insulation factors.

Energy price data for 1973-85 which are used in the model include

--wellhead price of crude oil,

--field price of natural gas, and

--refiner's markups for refined petroleum products.

With this information the model calculates the price of household/commercial and industrial natural gas and electricity and of refined petroleum products.

Price assumptions

FEA attempted to measure the possible effect of different world oil price assumptions on the U.S. energy market by using different sets of energy prices. These were referred to as the $4, $7, $11, and $15 scenarios. The $4 scenario assumed a constant $4 a barrel crude oil price through 1985. The $7 scenario assumed a $4 a barrel price in 1973, increasing to $7 a barrel for 1974-85. The $11 and $15 scenarios assumed a $4 a barrel price for crude oil in 1973, approaching $11 and $15 a barrel, respectively, in 1985 with about 87 percent of the adjustment occurring by 1980. These crude oil prices are average weighted prices for imported and domestic oil and are in constant 1973 dollars. The Project Independence report focused on the $7 and $11 scenarios.

Calculating national demand

The methodology used to calculate energy demand is termed "top-down" since the model calculates national energy demands and then breaks this data down into census regions.

In determining national demands, each sector is modeled individually. For the household/commercial sector, the model first predicts total energy consumed in the sector as a function of (1) the stock of housing, (2) the per capita income, and (3) a price index for total fuel and power. Electricity demand is then predicted and this figure is subtracted from total demand to determine the demand for heating fuel. Finally, the demand for heating fuel is spread among the various products (i.e., natural gas, distillate, residual, kerosene, still gas, and bituminous and anthracite coal) that can be used to satisfy this need.

For the industrial sector the same basic procedure is used. First, total demand is determined as a function of (1) a price index for total fuel and power and (2) a measurement of industrial activity. Then electricity demand is predicted and by subtracting this figure from total demand, the boiler fuel demand is calculated. Boiler fuel demand is then broken down into demand for the various boiler fuels (i.e., natural gas, bituminous coal, distillate, kerosene, residual, liquefied gases, and still gas). The demand for anthracite coal and bituminous coke by the industrial sector was estimated separately from the procedure as a function of time, and industrial activity and unemployment, respectively.

For the transportation sector, demand for gasoline, liquefied gases, residual fuel, jet fuel, and bituminous coal are predicted separately rather than as a total and then broken down. For example, gasoline demand is a function of gasoline price and per capita income while bituminous coal is a function of time. The demands for asphalt, naphtha, bituminous coal, petroleum coke, and natural gas as raw materials were, in general, determined as a function of the level of industrial activity.

A lagged adjustment of energy demand to changing conditions (e.g., energy prices, fuel availability, technology) has been incorporated into the model. Thus, in response to a sudden change in underlying conditions, demand will not adjust instantly to a new long-run equilibrium pattern but will do so gradually. FEA stated that this approach, while generally not able to entirely account for large adjustments from one state of the economy to another, is an improvement over a procedure which allows no adjustments.

Historical data was used to develop the equations that determine energy demands and their responsiveness to price. FEA noted that, while great care was taken in selecting time periods (for the historical data) which would not bias the results, there are two major limitations to this approach. First, estimates resulting from use of historical relationships rarely capture the technological or structural changes which will occur in the future. Also current large energy price increases are far beyond the range of historical experience. 1/

Regionalizing the national forecast

The national forecasts of energy demand by fuel and consuming sector were broken down into census regions.

1/See note on p. 16.

Three methods were required: development of regional fuel share equations, use of historical distributions, and use of related regional activity variables. For example, regional quantities of gasoline and jet fuel were forecast as functions of regional population and per capita income. A number of the major items such as electricity and natural gas in the household/commercial and industrial sectors were regionalized using 1972 regional shares. Fuels for which no regional demand data was available (primarily raw materials and lesser used fuels) were spread over the regions proportionately to forecasts of related regional economic activity.

Calculating price elasticity

Demand elasticity is an economic term used to represent how responsive consumers of a product are to a price change for the product (own-elasticity) or a competing product (cross-elasticity). The model was used to predict how energy price changes would influence demand in a given year by calculating own- and cross-elasticities of demand in future years. The elasticities were national and not regionalized as were the other data used in the integrating component.

FEA noted specific problems relating to the values of the elasticity coefficients calculated by the model. Some negative cross-elasticities resulted. These are theoretically incorrect results since they imply that as the price of fuel A increases the demand for the substitute fuel B decreases. Also, some own-elasticities declined with time, a result contrary to intuition. Additionally, some elasticities were considered too high by the FEA staff and were adjusted downward. FEA believes that these problems resulted in part from the econometric estimation technique used, the historical data problem mentioned earlier, and the regional variations in elasticities known to exist but which could not be incorporated since the top-down approach was used. 1/

Adjustments for conservation and demand management

One objective of demand forecasting was to estimate and incorporate the effects of non-price-induced energy conservation initiatives into the demand forecast. Strategies were developed to represent an all-out effort to decrease energy demand and alter energy-use patterns (the energy conservation strategy) and redistribute aggregate demand from fuel sources (the demand management strategy).

1/See note on p. 16.

Costs and effects of a number of energy conservation options for each energy-consuming sector were developed. These energy conservation options included proposals for increasing home insulation, improving the energy efficiency of buildings, improving automobile fuel efficiency, and stimulating increased recycling. The results of the conservation policies do not include reduction in demand due to price increases.

Demand management refers to mandated changes in the specific fuels used. It involves establishing a set of Government measures aimed at redistributing the end uses of those fuels that can be produced domestically, thus decreasing requirements for imported fuels. The specific actions evaluated attempted to reduce oil and natural gas consumption (two fuels that are partially imported). The strategy emphasizes substituting coal (an abundant domestic fuel source) for oil and natural gas by electric utilities and large industries and encouraging electrical use rather than direct consumption of oil and natural gas in the household and commercial sectors.

INTEGRATING COMPONENT

The integrating component was developed to simulate marketplace interaction of supply, demand, and resource constraint data in the U.S. energy system. To accomplish this, the following process was used:

1. An estimate was made of price and quantity demand for each energy product in a specified year. These initial estimates, along with a table of elasticities, are provided by the energy demand simulation model.

2. Energy production levels and prices necessary to meet demand at a minimum cost to the Nation are calculated under a set of constraints. These calculations are accomplished by a linear programming model.

3. Assumed demand prices are compared to calculated supply prices. If the differences between the corresponding prices for the various energy sources are minor, the procedure is terminated, with the last set of equilibrium prices and quantities being the solution. If the supply and demand prices are significantly different, the process advances to step 4.

4. Demand prices are adjusted in the direction of the supply prices. New demands are calculated using a simplified demand model and these new prices and demands are then used in step 1.

The repetitive process continues until it reaches a set of prices and quantities which are in equilibrium.

FEA stated that ideally, in step 4, the energy demand simulation model would be recomputed using the new prices to obtain new demand quantities but that this procedure was unworkable due to the model's complexity. A simplified version was used in step 4 to provide an approximation to the demand model for prices close to those initially used in generating the unconstrained demand forecast. 1/

The linear programming model

The linear programming description of the supply system is conceptually equivalent to the model supporting the emergency energy capacity study of the Office of Emergency Preparedness and the total energy hydrocarbons study of the PACE Company of Houston, Texas. The model for the former study has been modified to assemble the supply component for the Project Independence integrating model. The emergency energy capacity model was developed by Bonner and Moore Associates, Inc., for studying the consequence of alternate plans for coping with interruptions in the supply of imported oil.

The linear programming model begins with projections of the amount of fuel demanded by each region as a function of price. These projections were determined by the energy demand simulation model in the demand component. Using the revised matrix, it works through the transportation processing and distribution system to discover what fuels by region are available to satisfy the demands for fuel. The model uses decision rules which assume that supply patterns are chosen to minimize costs to the Nation.

FEA stated that ~~this~~ this approach implies an efficient domestic energy market and, to the extent that this assumption is invalid--due to factors such as imperfect market information--the model will overestimate energy use and underestimate variations in regional prices. 1/

Termination of the repetitive process

The linear programming model calculates a solution which includes supply prices. If these supply prices calculated by

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1/See note on p. 16.

the model are sufficiently close to the price estimates at the beginning of the process, the repetitive process is terminated. Otherwise, a new set of prices is produced. These new prices are then used by the simplified demand model to obtain a new set of demand quantity estimates which are used as the basis of the next linear programming model solution. The assumption is made that all demands exhibit constant elasticities and cross-elasticities throughout or at least over the relevant range of fluctuations in price created through the repetitive process.

Report writers

The solution received from the linear programming model is translated into a more readable format by a series of computer programs called report writers.

Reports produced may be divided into two categories:

--PIES-74 model report--The basic executive report associated with a given model run. It summarizes the information contained in a model solution, providing English language headings for comprehension.

--Resource reports--Resource report writers take the results of a model solution and calculate the estimated amount of resources necessary to produce the fuel supplies used in the solution. Resources can be either cumulative, which describe resources needed from January 1, 1975, until January 1 of target year, or current which describe resources needed during the target year itself. Resource report writers were developed for finance, water, environment, materials, and equipment.

Integrating component output

The output consists of estimates of U.S. consumption of energy resources for a specified year (e.g., 1985), a specified scenario (e.g., business-as-usual), and a given price of crude oil (e.g., $11 a barrel). Estimates were presented in physical units (e.g., millions of barrels of petroleum) and grouped by consuming sector (e.g., household/commercial). In addition, substantial amounts of data related to the energy system and required to meet estimated consumption were provided (e.g., the quantity and price of various types of coal produced in the north Great Plains coal region, the quantity and price of residual fuel refined, etc.)

FEA stated that its integrating component is not dynamic. Rather, it presented an equilibrium solution for a given year--1977, 1980, or 1985, but did not guarantee that the supply pattern (regarding its development over time) or its costs were either feasible or most efficient. Thus, the model yielded "snapshots" of supply and demand in a given year--independent of the desirability of the supply pattern in previous or future years. Construction lags or movements in price elasticities over time were included to approximate major changes, but nothing in the model assured a facility that is economic and feasible in 1980 would continue to operate or even exist in 1985. 1/

The detailed resource constraint data was not used to directly limit equilibrium solutions of the integrating component. FEA stated that the large volume of data and its inability to precisely set absolute maximum constraints prevented direct use of this data in the system and necessitated an analysis of the resource requirements after the equilibrium solution was computed. The reverse link, i.e., the effect of the resource constraints on the equilibrium solution, was not included.

FEA stated in the 1974 Project Independence report that the integrating component was run without many capacity restrictions on conversion and distribution of energy which tended to understate regional differences. 1/

ASSESSMENT COMPONENT

Energy forecasts for the alternative energy strategies resulting from the integrating component were evaluated in terms of their environmental, economic, and international impacts. According to FEA, this aspect of the Project Independence analysis is important since energy policy ought not be developed in a vacuum. FEA believes that the success of energy strategy should not be judged solely in terms of the degree to which it achieves its objectives. It must also be judged in terms of its influence on other national priorities.

There is a need to assess the environmental impact of energy strategies because each strategy varies extensively not only in terms of the contributions of each energy source to the total energy mix but also in the origin of these resources. For example, in 1985 under the accelerated development scenario, greater use was made of oil shale, Alaskan oil and gas, and outer continental shelf oil and gas than under the business-as-usual scenario.

1/See note on p. 16.

Analysis of economic impact is required since each energy strategy combines different energy policies and produces different effects on the national economy. This economic effect is transmitted directly through such factors as changes in prices and quantities of energy products, allocation of production between domestic and foreign sources, and effects on the Federal budget. Direct effects, in turn, induce secondary effects. For example, energy price increases will affect various sectors of the economy in proportion to the amount of energy they require and the differing possibilities for substitution. FEA's economic analyses assessed the probable impact of each energy strategy on many aspects of the U.S. economy including economic growth, price stability, employment, and balance of payments. However, there was no feedback of these results to refine energy demand estimates and reassess the energy forecast. 1/

The oil embargo demonstrated U.S. vulnerability to political and economic coercion due to heavy U.S. dependence on imported oil. However, the integrating component did not have the capacity to examine international issues such as import security, international energy market implications, and alternative international initiatives that the United States could pursue. Consequently, a separate model was used for international assessment.

Environmental assessment

FEA analyzed the environmental impact of broad alternative energy strategies. For each 1985 energy supply/demand scenario produced by the integrating component, estimates were made, by region, of the pollution loading--the amounts of given pollutants resulting from the extraction and processing of each region's energy resources. Pollution loadings are calculated by multiplying the amount of a region's energy production by the amounts of various pollutants resulting from the extraction and processing of each unit of the various energy resources.

In its analysis, the integrating component used different geographic regions for each energy production and conversion activity. For example, the coal supply regions differ from the petroleum supply regions resulting in inconsistent and overlapping boundaries. The environmental analysis produces pollution loadings from energy development in each census region (Alaska was considered as a separate region) by breaking down the pollution data into small subregions (river basins) and then adding the data, by census region, to be consistent with PIES structure.

1/See note on p. 16.

Pollution allocation model

A pollution allocation model for analyzing the environmental impact of the integrating component's results was developed for FEA by Energy Resources Co., Inc. The model's objectives were to aggregate loadings of the 15 selected pollutants into common geographic areas and to analyze these loadings. Of the 15 pollutants selected, 12 were water and air pollutants and the other 3 related to solid waste and land use.

The environmental analysis for Project Independence considered only 1985 scenarios. The analysis was conducted as follows:

1. The production and pollution loadings for each of the 1985 scenarios were allocated to smaller regions with common boundaries. This permitted calculation of total pollution loadings for a given geographic area. The 335 river basins as defined by the National Oceanographic and Atmospheric Administration were selected as the smaller regions. The allocation of pollutants to each river basin was based on the known location and production of energy raw materials and location and size of existing and planned conversion facilities.

2. Pollutant loadings were aggregated into larger regions (census region or national) and the predicted loadings compared to available 1972 loadings by energy activity or by area. Since this was done for each scenario ($7 oil and $11 oil, business-as-usual, accelerated development, etc.), the effect of these strategies on the level of various pollutants could be examined.

3. The impacts of pollution loadings at either the river basin level or for a larger area were then analyzed to determine their effect.

Energy Resources Co., Inc., noted that pollution loadings are only those directly attributable to energy material extraction and processing on a per unit of energy output basis. Because pollution from other energy-related activities--such as construction of energy facilities or secondary development induced by energy development--could not be estimated on a per unit basis of energy output, pollution loadings did not include pollutants from such sources. In addition, pollution loadings resulting from the end use of energy was not analyzed. Further, due to technical difficulties with the transportation portion of the linear programming model of the integrating component, pollution loadings from transportation and transmission of energy were not included. 1/

Economic assessment

FEA's analysis of the economic impact of the alternative energy strategies was based on a forecasting system comprised of two large computer models, INFORUM and LTMAC. The linking of these models enabled FEA to examine the economic impact at the national level (LTMAC) and the industry level (INFORUM) in a consistent manner. INFORUM provided the means for relating energy prices to the prices in all other sectors and provided information on production levels for those sectors. LTMAC, the Chase Econometrics long term macroeconomic model, linked this production activity to income, the capital market, and the labor market.

INFORUM

INFORUM is a large input/output analysis model. Input/output analysis examines the interindustry flow of raw materials, intermediate products, and technical and financial services that precedes the delivery of finished products to final markets. The results of this type of analysis are represented in an input/output table which displays on its horizontal rows the sales (outputs) by each industry to other industries and, in its vertical rows, the purchases (inputs) by each industry from other industries.

INFORUM divides the economy into 185 industries and shows the sales of each of these to each of the others and to many types of capital investment, to consumers, to Government, and to exports. More than 1,000 equations are used to forecast consumer demands, investment, export and import behavior, labor productivity, and changes in materials used by the 185 industries. Input/output coefficients were based on the Department of Commerce input/output data for 1967 which was the most up-to-date and complete data source available. Forecasts were generated to 1985 for FEA's analysis.

LTMAC

LTMAC is an econometric model which solves a large system of equations simultaneously to develop its forecast. The model was run to forecast to 1985 for FEA's analysis. LTMAC analyzes essentially the same economic sectors as the DRI macroeconomic model in the demand component; however,

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1/See note on p. 16.

there are differences. For example, LTMAC has a more detailed foreign (export/import) sector than DRI and the labor sectors of the two models calculate employment and unemployment in different classifications (age, race, industry, etc.).

Linking the macroeconomic and input/output models

The linking methodology FEA uses allows INFORUM to take advantage of the data made available by an initial LTMAC forecast. In general, linkages between the models result in using the LTMAC forecast of broader macroeconomic categories as the criterion--requiring the aggregation of the more detailed INFORUM results to be consistent with the LTMAC forecast. Examples of the linkages follow.

--Given the LTMAC forecast of civilian government and military and private employment, INFORUM adjusts its estimated level of employment by industry so that the resulting unemployment rate matches the LTMAC forecast.

--LTMAC forecasts 13 categories of personnel consumption expenditures (PCE) while INFORUM has 130 PCE sectors. INFORUM calculates its own forecasts and its 130 PCE sectors are grouped into 13 PCE categories according to LTMAC definitions. The INFORUM forecast is then adjusted so that the growth rate of each group matches that of the corresponding LTMAC category.

Social and income effects

As part of the economic impact assessment, the social and income effects of each policy strategy were evaluated using three different approaches.

--The first approach traced the link between energy policy and the functional distribution of income and the link between the functional distribution of income and the levels of income received by various income classes.

--The second approach focused on the labor market to trace relationships between total unemployment and industrial unemployment, relationships of industrial unemployment to occupation, and effects on low income groups. Using Bureau of Labor Statistics data on occupations and skill levels, inferences were drawn about the distribution of unemployment among income classes.

--The third approach concentrated on income effects on a regional basis. Shifts in employment levels by industry were estimated and these shifts were translated into earnings estimates for a number of industry classifications for States and census regions.

International assessment

The oil embargo demonstrated U.S. vulnerability to political and economic coercion resulting from heavy U.S. dependence on imported oil. The objectives of the international assessment were to:

--Estimate expected world oil prices and import security through 1985.

--Assess how changes in U.S. oil import demands resulting from alternative domestic energy strategies will affect the international energy market.

--Identify and evaluate alternative international energy initiatives the United States could pursue.

An adaption of the Kennedy-Houthakker world oil model was used for one segment of this analysis--to study short term market effects resulting from the United States building of emergency stockpiles of crude oil, specifically

--the levels of world market price fluctuations stimulated by short term increased petroleum demands during a buildup period and

--the extent to which emergency storage buildup programs may hold up world oil prices in an otherwise declining price market.

The effects of energy stockpiles

The Kennedy-Houthakker world oil model is a regional, multicommodity economic model of the world oil market, excluding the Communist world. The model divides the world into six regions: the United States, Canada, Latin America, Europe, the Middle East, and Africa and Asia. Five commodities are considered: gasoline, kerosene, distillate fuel, residual fuel, and crude oil.

The model consists of four segments: crude production, transportation, refining, and demand for products. In each region the demand for refined products and the supply of crude oil are a function of price and the model determines physical flows and prices simultaneously.

This model was modified for the Project Independence analysis. In the model's operation, data is input concerning supply and demand in each region; the type of refining technology, including the cost of capital goods; and the cost characteristics of transportation among regions. Data on government policy options is also input, and the model can be used to investigate the effects of these policies. Given these variables, the model determines consumption levels, production and price for each commodity in each region, the pattern of world trade flows, and the refinery capital structure and output levels in each region.

To determine the market impact of building emergency energy stockpiles, data concerning world production capacity and demand for crude oil was required. Chase Manhattan Bank provided the world production capacity estimates for crude oil, and world demand estimates were obtained from the Organization for Economic Cooperation and Development.

FEA had to make some assumptions concerning the acquisition of the crude oil used to build these stockpiles. Key assumptions were that:

--The supply for U.S. (and other consuming countries) storage buildup levels was assumed to have been purchased from the world export market.

--Producer countries were not assumed to cooperate by increasing export supply during the buildup.

To simulate the buildup of energy stockpiles, levels of U.S. imports were placed higher than required to meet normal demand.

CHAPTER 4

CONTINUED DEVEOPMENT OF PIES

PIES-74, developed as an integral part of the Project Independence effort, was initially constructed and run to aid in the preparation of the November 1974 Project Independence report. After the report was completed, FEA used PIES as a policy-analysis tool and has further refined and developed the system. This refined system, used to support the "National Energy Outlook" published by FEA in February 1976, is not addressed in this report.

A July 1975 plan for the continued revision and improvement of PIES--"Organization for Operation and Improvement of PIES"--is the most current document outlining PIES' future structure. The plan states in part that:

> "The information and procedures developed during the Project Independence analysis provide a foundation and structure for the evolution of energy policy analysis and development. Capitalizing on this knowledge requires a careful coordination of our resources. This paper presents the structure for consolidating and organizing the future operation and improvement of the Project Independence Evaluation System (PIES). * * * This proposal focuses on the requirements for maintaining and improving the system as well as identifying responsibility for coordinating the application of the system for policy analysis. The primary objective of these efforts is to prepare the systems and necessary analytical support for the publication of a revision of the Project Independence Report on December 1, 1975."

FEA's planned modification and revision of PIES is based on the assumptions, among others, that:

--PIES will continue to be used and improved as the primary system for quantifying and evaluating long-run energy policy options.

--To the extent possible, PIES activities previously performed by other Government agencies, such as data control, should be absorbed by FEA.

--A revision of the 1974 Project Independence report and the necessary improvements in the analytical systems will be completed by December 1, 1975.

In order to accomplish the modification and revision, a formal organizational structure and statement of objectives for maintaining and operating PIES, along with specific tasks and milestones, was established in the form of the previously mentioned plan.

This plan can be separated into several categories which are discussed on the following pages:

--Policy applications.

--Data collection, validation, and improvement.

--Resource supply and cross-cut modeling.

--Demand component.

--Integrating component.

--Assesment component.

POLICY APPLICATIONS

The plan calls for establishing a function within PIES to

--identify major policy questions that PIES must address and

--propose system changes or characteristics needed to be responsive to policy issues or policy users.

This information includes establishing a users' group within FEA which would

--develop a statement of the model's goals and capabilities,

--assist users in making requests to run the model, and

--disseminate information about PIES policy applications.

DATA COLLECTION, IMPROVEMENT, AND VALIDATION

For the November 1974 report, task forces, made up primarily of individuals from other Government agencies, developed the data used by PIES-74. According to FEA's plan, FEA will assume primary responsibility for maintaining this data for the next report. Specifically, FEA will

--identify all data bases being used to support PIES,

--establish procedures and standards for updating and improving the PIES data base,

--implement procedures for data base collection and maintenance, and

--establish and implement procedures for validating the data base to insure that the data elements are properly defined, measured, estimated, and recorded.

RESOURCE SUPPLY AND CROSS-CUT MODELING

The resource supply and cross-cut (nonenergy data such as water and manpower) task force efforts were primarily the responsibility of other Government agencies. To some extent these task forces used models, which were not considered a part of PIES-74, to develop their data. With the restructuring of PIES for the next report and the decreased dependence on other agencies, FEA is assuming responsibility for these efforts. Specific tasks FEA has outlined in its plan include

--documenting, improving, and validating the oil and gas supply model;

--participating in the development of a coal supply model;

--validating the methodologies and models used to forecast supply of all other fuels; and

--assimilating and improving all the cross-cut models needed for PIES.

DEMAND COMPONENT

The demand component will be revised. The major change is that for the primary fuels (coal, oil, gas, electricity distributed) a regional demand model will be developed which calculates regional energy demands and elasticities and adds these to determine national energy demands. Other planned changes to the demand component include

--mechanizing the implementation of the conservation scenarios,

--developing and refining the demand component interface with the integration component, and

--validating and documenting the model.

INTEGRATING COMPONENT

Planned changes to the integrating component include

--examining ways to incorporate macroeconomic models into the integrating component,

--incorporating the long term contract price effects for natural gas into the system,

--exploring the feasibility of making the demand model of the demand component accessible to the integrating component,

--incorporating the resource constraints into the system, and

--expanding and updating the transportation data and structure of the system.

ASSESSMENT COMPONENT

Plans outlined for the assessment component include

--improving international assessment so that PIES can address international policy issues and

--revising the economic impact analysis by (1) reassessing the capabilities of the DRI and Chase models, (2) determining refinements to the models, and (3) establishing a method for phasing the model(s) into the integrating component.

CHAPTER 5

APPRAISAL OF PIES-74

We believe that PIES-74 was a valuable initial attempt to provide an integrated framework for evaluating energy policy. Given severe time constraints, FEA developed an innovative framework for analyzing the complex and interdependent sectors of the U.S. energy system. Nevertheless, the initial version of PIES contained serious problems which warrant improvement.

PROBLEMS IN PIES-74 METHODOLOGY

The initial version of PIES contained a number of problems. FEA is aware of these problems and is investigating the feasibility of correcting them. Until corrective action is taken, we believe that PIES will not reach its potential and the results may not be reliable. In our opinion the major problems are:

--The approach used in the development of oil and natural gas supply estimates. Any model which attempts to estimate supply for domestic oil and natural gas must depend (either explicitly or implicitly) on data whose accuracy cannot be verified (e.g., future exploration success and magnitude of undiscovered recoverable resources). The FEA supply model is no exception. Consequently, low reliability must be assigned to individual values resulting from the model. (See p. 9.)

--The development of energy price elasticities. Some energy price elasticities resulting from the demand component required manual adjustment to correct for obvious errors. Such adjustment raises questions regarding the accuracy of all elasticities developed by the system. These elasticities are important because of their use in the integrating component to balance supply and demand. (See p. 23.)

--The approach used to relate energy and economic forecasts. Any energy forecast has significant economic implications and should be consistent with economic forecasts. However, in PIES-74 the demand estimates were not integrated with the estimates of economic activity. This precluded a satisfactory analysis of the economic implications of an energy forecast. (See p. 18.)

--The static nature of PIES-74. The model produced "snapshots" of supply and demand in a given year--independent of the desirability of the supply pattern in previous or future years. For example, nothing in the model assured that an energy facility which is economic and feasible in 1980 would continue to operate or even exist in 1985. Thus, there is no guarantee that the solution calculated for 1985 is consistent with the solution calculated for 1980 or with any other year. (See p. 27.)

--The incomplete assessment of environmental, economic, and international impacts. For example, in the environmental assessment, analysis of pollution from transportation, transmission of energy, and the end use of energy was not included. This raises questions concerning the conclusions. (See p. 29.)

OTHER PROBLEMS

Our review disclosed that while sensitivity testing was conducted on some parts of PIES-74 and FEA stated that some parts of PIES-74 were validated, no systematic validation or sensitivity testing program was conducted on the entire system. Also, although FEA stated that it conducted extensive verification of the PIES-74 system, this effort was not documented.

Verification, validation, and sensitivity testing as used in this report are defined as:

Verification--Insuring that the simulation model behaves as the developer intended.

Validation--Testing the agreement between the behavior of the simulation model and actual experience.

Sensitivity testing--Seeking to determine the extent to which model results are dependent upon certain data or combinations of data. More specifically, it determines the extent to which the output of a computer model will be influenced by changing the values of the various factors (assumptions, input data, etc.) being considered.

Verification and validation have also been described as a process of building an acceptable level of confidence in the model; that is, confidence that an inference about the simulated process is valid for the actual process.

There was also a general lack of documentation to support PIES-74 during the time we were attempting to acquire information on the system. This lack of documentation lengthened the time required for our review and limited the scope of our analysis.

Computer documentation, as used in this report, is defined as information recorded during the design, development, and maintenance of computer applications to explain pertinent aspects of a data processing system--including purposes, methods, logic, relationships, capabilities, and limitations.

Computer model documentation is the instrument which allows people interested in a modeling effort--the user, the model developer, potential users, etc.--to communicate. Complete documentation is important to (1) insure that the model is thoroughly understood and can be operated and maintained in the present and the future and (2) facilitate verification of program operations by a third party (i.e., someone other than the model developer or initial user) such as GAO.

The scope and content of the documentation effort should depend on the needs of potential users, the cost to prepare the type of application, the model's sharing potential (for use by others in the Federal Government), the complexity of the system, frequency of use, longevity and stability of the model, and personnel considerations. In this regard, PIES is being modified extensively, is recognized as being extremely complex, and is being used in an important issue area.

We believe emphasis should be placed on three areas: (1) model verification/validation, (2) sensitivity testing, and (3) model documentation. Each, essential in developing a computer model, was substantially lacking in FEA's development of PIES-74. FEA--since it is committed to PIES' continued development--can probably correct these deficiencies at the same time it revises and improves the system.

OTHER APPRAISALS OF PIES-74

Several organizations and institutions have reviewed the November 1974 Project Independence report. While the scope of these reviews generally encompasses the whole Project Independence effort, we have summarized here comments pertinent to the scope of our report--those relating to PIES-74. Reviewers included the:

--Massachusetts Institute of Technology (MIT) Energy Laboratory Policy Study Group.

--Battelle Columbus laboratories.

--Panel on Project Independence Blueprint; Subcommittee of the Department of Commerce Technical Advisory Board.

Each reviewer criticized specific parts of PIES-74. However, Battelle stated that PIES-74 was useful for analyzing a great many energy options and policy issues. The MIT review noted that before this effort there was no central analytical tool available in the Government for analyzing energy alternatives and that energy data collection capability within the Government was fragmented. The MIT review concluded that:

> "* * * the various pieces were drawn together into a coherent system which can provide a framework for managing data, coordinating judgments, and forcing consistency in the various assumptions that must be made in any analysis of a system as complex and interdependent as the energy sector."

Rather than summarizing each review separately, these comments are grouped as they pertain to each component of the system--supply, demand, integrating, and assessment. These comments represent the views of the various reviewing institutions. We have not assessed these comments but we believe that they identify issues of which FEA should be aware.

SUPPLY COMPONENT

The MIT group stated that the supply estimates for domestic oil and natural gas are based on a methodology that is only a minor improvement over the NPC model on which they are based. Furthermore, it stated that the results are almost totally dependent on the judgments of the analyst feeding in drilling and discovery rates to the model. The method of analysis has been applied so that it appears to underestimate the likely response of oil and natural gas supplies to price changes. This occurs because, under FEA's procedure, an increase in price in 1975 brings about increased drilling only after 1980 or even later. In particular, the method seriously underestimates the likely level of exploratory activity for natural gas by basing the expected drilling rates on the experience of the early 1970s when gas drilling was restrained by the effects of field-price regulation.

According to the MIT reviewers, no attempt was made in FEA's oil forecasting method to differentiate drilling regions according to the likelihood of success. Some locations were not gone over by geophysical research groups as thoroughly as others. In addition, they pointed out that the NPC model assumes there is no difference between the economics of drilling exploratory wells and production or development wells. Drilling development wells involves less risk and takes place depending on whether it is profitable to remove oil from the reserve base at the present time or to wait and produce it later.

In the area of the natural gas supply, MIT reviewers were far more critical.

> "The FEA computer exercise is a classic example of using a complicated program to assume certain results. In the Business As Usual case, drilling rates are assumed to increase at 5 percent per year, as in the earlier NPC study, even though they actually have been increasing at four times this rate in the last few years. * * * Because of the assumed constraints on drilling, the production of natural gas from non-associated reservoirs increase only by one percent while assumed prices increase by 60 percent. In effect, drilling assumptions imply an inelastic supply of natural gas with respect to oil and gas price."

The MIT group concluded that the methodology used to develop the supply estimates for domestic oil and natural gas should be replaced by a combination of econometric models and engineering-geological analysis. The group stated that both could make economic choice explicit and provide a structure for testing and validating forecasts.

DEMAND COMPONENT

The MIT report stated that FEA's method for introducing demand into the integrating component appears satisfactory in principle, given the available data. However, a number of serious problems were encountered in the actual operation of PIES-74. The MIT reviewers felt that, although attempts were made to compensate for some of the problems arising in connection with the demand model, sufficient difficulties remain so that overall results must be viewed with caution.

The reviewers' major concerns can be separated into four categories:

--Relationship between energy and the economy.

--Energy price scenarios.

--Energy price elasticities.

--Energy conservation.

Relationship between energy and the economy

According to MIT, total energy demand is closely related to the GNP's growth rate, although to date very little analysis has been performed on that interaction. MIT stated that because the energy model was not integrated into the macroeconomic model the impact of energy prices on overall prices and wages could not be satisfactorily analyzed. Battelle noted that FEA assumed full employment and high-level GNP for the entire 1975-85 period. Battelle reviewers suggested that the analysis should have been systematically done in two alternative contexts, high and low GNP.

FEA selected the Data Resources, Inc., projection of the 1985 economy. According to the Battelle reviewers, implicit in this analysis are assumptions of (1) a Government surplus, (2) no changes in social security or military spending, and (3) some cuts in Federal income tax rates. They believe the rationale behind accepting these assumptions should have been explained.

Energy price scenarios

In PIES, the price of crude oil was one of the more important inputs. According to MIT, the assumption is made in PIES-74 that the world price of oil will smoothly approach some given real price. Although such an assumption is convenient for analytical purposes, it may be very misleading. MIT further stated that there is a good chance that world oil prices will not gravitate to some stable value but may oscillate in response to world economic conditions and the fortunes of the oil cartel. By omitting this possibility, MIT felt the FEA analysis misses the opportunity to illuminate some policy questions; e.g., guarantees against down-side price risk in order to spur domestic supply.

Energy price elasticities

MIT stated that the energy demand simulation model predicts that in the household/commercial sector the demand for natural gas will fall as the price of oil rises and that this negative cross-elasticity is contrary to expectations. It said that in the estimation procedure, FEA properly omitted data from the early 1970s--when the market could no longer be assumed to be in supply-demand equilibrium. Consequently, projections were based on the late 1950s and the the 1960s. During this period, however, natural gas was simply unavailable in many areas of the country because of the lack of pipelines. As a result, in one year there was no demand in a region and the next year--after the pipeline was opened--there was a significant change in the fuel share of natural gas without any change in relative prices. Since the FEA figures represented national demand estimates, this essential fact was obscured.

Energy conservation

The Project Independence report describes a number of possible conservation actions and estimates resulting energy savings. MIT stated that FEA had intended to use computer models to analyze the various conservation actions but it did not. MIT stated that the positioning (shifting) of demand curves associated with each initiative for crude oil price scenarios of $4, $7, and $11 was based on essentially subjective evaluation. MIT pointed out that this means these results, unlike the remainder of PIES-74, cannot be duplicated by independent analysts. Furthermore, the investment and social costs associated with the given conservation initiatives have not been developed so that resource costs and availabilities for conservation technologies cannot be evaluated.

In the transportation conservation area, the Battelle group feels that the approach taken does not reflect a full consciousness of human behavior or of the political ramifications involved. Furthermore, it said the analysis does not appear to appreciate the extent of the automotive industry's impact on the national economy. What is needed, these reviewers pointed out, are integrated studies of the economic, societal, and political aspects of conserving fuel in automobiles, in concert with the technical developments, so that the transition to a conservation ethic can be orderly. In the view of the Battelle reviewers, although the energy conservation analysis succeeds in presenting the energy savings potentially achievable through various strategies, it should have emphasized more heavily the need to educate the general public more fully regarding the benefits of energy conservation.

INTEGRATING COMPONENT

The function of the integrating component was described in chapter 3. The specific aspects of this component which concerned the reviewers were

--the partial equilibrium solution,

--the electric power calculations in the linear programming model, and

--the model's static nature.

Partial equilibrium solution

MIT pointed out that even if a supply-demand equilibrium is attained in the integrating component, it may not represent true equilibrium. The reason for this is that the prices which were arrived at in the solution may differ from those originally assumed and used in the demand component and thus used to produce the national price elasticities. In this case, the MIT reviewers stated that the final solution from the integrating component should have been run through the energy demand simulation model again.

Electric power calculations

MIT stated that forecasts of electricity supply in the report follow from what it termed a "constrained cost minimizing" approach. Inputs to this approach include: fuel prices, demands for electricity, capital costs of alternative types of generating equipment, system load factors, increments of nuclear capacity, proportions of new base, intermediate and peak capacity that will be added to meet incremental loads. The MIT reviewers felt that efforts could be directed towards having plant utilization and capacity expansion decisions determined within the integrating component, as they should be in a consistent cost minimizing framework. MIT also stated that, although the total coal consumption for electric power generation predicted by the model for 1985 appears to be accurate, too much actual coal capacity has been predicted. This amounts to about $30 billion (1973 dollars) in excess capital requirements. The MIT report stated that the effect of this has been to overstate the investment requirements for plants using coal--the marginal fuel type.

Static nature of the model

The Department of Commerce Technical Advisory Board expressed concern that FEA's model is static. It stated that although constraints may be included to reflect time dependency or "dynamic" aspects, it was not clear how these were handled in the analysis.

ASSESSMENT COMPONENT

The Battelle study summarized the environmental assessment effort as follows:

--The methodology seems inappropriate.

--The technology assessment appears superficial and incomplete.

--The FEA analysis apparently has not used all available information.

MIT stated that environmental goals are not necessarily consistent with objectives of reduced dependence on foreign energy sources and a vibrant economy. Environmentally, low-demand growth is superior to high-demand growth; importing fuel is less detrimental to the environment than producing it domestically. The problem, therefore, is one of advancing on the path of increased economic and energy welfare, while at the same time not sacrificing too much gain in quality of the natural environment, human health, and safety. In the opinion of MIT's study group, neither the techniques nor the data exists necessary to accomplish a complete determination of the optimal imports and environmental quality. But, they felt, very little of what could be done is attempted in PIES-74 environmental assessment analyses. For example, no analysis was made of problems associated with atomic wastes, radioactive emissions, or nuclear safety.

Economic assessment

The Battelle reviewers felt that the assumptions made for the economic impact analysis are too broad and tend to limit the usefulness of the conclusions. The analysis makes many assumptions which do not allow for flexibility when analyzing the many economic conditions caused by an energy shortage. For example, assumptions include no changes in productivity, no major shifts in demand, no major substitution effects, no changes in major institutions, no changes in consumer and business psychology, no changes in the tax base for State and local governments, and more. The Battelle report claimed that the analytical constraints caused by these assumptions are sufficient to raise serious questions as to the validity of the conclusions presented. In addition to the impacts assessed, the Battelle reviewers believed there should have been some evaluation of the effects of the economic constraints on the business cycle; the capital market; the distribution of income among each of the major economic sectors; land use; Federal, State, and local tax systems; economic institutions; public services and programs; and consumer and business psychology.

The Battelle reviewers felt that the social impact analysis failed to identify adequately the social impact of the price of oil and the pursuit of the alternative energy strategies. They believed that since it was assumed that the social impacts of the alternative strategies were transmitted only by altering the distribution of purchasing power, the analysis failed to identify the nature of social systems and structures, thus, making it basically an economic analysis.

The Battelle report stated that, in essence, there is no social framework presented in the Project Independence analysis and only a few social impact indicators are used. In addition, conclusions are based on old data; conditions have changed dramatically since the data was collected and the effects of these changes should have been explored more thoroughly. The reviewers felt that if the social impact analysis is to be made more relevant it must consider the social well-being of the American public. To do this, it should be recognized that material well-being should not be equated with social well-being.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

The oil embargo of 1973 and subsequent higher prices of imported oil have given additional impetus to the formulation of a national energy policy. The Congress, with its responsibilities for initiating and acting upon proposed energy legislation for appropriations, oversight, and investigations, has a demonstrated need for policy appraisals or assessments. The executive branch, with its initiation and execution functions, also has a need to make its own appraisals in the energy area.

Approaches and techniques of analysis and evaluation should be used not to replace but to support those institutions involved in public decisionmaking. The development of appropriate tools for policy analysis, such as models, are costly, but we believe that the information and data made available can more than compensate for their cost. An analysis of the country's future energy options should include such complex factors as interactions between oil, natural gas, coal, and other fuels; energy production, transmission, and distribution systems; the role of energy prices in determining energy supply and demand; regional variations in the U.S. energy system; and the economic, environmental, and international consequences of these options. We believe that it would be difficult to address, understand, and analyze these complexities without using a tool such as PIES.

The initial development of PIES was a timely effort in response to the urgent need for an analytical tool to support Project Independence. However, the initial version of PIES, as used in the November 1974 report, has certain shortcomings which could be improved. FEA is aware of these problems and is implementing a plan for improving PIES. (See ch. 4). We agree with FEA that corrective action is essential. FEA stated that the latest version of PIES incorporates extensive improvements and that this version was used in preparing the "National Energy Outlook" published by FEA in 1976.

We recommend that the Administrator, FEA, add to this plan (1) an analysis of the problems resulting from the static nature of PIES-74 and the procedures which can be used to alleviate them, (2) an analysis of the limitations in the environmental impact analysis and the procedures which can be applied to correct them, and (3) a comprehensive, well-documented verification, validation, and sensitivity testing effort.

We further recommend that, in implementing its plan, FEA give highest priority to developing complete documentation for PIES. We believe this will allow information generated by PIES to be of greater use to analysts and decisionmakers. The availability of this documentation should foster discussions and interactions which will result in increased understanding and confidence in PIES and ultimately lead to further improvements in the system. In addition, we recommend that priority be given to improvements in the following areas:

--The methodological approach used to estimate energy supply, in particular crude oil and natural gas.

--The energy demand estimation technique used in calculating energy price elasticities.

--The representation of the relationship between the energy system and the economy.

--A more thorough assessment of the economic and international impacts of alternative U.S. energy policies.

Other aspects of the plan also warrant attention by FEA but we feel the items identified in the previous paragraphs deserve priority treatment.

FEDERAL ENERGY ADMINISTRATION
WASHINGTON, D.C. 20461

FEB 27 1976

DEPUTY ADMINISTRATOR

Mr. Harry Havens
Director, Office of Program Analysis
U. S. General Accounting Office
441 G Street, N. W.
Washington, D. C. 20548

Dear Mr. Havens:

The Federal Energy Administration has examined the General Accounting Office Review of the 1974 Project Independence Evaluation System and accepts the GAO conclusions stated in that document. While we do not fully agree with all criticisms by other organizations cited in the review, we understand that these criticisms are not necessarily endorsed by GAO but are included for informational purposes.

The review professionally evaluates the Project Independence Evaluation System as it existed in December 1974 when the Project Independence Report was published. Since that time, however, the system has been extensively revised; many of the problems identified in the GAO review have been corrected. Additional shortcomings suggested by the review are being addressed or have been addressed in analyses based upon outputs from the Project Independence Evaluation System. It is this revised version of the system which has been used for the National Energy Outlook published by FEA in March 1976.

We appreciate the major effort expended by the General Accounting Office in carefully reviewing the PIES system. We at FEA believe that such professional reviews of our major analytical systems can help to assure continual improvement in our ability to provide reliable forecasts and analyses of major energy related questions.

Sincerely,

Eric R. Zausner
Deputy Administrator

ADDITIONAL INFORMATION ON MODELS DISCUSSED IN THIS REPORT

SUPPLY TASK FORCE MODELS

Model name--NPC Oil and Gas Supply Model

Developer--National Petroleum Council with FEA modifications

Computer system or network--National Institutes of Health computer system

Computer--IBM 370/168

Computer location--Bethesda, Md.

Computer language used--FORTRAN

Model name--Coal data integrating model

Developer--TRW Systems Group

Computer system or network--TRW timesharing system

Computer--CDC 3300

Computer location--Redondo Beach, Calif.

Computer language used--FORTRAN

Model name--Oil shale model

Developer--Battelle Memorial Institute

Computer system or network--Battelle

Computer--CDC 6400

Computer location--Columbus, Ohio

Computer language used--Nucleus

Model name--Synthetic fuel model

Developer--Battelle Memorial Institute

Computer system or network--Battelle

Computer--CDC 6400

Computer location--Columbus, Ohio

Computer language used--Nucleus

CROSS-CUT TASK FORCE MODELS

Model name--Simulation model of North American Pipeline System

Developer--J. B. Debanne

Computer system or network--MIT

Computer--IBM 370/168

Computer location--Boston, Mass.

Computer language used--FORTRAN

DEMAND COMPONENT

Model name--DRI macroeconomic and industry model

Developer--Data Resources, Inc.

Computer system or network--DRI timesharing network

Computer--Burroughs 6700/7700

Computer location--Lexington, Mass.

Computer language used--ALGOL

Model name--Energy demand simulation model

Developer--Federal Energy Administration

Computer system or network--DRI timesharing network

Computer--Burroughs 6700/7700

Computer location--Lexington, Mass.

Computer language used--Modsim

ASSESSMENT COMPONENT

Model name--Pollution allocation model

Developer--Energy Resources Co., Inc.

Computer system or network--First Data Corp. timesharing system

Computer--PDP-10

Computer location--Waltham, Mass.

Computer language used--BASIC

Model name--Long term macroeconomic model (LTMAC)

Developer--Chase Econometrics Associates, Inc.

Computer system or network--Remote batch facility

Computer--Univac 1108

Computer location--New York, N.Y.

Computer language used--FORTRAN

Model name--INFORUM

Developer--Clopper Almon

Computer system or network--Remote batch facility

Computer--Univac 1108

Computer location--New York, N.Y.

Computer language used--FORTRAN

Model name--Kennedy-Houthakker world oil model

Developer--Michael Kennedy

Computer system or network--DRI timesharing system

Computer--Burroughs 6700/7700

Computer location--Lexington, Mass.

Computer language used--FORTRAN

INTEGRATING COMPONENT

Model name--Simplified demand model

Developer--Federal Energy Administration

Computer system or network--CDC Cybernet timesharing system

Computer--CDC 6400/6600

Computer location--Rockville, Md., and Minneapolis, Minn.

Computer language used--FORTRAN

Model name--Linear programming model

Developer--Federal Energy Administration

Computer system or network--CDC Cybernet timesharing system

Computer--CDC 6400/6600

Computer location--Rockville, Md., and Minneapolis, Minn.

Computer language used--PDS and APEX mathematical language

COMMITTEE ON SCIENCE AND ASTRONAUTICS
HOUSE OF REPRESENTATIVES
SUITE 2321 RAYBURN HOUSE OFFICE BUILDING
WASHINGTON, D.C. 20515

November 14, 1974

B-178205

Honorable Elmer B. Staats
Comptroller General
of the United States
Washington, D.C. 20548

Dear Mr. Staats:

The Committee on Science and Astronautics has been actively involved in the review of energy research and development since 1971. In the 93rd Congress, the Subcommittee on Energy worked primarily on legislation dealing with solar and geothermal energy. The recently approved reorganization of the House Committee structure, as contained in H. Res. 988, will change the Science and Astronautics Committee to the Committee on Science and Technology. Under this reorganization, it will become the responsibility of the Committee to review all aspects of energy research and development.

One policy tool available to the Committee will be the Project Independence Blueprint prepared by the Federal Energy Administration. Much of the information in the document was obtained by the use of computer simulation models.

I should like to request GAO to undertake a thorough review and analysis of the methodology used in the computer programs, including the following aspects:

1. The major assumptions made in the model.

2. Enumeration of any specific computational methods.

3. The source and reliability of the input data.

4. The sensitivity of output input information to the input data.

5. Results of tests of the computer simulation models.

It would be helpful if the review can be completed by the end of February 1975.

Any questions your staff might have regarding the information requested can be discussed with Mr. Kirk Hall of the Committee Staff.

Sincerely,

OLIN E. TEAGUE
Chairman
Committee on Science and
Astronautics

LIST OF RELATED GAO REPORTS

"Improvement Needed in Documenting Computer Systems" B-115369, Oct. 8, 1974

"Auditing a Computer Model: A Case Study," May 1973

"Advantages and Limitations of Computer Simulation in Decisionmaking," B-163074, May 3, 1973

PRINCIPAL OFFICIALS

RESPONSIBLE FOR THE ADMINISTRATION OF

ACTIVITIES DISCUSSED IN THIS REPORT

	Tenure of office From	To
FEDERAL ENERGY ADMINISTRATION (note a)		
ADMINISTRATOR OF FEDERAL ENERGY ADMINISTRATION:		
Frank G. Zarb	Dec. 1974	Present
John C. Sawhill	May 1974	Nov. 1974
William E. Simon	Dec. 1973	May 1974
DEPUTY ADMINISTRATOR:		
Eric R. Zausner	Aug. 1975	Present
ASSISTANCE ADMINISTRATOR OF OFFICE OF POLICY AND ANALYSIS:		
Vacant	Aug. 1975	Present
Eric R. Zausner	Jan. 1974	Aug. 1975
DEPUTY ASSISTANT ADMINISTRATOR FOR ANALYSIS:		
Bart A. Holaday	Jan. 1974	Present
DIRECTOR, OFFICE OF QUANTITATIVE METHODS:		
William Hogan	Sept. 1975	Present
William Hogan (acting)	Jan. 1974	Sept. 1975

a/Federal Energy Office prior to June 1974.

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