MASTER

THE MODELLING OF CAPITAL
REQUIREMENTS IN THE ENERGY SECTOR:
CAPITAL MARKET ACCESS

FINAL MEMORANDUM

Prepared by

Energy Resources Co. Inc.
Cambridge, Massachusetts
and its subcontractor:
Data Resources Inc.
Washington, D.C.

April 1978

Prepared for

United States Department of Energy
under Contract No. EL-78-C-01-2529
Task Order No. 003

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MODELLING OF CAPITAL REQUIREMENTS IN THE ENERGY SECTOR

1.1 Study Purpose

The Department of Energy (DOE) is currently engaged in the development of formal modelling techniques for analyzing the capital requirements of energy industries. The desire is to be able to forecast any problems which may occur in the supply of capital which will be necessary to meet the large expansion needs of the domestic energy industry. To that purpose, a survey has been undertaken of a number of models which forecast energy-sector capital requirements or which detail the interactions of the energy sector and the economy. The survey is designed to identify those models which can be useful as prototypes for some portion of DOE's modelling needs. The models were also examined to determine any useful data bases which could serve as inputs to an original DOE model.

The first topic discussed below considers the various modelling capabilities which are needed for analysis of capital markets vis a vis the energy sector. The following sections examine a selected group of models for the extent to which they have these capabilities. The next segment of the report covers the data sources being used by these models, and any other data sources which could be useful. This information is supplemented by summary matrices describing the model characteristics and the level of detail included in each. Also, a catalogue of the relevant data bases is provided.

2.1 Useful Components of an Energy Sector-Capital Markets Model

Ideally, the model that is eventually constructed at DOE would provide a complete description of energy demand and supply, physical capital requirements and financing requirements for the energy sector, and of the interaction between the energy sector and the economy and national capital markets. None of the existing models attempt to cover this agenda. As a result it is useful to divide an idealized capital market model into its component parts. The major details for each component are described below. This discussion will serve as the basis for the analysis of the existing models and for describing the applicability of each model in the matrices presented at the end of the report.

The models were examined to determine their capabilities in the following areas:

1. Energy demand forecasting. This would be provided preferably on an industry-by-industry basis. The demands should be price sensitive and allow for the possibility of fuel switching.
2. Energy supply forecasting. Supply forecasting should take into account technical considerations of resource availability and the requirements of resource extraction, conversion, and distribution.
3. Conversion of supply forecasts into physical capital requirements and into financing needs. The supply scenarios need to be converted into industry financing requirements to determine the

total capital bill for the industry. This involves estimating the costs of exploration and extraction, energy facility construction, and energy transmission and distribution. Other substantial cost items such as the cost of environmental controls must also be calculated. The total capital needs must then be assessed to determine the external financing requirements for the energy industries.

4. Capital market modelling. A final component of the desired model would examine the aggregate and sectoral capital flows to determine the ability of capital markets to finance the necessary expansion.

3.1 Existing Models

The existing energy-economy models were designed to fulfill a large number of purposes. The models selected for analysis here have been classified into the following groups for the purposes of discussion:

1. Capital-market or capital-availability forecasting models.
2. Physical capital or construction (of energy facilities) forecasting models.
3. Macroeconomic forecasting models with input-output analysis capabilities.
4. Utility models.
5. Other models.

included in this discussion, are the models analyzed by the subcontractor to this project, Data Resources Inc. The categories are not designed to completely describe the models. Models are grouped according to their most significant characteristics for the purposes of this study. For example, a number of models examine the physical capital requirements of the energy sectors. However, several of these have been placed in the macro/input-output model category for discussion.

3.1.1 Capital Markets and Capital Availability Models

Fossill1

The Fossill1 model was designed at the Thayer School of Engineering at Dartmouth College for wide-ranging policy analysis purposes. It is a system-dynamics model which is a modelling technique developed for sensitivity analyses of complex, nonlinear systems. As such, it is capable of providing a first-order approximation of policy impacts on the energy sector and the economy, but is not designed to provide exact quantitative forecasts.¹ The functional forms used in the model are mathematical approximations of what are presumed to be key factors in the production and demand processes. Some relationships are estimated through regression analysis. The model nonetheless has several interesting characteristics.

First, it explicitly considers the internal and external financing requirements of the principal energy sectors. The flow of funds for investment are dependent on company revenues and on the rate of return to investment (ROI). The ROI is allowed to vary with changing market forces. Also, the model is a disequilibrium model. Markets are not

presumed to clear and capital supply shortfalls could thus result if the rate of return is insufficient. This possibility could be of interest for the modelling of capital supply. In Fossill a supply/demand imbalance affects the rate of return on investment. Then the ROI, the capital intensity of a supply technology, the tax rate, and the estimated fixed and variable costs are summed to determine the price.

Bankers Trust Model

The Bankers Trust Company has developed some projections of capital requirements for the energy sector and has compared them to a flow of funds analysis of future capital markets. This work is the most complete of a number of prediction efforts made by financial institutions (Irving Trust Company and Manufacturers Hanover are others). It does not, however, provide a reproducible methodology or original analytic techniques. The capital requirements are estimated from data published by various government and private organizations. The capital market estimates are based on extrapolations of current savings and investment trends. Simple assumptions are made about the rate of growth of GNP and energy demand, and all portions of the study include considerable subjective judgement.

The study results do, however, respond directly to the question of capital availability. The last analysis, published in 1976, foresaw few signs of a capital shortage. An update of the projections is to be presented in mid-1978.

DRI Macroeconomic Model of the U.S. Economy

The DRI Macro Model is a Large-scale simultaneous model of the domestic economy, consisting of over 800 behavioral equations describing consumer behavior, government finances, industrial activity, income, wages and prices, and the financial environment. It is quarterly and is simulated to 1990 regularly by DRI and its clients. Maintained on a computer and accessible through English-language interactive dialogue, it is kept current, as updating takes place quarterly, and reestimation on an annual basis. It is used for analysis of issues which have national implications such as energy policy, tax policy, labor policy, social security packages, and monetary policy. It is the financial interaction in this model that is of most interest in this investigation.

The current DRI model has a financial sector which consists of equations delineating the financial behavior of household, business, financial institutions, state and local government, and the central government. Some 26 markets for financial assets and liabilities are modeled. A total of 201 equations describe the determination of:

1. M1 through M5
2. commercial bank reserves, loans, investments and deposits
3. household demands for financial assets and liabilities
4. central bank monetary policy
5. new debt issued by Federal, state and local governments
6. most loans, investments and liabilities of savings and loans, mutual savings banks, life insurance companies and credit unions

7. business demands for money, large C-D's bonds commercial paper; short-term liabilities such as bank loans, issues of commercial paper and new stock and long term bond and mortgage liabilities; and construction -in- process, as indicated on the nonfinancial corporate sector balance sheet.

These features of the model facilitate the analysis of a capital adequacy or capital shortage question. An example of usage of the model for this issue appeared in the Summer 1975 Data Resources Review, entitled "The Capital Shortage: Near-Term Outlook and Long Term Prospects," authored by Allen Sinai and Roger Brinner.

3.1.2 Models of Physical Capital Requirements

Energy Supply Planning Model

This model was developed by Bechtel Corporation to assess the resource requirements of meeting various energy supply scenarios. It is based on Bechtel's experience in energy facility construction, and its cost estimates are therefore founded on reliable engineering cost data. To operate the model, the user must input a detailed future energy demand scenario, specifying regional demands for each type of fuel for a given year, say the year 2000. The model then generates the capital and manpower requirements for satisfying this demand through construction of the necessary energy facilities.

The analysis of capital costs is limited to the requirements of facility, construction, and operation. Certain "owner" charges, such as interest expenses during construction and lease acquisition costs, are excluded. Also the model was not designed to describe firm or industry finances, so there is no estimate of external financing needs. The model simply calculates the total capital (and manpower) bill for construction and operation of energy facilities.

ICF Oil and Gas Model and Coal Model

The ICF models, which were originally developed for PIES, produce supply curves for the future development of the oil and gas and coal energy industries. The curves are based on cost estimates of all facets of resource development, including drilling and mining depths, drilling success ratios, and all operating costs. The cost estimates are

then combined with an assumption about the necessary rate of return to determine the revenue requirements and thus the supply curves for the industries.

These models provide an thorough analysis of supply costs and have been used as the basis for other work such as the modelling of regional coal markets done at Argonne National Laboratories. For considering only capital outlays, it is most useful to look at the data collected by ICF before it is input into their model. The model combines capital outlays necessary for development with the operating costs and other uses of working capital to provide the total extraction costs. More importantly, ICF has also developed subroutines which forecast balance sheets, given an estimated future price and output. The balance sheets thus outline the financing needs for these industries.

Stanford Research Institute National Energy Model

The SRI model is a simultaneous equation system of energy markets combined with a description of the "energy network" which describes all of the necessary supply functions such as resource extraction, transportation, conversion, and distribution. For each type of energy resource, supply curves were developed based on resource supply costs and the judgement of production specialists. This work focuses on the estimation of marginal supply costs. Similarly, demand curves are developed for each of 13 functional energy demands (e.g., space heat). Price elasticities are estimated for each demand curve. An iterative computer model then operates to derive market clearing prices and quantities in each of the energy markets. Beginning levels of supply and demand are inputted, and the computer model adjusts these

quantities according to the estimated slopes of the two curves. Thus the model does not use an optimization approach, but attempts to approximate market equilibrium.

The output of the model which is of interest here is the forecast of the capital requirements for expansion of the energy industry. Assumptions are made about the fashion in which the supply and demand curves change over time, and these, combined with the constraints of resource availability, allow for a dynamic forecasting model. To meet future demands, the model determines the additional energy facilities which would need to be built. The number of new facilities multiplied by the cost per utility equals the capital requirements for each category in the energy network. A required rate of return on investment is included in the estimate of facility costs. The capital requirements are specified by region and by year. The model also incorporates a secondary effect which allows the price of capital equipment to rise in periods of rapid expansion, causing an increase in supply costs and an increase in prices. By definition, this effect has no relation to any financing difficulties which could occur for an energy industry. The sensitivity of energy supply to changes in the cost of capital can be determined by running the model with varying discount rates.

3.1.3 Macroeconomic Forecasting Models with Input-Output Analysis Capabilities

Wharton Annual and Long-Term Forecasting Model

The Wharton model includes a 53-sector input-output table within the framework of a macroeconomic forecasting model. The sectoral breakdown includes detail on the major energy industries, which was recently added to the model. The energy sector detail includes separate input-output analyses of the crude oil and natural gas industries. This feature is unique to the Wharton model. Another feature of the Wharton model is the emphasis on demographic information which predicts labor supply and other population variables as part of the forecasting efforts.

The input-output table provides forecasts of energy demand for the major industrial sectors. However, the input coefficients do not allow for fuel switching in response to price changes. Residential energy demand is specified in terms of total demand by fuel type.

For forecasting investment, the model specifies the desired capital/output ratio and the desired time stream of investment. However, the model does not track energy supply capacity on a reliable engineering basis.² Therefore, forecasts of energy investments may not be consistent with energy supply and demand.

Brookhaven/University of Illinois Model

The Brookhaven Energy Supply Optimization Model (BESOM) has been combined with the University of Illinois input-output

model to provide consistent forecasts of energy and economic futures. BESOM is a linear programming model of the energy system. It determines the optimal allocation of resources and conversion technologies to end uses in terms of minimum costs or minimum environmental damage. The model is designed to allow for a wide range of fuel substitution. In using BESOM in conjunction with the input-output model, an optimal fuel mix is determined which must be consistent with the demand and supply derived from the input-output model. The discrepancies are resolved by revision of the input-output coefficients. Several iterations are required between the two models in order to achieve consistency between fuel demands and fuel mix in the two models.

The model specifies the capital requirements for 110 sectors, including 12 energy sectors. As for the Wharton model, capital requirements are estimated by forecasting output levels and then applying the capital/output ratio for the industry, to determine the capital requirements. However, in this case only the various costs of overhead capital (administrative expenses, office construction, marketing) are taken from the input-output model. The estimates of the physical hardware needed are provided in the optimization model. Notice that some other models, such as the Bechtel and SRI models, do not estimate overhead capital costs. On the other hand, the Brookhaven/University of Illinois model does not provide a schedule for bringing the facilities on line. Time phased and multi-period versions of the Brookhaven model have not as yet been linked to the input-output model. If this were done, the model could be used to generate annual cost and facility schedules.

The Hudson-Jorgenson/Brookhaven Model

The Hudson-Jorgenson model was developed to assess the impacts of energy policy on the economy. It combines a macroeconomic growth model of the U.S. economy with an input-output model designed to focus on interindustry energy flows. The interindustry energy model has nine sectors, five of which represent energy sectors. By combining this model with the Brookhaven model of the energy system, it is possible to obtain considerably more detail on the energy sector with breakdowns provided for energy resource sectors, energy conversion processes, and energy product sectors. The importance of this model revolves around (1) the integration of a detailed energy system model with a large macroeconomic input-output of the U.S. economy and (2) the fact that in the Hudson-Jorgenson model, the input-output coefficients are generated endogenously as functions of the price of primary inputs. Most models use fixed input-output coefficients and cannot therefore be used to model the substitution possibilities between energy and nonenergy inputs.

The Brookhaven model determines the optimal use of resources given an economic environment. Thus once the macroeconomic growth model specifies the components of final demand, including the level of investment, the Brookhaven model allocates the investment among the available set of energy technologies. In this fashion, the model can be used to provide an estimate of the capital requirements. The aggregate supply and demand of investment goods is, however, assumed to balance only at the national level. The model, therefore, would not provide information on a shortfall of capital, in physical or financial terms, for the energy sector.

3.1.4 Utility Models

MIT Regional Electricity Model

The MIT model is a regionalized engineering econometric simulation model of U.S. electricity supply and demand. It includes econometrically estimated demand functions of total energy consumption for the residential and industrial sectors. In each case, single equations were fitted relating energy demand to an energy price index and to incomes or value-added variables. Econometric estimates were then made relating physical capital requirements and capital expenditures for the utility industry to the configuration of electricity demand. The analysis of supply costs also covers nuclear fuel costs.

A set of financial accounting relationships are specified that combine the model-derived supply costs with tax, rate-making, and accounting rules for the electric utilities. A cursory analysis of the average utility debt structure and financing constraints is provided. The debt structure information is then used to generate an overall cost of capital to the firm. The cost of capital together with the capital expenditures, adjusted for taxes and depreciation, yields the average price for electricity (on a regional basis). For the analysis of capital markets, it would be possible to vary the imputed cost of capital and other constraints, such as the limit on the extent of debt financing to determine their effects of the prices, demand, and supply of electricity.

Teknekron Electric Utility Simulation Model

the Teknekron model simulates the decisions of the utility sector for system planning and operation and for utility finance. The inputs to the model include demand projections, financial market conditions, fuel prices, and availabilities, advanced technology deployment, and environmental regulations. The demand projections (regionally specified) are used to estimate construction requirements for generation transmission and distribution on the basis of an engineering process model. An optimization model then allocates electricity production among the various generating facilities on the basis of least cost. The operating expenses combined with the construction requirements bill are inputted to the financial submodel. The cost figures are then inflated by the estimated target rate of return on capital to determine the revenue requirements. The revenue requirements, in turn, are converted into electricity price forecasts, given the electricity demand.

Like the MIT model, the Teknekron model therefore can be used to forecast the balance sheet for the utility sector. It also assumes, like other models, that the necessary investment funds will be forthcoming if the target ratio of return is satisfied.

Temple, Barker and Sloane: Regulatory Analysis Financial Model (RAM)

RAM is a computer-based model designed for constructing a balance sheet, income statement, and sources and uses of funds statements for individual electric utilities. Given a set of assumptions concerning demand, capital expenditures, operating costs and financial and regulatory policies, it applies simple trends, regression analysis, and tax accounting logic to produce the results. The development of the model was funded by the Experimental Technology Incentives Program of the National Bureau of Standards, with technical oversight provided by FPC.

This model requires critical data items to be input for the forecast interval that may be developed by other, more complex models. Its design as a complement to other models and tools used in the planning process keeps the structure simple. The original purpose of the model was to aid in determining the implications of new corporate or regulatory policy, cost estimates for a utility's external financing, required revenues, return on equity, and financial health. It does not directly answer the question of capital supply or capital required, but used in conjunction with other models, could be used for sensitivity of utilities' finances to changes in the capital markets, the energy environment, and overall economic atmosphere.

3.1.5 Other Models

Argonne Coal Market Model

The Argonne coal market model predicts long-term regional production and interregional flows of coal. It is a linear programming model which determines the least cost method of supplying a specified amount of coal to each regional market. The forecast output does not, however, specify the capital requirements for the coal industry. The model is built upon the coal industry supply curves generated by the ICF coal model and capital costs are imbedded in the total marginal cost estimates.

DRI/Zimmerman Coal Model

The DRI/Zimmerman Coal Model is a supply and distribution model in which geological, engineering and economic concepts are intergrated so that coal production, prices, and shipments, by quality of coal may be forecasted. The supply curves are based on cumulative cost functions that yield the long-run marginal cost of mining. The coal is distributed optimally through a linear programming framework. There are six supply areas, for which the supply of surface- and deep-mined coal are forecast for each of six sulfur ranges. It utilizes carefully constructed cost forecasts for mining machinery and equipment and labor costs. Capital expenditures

are estimated using engineering estimates prepared by the U.S. Bureau of Mines, representing mines with a specified set of physical characteristics. Return on investment may be varied exogenously.

The model is useful for policy analysis at the national, regional, or state level, including considerations of the environment, taxes, transportation, and prices. The model resides on the DRI computer, accessible thru English-language interactive dialogue for simulations which are annual, extending to 1990. It relies on and is consistent with forecasts from the DRI Macro Model, DRI Energy Model, and the DRI Cost Forecasting Models.

DRI Energy Policy Model

Basically a demand model, the DRI Energy Policy Model forecasts energy demand for primary fuels by the major consuming sectors, on a regionalized basis. It includes over 400 econometric equations and 1,000 identities which simulate prices, demands and supplies of major fuels. Through the demand forecasts and resultant fuel mix outlook, a basis is provided for generating capital needs for the residential, commercial, and industrial sector. For the electric utility sector, fuel costs, operating costs and capital expenditures are forecasted in an econometric and cash flow framework, producing an income statement and balance sheet for the industry.

Improved Oak Ridge Model of Residential Energy Use

This model was developed by Eric Hirst, et. al., at the Oak Ridge National Laboratory to simulate energy use in the residential sector from 1970 through 2000. It is a complex recursive model, drawing on both econometric analysis of residential fuel demand and engineering studies of energy efficiency/cost relationships for appliances and structural thermal integrity. The model provides considerable detail on the annual energy use of four fuels (electricity, gas, oil, other) by eight end uses (space heating, water heating, refrigeration, food freezing, cooking, air conditioning, lighting, other) for three housing types (single-family units, apartments, mobile homes). Other concepts forecasted include annual equipment installations and ownership, equipment costs, and costs for improving the thermal integrity of new and existing housing units.

The model is unique in that it provides a successful framework for analyzing the energy needs of the Residential sector as opposed to the Residential/Commercial sector--a more commonly forecasted concept. In addition, the synthesis of appliance technology models which analyze the costs of upgrading appliance efficiency of improving residential thermal integrity with standard fuel demand equations render the model well equipped for evaluating the economic impacts of various conservation programs. The model does have shortcomings, however, the most important of which are the

basing of price and income elasticities on insufficient data,
and exogenous determination of equipment efficiency and
structural thermal integrity.

4.1 Documentation of Model Runs

The following list covers the principal sources of descriptive material on operation of the various models:

Fossil11 - Capabilities exist in-house at DOE for model runs. A description of model operation, as applied to the National Energy Plan, is presented in Managing the Energy Transition (Vaill, R.).

Bankers Trust Model - A forthcoming update of their energy-capital markets analysis may be obtained from the Public Relations Department of Bankers Trust Company.

Energy Supply Planning Model - The Bechtel model is maintained in-house at DOE.

SRI National Energy Model - A model description and several model runs are provided in the EPRI publication No. EA-433. This model is proprietary to SRI.

Wharton Long-Term Annual and Industry Forecasting Model - A dated version of the model is described in "The Wharton Long-Term Model: Input-Output Within the Context of a Macro Forecasting Model," by R.S. Preston in International Economic Review, February 1975.

Brookhaven/University of Illinois Model - The model was developed under contract with ERDA.

Hudson-Jorgenson/Brookhaven Model - A description of the model and sample outputs are provided in "Economic and Technological Models for Evaluation of Energy

Policy," by D. Jorgenson and K. Hoffman in the Bell Journal of Economics, Autumn 1977.

MIT Regional Electricity Model - Descriptions of the model may be obtained from the MIT Energy Laboratory. Once source publication is "Full Utilization by the Electric Utility Industry in the United States 1975-1995," by P.L. Joskow and G. Rosanski.

Teknekron Electric Utility Simulation Model - The model is covered under contract with DOE.

Argonne Coal Market Model - The Argonne model is covered by contract with DOE.

DRI Models - The DRI Macro and Energy Models are currently covered by contracts to DOE; the DRI/Zimmerman model is not. Information or analyses performed with any of these models may be obtained from DRI.

Temple, Barker, & Sloane Regulatory Analysis Financial Model - The model is currently used at DOE through a contract with TBS; they will provide further information or documentation.

Oak Ridge National Lab Residential Energy Use Model

The model is available to DOE and is currently being incorporated into the PIES model.

FOOTNOTES

1. Dartmouth System Dynamics Group, Thayer School of Engineering, Dartmouth College, Fossilll: Introduction to the Model, p. 5.

2. Telephone conversation between John Eyraud, ERCO, and Bill Finan, Wharton, April 13, 1978.

5.1 Data Review

It has been determined that each model, most of which are available to DOE, or have been developed under government contract is based on credible data sources with which the project managers are satisfied; many of the data sources come direct from the government. We have pointed out where that is not the case. Where estimates or special surveys have been used, as opposed to data which is maintained on an on-going basis, there could be problems with sampling as well as timeliness. Should these models be chosen to work with, additional effort might be necessary to update the data base and would be judged individually. The areas of new technology and depletable resources which are of great interest today are precisely those areas which carry some concern with respect to data accuracy and reliability.

An overview of each of the models follows and a catalogue of the actual sources, by concept and where applicable appears in Section 7.1.

Oak Ridge Residential Energy Demand

The Oak Ridge Model is based on publicly available data sources, both government and private, for the housing stock, fuel demand and equipment market share sub-models. The formulation of the model in this area using this data is considered state-of-the-art and no significant criticisms can be raised in its use. The technology data for major appliances are based on engineering estimates which have been documented in separate publications; these were gained through surveys. Where forecasted information has been necessary, PIES output

has been used; other forecasting models output could be used just as well. The fuel prices used are estimated to ORNL from DOE and could possibly be subject to change. In general, the users and architects of this model are currently quite satisfied with the data obtained.

Temple, Barker & Sloane, Regulatory Analysis Financial Model

This model, being based on accounting logic rather than behavioral econometrics, is judged for data input only so far as accurate data is available to the user at the time of use of the model. The model has been tested using only publicly available information as input, and where this is a true representation of an individual utility's financial activity, the model is valid. Input data required to run RAM include balance sheet and income statement figures available thru such sources as:

FDC Form 1

Uniform Statistical Report filed by each utility
annually with Edison Electric Institute
annual reports to stockholders

the utility's most recent stock or bond prospective

Forecasted inputs that are necessary can critically affect the outcome of the analysis, and as such, should be used as assumptions and levers in performing sensitivity analyses with the focus on the financing of given conditions, rather than actual outlays required for particular projects. Forecasted inputs may come from other models or through simplified projections, including:

the proposed capital budget
energy supply and demand
expected fuel prices
purchased power agreements

purchased power costs
plant retirements
expected capital structure

Bankers Trust Company

The forecasts published by Bankers trust were based on a set of independent forecasts and analyses for the various economic and energy sectors; no formal operational model exists. The demand and supply estimates were related to the existing capital requirement estimates and the study of capital markets and industry financial positions. The sources for these estimates on which the conclusions were based were US Government and private forecasts as well as industry sector financial data aggregate from the individual company level. The figures represented are thus as good as the forecasts and models on which they were based as well as the judgements placed on the independent forecasts.

Bechtel Energy Supply Planning Model

This model calculates the total direct capital, manpower, and material resources required to bring on-line and to operate the energy supply and transportation facilities required for a specified energy fuel mix. The regional demand, transportation, location, and fuel mix data are all derived from public sources which are the most reliable available for those areas. The operations data, including the manpower and equipment categories, and the construction data are based on past construction experience, engineering literature, and a recorded industry average collected by Bechtel's operating divisions. Their experience in these areas and relations with vendors, builders, and manufacturers allowed for a wide range of accuracy, that they have

judged critically, assigning percentage accuracy ranges to the concepts with a 75-90 percent confidence level. Many estimates are assigned good accuracy while noting that large variations often occur in practice, and others were used with no experience on which to base the estimate. These must be monitored and improved as we do gain experience in these areas, and as a result, the model results will continue to become more reliable. As an aggregate model, these are probably the best that are available in an integrated fashion.

Teknekron, Inc. Electric Utility Simulation Model

The Teknekron model draws data from many sources, including public published reports and government releases. Certain factors are calculated based on public data and others are necessary for the user to specify for the forecast interval. Because discrete unit information is used to aggregate and merge to the state level, and where future estimates are provided, the data set requires continual refining and updating. The methodology for arriving at the future mix of generating units, the reserve margins, the fuel composition characteristics, fuel prices, construction costs, retrofitting cutoffs and dialy capacity factors as examples, can be critical to the model results and should be documented further by Teknekron. The financial sector is dependent upon simulated values from the other model sections and the financing mix, bond rates, tax rates and other coefficients are fixed and specified.

Data Resources, Inc. Models

The models available from DRI are all based on public data

sources, for the DRI Macro Model, Energy Model and DRI/Zimmerman Coal model, as discussed. The data sources for each of these models is outlined in the last section of the report, and in addition, because the data and models are accessed daily, subscribers to DRI may acquire a list, on line to the computer, that includes a separate and complete description for each individual data series used in the model including the date it was last updated.

Fossil 1

The Fossil 1 Model is based on public data sources and estimates which have been arrived at through use of large scale models. Where the data was not used in raw form, simple mathematical approximations or behavioral relationships were used to transform the data. In some cases, more than one source was used for the same concept, deriving a consensus estimate, indicating some scrutiny and data awareness was exercised in the design of the model.

Baughman & Joskow Regionalized Electricity Model

The data used for the demand model is publicly available information as is that used for the electricity model. For the supply model, cost data required for equipment required, operations and maintenance, and the construction data for plant alternatives were acquired through industry survey, taken by the designers of the model.

SRI National Energy Model Data Sources:

Data sources for the SRI National energy model can be roughly divided into two categories: 1) simple time-series or cross-sectional data on energy consumption, production, distribution, etc.; and 2) specialized economic/engineering studies. The end-use demand sectors of the model seem to use more of the former group of data, and the production and distribution sectors tend to concentrate on methodology drawn from the latter. Most of the data used is in the public domain, though a number of the economic/engineering studies cited were done under contract for the private sector.

ICF Oil and Gas Supply Model Data Sources:

As is the case with the SRI Model, the ICF Model draws heavily on both standard time-series and cross-sectional data as well as specialized engineering studies of production processes in the oil and gas drilling industry. In particular, the ICF Model draws heavily on methodology developed by the National Petroleum Council in estimating supply curves for both oil and gas production. Virtually all of the data listed in estimating this model is available to the Department of Energy, being either in the public domain or having been generated under contract for the DOE.

Additional Data

The following data would be useful in analyzing the future costs of energy facilities or materials needed to build those facilities. The area of cost forecasting is one which seemed to received the least sophisticated attention in the models surveyed.

1. Handy Whitman data for electric utilities construction and equipment and gas utilities construction and equipment, including detailed configurations and weighting factors for materials.
2. Metals Week Data for produce list prices, consumer buying prices, dealer prices, import prices, foreign exchange rates and quotations from commodity exchanges.
3. Engineering News Record construction materials by 25 major cities.

For electric utility analysis, the following would provide further detail for modeling capacity requirements and types of plants needed.

1. Inventory of Power Plants in the U.S. (DOE and FPC) - data on individual generating units by county, company, location, nameplate rating, type, alternative fuels used.
2. Steam-Electric Plant Factors (National Coal Association) individual generating units capacity and type and actual fuel consumption

For natural gas and oil production and reserves, by state, the API, AGA and Canadian Petroleum Association's Reserves of Crude Oil, Natural Gas Liquid in the US and Canada provides reserve and production data by state, annually.

For modelling the commercial sector, the FW Dodge Division of McGraw Hill has monthly contract awards data by county, from 1960. The Treasury Department also provides Business Building Statistics for the commercial sector.

6.1 Summary Matrices of Capital Market Models

TABLE 1
MODEL DESCRIPTION MATRIX - FOSSILLI

MODEL AND SCOPE	DEMAND SECTORS	DEMAND STRUCTURE AND DETAIL	SUPPLY SECTORS	SUPPLY STRUCTURE AND DETAIL
<p>Fossil111, Thayer School of Engineering, Dartmouth College; model is covered by contract with DOE.</p> <p>Fossil111 is a system dynamics computer model designed for policy analysis which models the sensitivity of energy supply to various financial, geological, and environmental factors. A GNP input is translated into energy demand and the demand inputs drive supply sectors which predict investments and supply. No regional breakdowns of the information are available.</p>	Individual	Simple econometric model relating GNP with energy prices, to energy demand	Oil and gas	Borrowing conditions, returns to drilling, total reserves, government regulations
	Transportation			
	Household			
	Commercial		Coal	Borrowing conditions, coal resources, environmental standards, safety standards, technological development
	Electric utilities		Electricity	Borrowing conditions, environmental standards, fuel choices
			Within these sectors, 23 technologies are covered	

TABLE 1 (CONT.)

MODEL	FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
Fossil III, Thayer School of Engineering, Dartmouth College; model is covered by contract with DOE.	Capital investment is dependent upon the following variables: (1) average rate of return, (2) price or tax incentives, and (3) government regulation	<p>1. The sensitivity of energy sectors to various government policies can be modeled since the model allows a wide range of exogenous nonlinear input</p> <p>2. A simple, endogenous model of OPEC activities is provided. Also import policies can be modeled for their effects on supply and demand</p> <p>3. The model forecasts the level of investment based on average rates of return and industry revenues</p>	<p>1. The model is not designed for exact quantitative forecasts but only for sensitivity analyses</p> <p>2. The modelling of the investment decision does not handle future expectations or uncertainties</p>

TABLE 2

MODEL DESCRIPTION MATRIX - BANKERS TRUST MODEL

MODEL AND SCOPE	DEMAND SECTORS	DEMAND STRUCTURE AND DETAIL	SUPPLY SECTORS	SUPPLY STRUCTURE AND DETAIL
<p>"Capital Resources for Energy Through the Year 1990," Bankers Trust Company; study results are distributed freely</p> <p>This is not a forecasting model, but represents a study of capital requirements and availability based on projections of historical data series</p>	<p>Household</p> <p>Commercial</p> <p>Industrial</p> <p>Electrical generation</p> <p>Exports</p>	<p>Projections are based on historical trends and expert judgements of future developments</p>	<p>Coal</p> <p>Petroleum</p> <p>Gas</p> <p>Nuclear</p> <p>Hydropower</p> <p>Shale</p> <p>Other</p>	<p>Projections are based on data from other sources and interpretations by Bankers Trust of future developments</p>

TABLE 2 (CONT.)

MODEL	FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
<p>"Capital Resources for Energy Through the Year 1990," Bankers Trust Company; study results are distributed freely</p>	<p>Relationship of the flow of funds to GNP was analyzed on a historic basis. Subjective judgements were also made of the volume of funds in future capital markets.</p>	<p>The study provides an estimate of the ability of capital markets to meet the external financing requirements of the energy sector.</p>	<p>1. No formal modelling is done.</p> <p>2. There is no analysis of the components of investment decisions in the energy sector.</p>

TABLE 3
MODEL DESCRIPTION MATRIX - ENERGY SUPPLY PLANNING MODEL

MODEL AND SCOPE	DEMAND SECTORS	DEMAND STRUCTURE AND DETAIL	SUPPLY SECTORS	SUPPLY STRUCTURE AND DETAIL
<p><u>Energy Supply Planning Model</u>, Bechtel Corp. The model is covered by contract with DOE.</p> <p>ESPM converts future energy scenarios into capital and manpower requirements on the basis of Bechtel's engineering data for "nominal" or average facilities. Model inputs and outputs are specified on a regional basis.</p>	None	---	Petroleum	Drilling depths, no. of wells, well productivity, success ratios, drilling area
			Oil shale	Mine type, depth, and productivity, support services, recovery process
			Natural gas	Well depth, no. of wells, success ratios, well productivity, well location
			Coal	Coal region, mine type, depth, width, and productivity, onsite processing
			Nuclear	Mine type, depth, width, and productivity
			Electric power-related facilities	Fuel type, fuel input, other variables depending on plant

TABLE 3 (CONT.)

MODEL	FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
<u>Energy Supply Planning Model</u> Bechtel Corp.	Negligible financial detail	<p>1. The model forecasts costs for a future energy mix by computing the cost and number of necessary facilities.</p> <p>2. The model specifies operating costs and capacity utilization</p>	<p>1. Only energy facility construction costs are considered in detail.</p> <p>2. Industry finances are not assessed.</p> <p>3. The model does not forecast imports, energy prices, or gross industry revenues.</p>

TABLE 4
MODEL DESCRIPTION MATRIX - ICF OIL AND GAS AND COAL MODELS

MODEL AND SCOPE	DEMAND SECTORS	DEMAND STRUCTURE AND DETAIL	SUPPLY SECTORS	SUPPLY STRUCTURE AND DETAIL
ICF Oil and Gas and Coal Models Developed by ICF Inc. originally as inputs to PIES, the ICF models develop supply curves representing the breakeven costs (on a discounted cash flow basis) of energy supply. The supply curves are generated from fully specified estimates of production costs. Regional breakdowns are available.	None	---	Oil	Drilling depths, drilling success ratios, capital costs
			Gas	Drilling depths, drilling success ratios, initial gas reserves, capital costs, well production
			Coal	Capital requirements, coal reserves, environmental considerations

TABLE 4 (CONT.)

MODEL	FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
<u>ICF Oil and Gas and Coal Models</u>	Inputs to model include: industry fixed assets, depreciation factors, tax considerations (write-offn, tax credits), average rates of return (based on expected debt-structure)	<p>1. The models provide a complete specification of capital requirements and financing needs for the industries.</p> <p>2. Changes in the supply curves due to changes in the required rate of return could be derived by adjusting the exogenous ROR variable.</p>	No modelling is attempted of energy sector-economy interactions.

TABLE 4 (CONT.)

MODEL	FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
<u>ICF Oil and Gas and Coal Models</u>	Inputs to model include: Industry fixed assets, depreciation factors, tax considerations (write-offs, tax credits), average rates of return (based on expected debt-structure).	<p>1. The models provide a complete specification of capital requirements and financing needs for the industries.</p> <p>2. Changes in the supply curves due to changes in the required rate of return could be derived by adjusting the exogenous ROR variable.</p>	No modelling is attempted of energy sector-economy interactions.

TABLE 5
MODEL DESCRIPTION MATRIX -
STANFORD RESEARCH INSTITUTE, NATIONAL ENERGY MODEL

MODEL AND SCOPE	DEMAND SECTORS	DEMAND STRUCTURE AND DETAIL	SUPPLY SECTORS	SUPPLY STRUCTURE AND DETAIL
<p><u>Stanford Research Institute, National Energy Model</u></p> <p>This is a simultaneous equation system for balancing supply and demand in a large number of distinct energy submarkets. Supply and demand curves for each market are estimated, and an iterative computer model is then used to determine an equilibrium solution. The model also forecasts the energy facilities needed to meet future demands. Regional breakdowns of the inputs and outputs are used.</p>	<p>Demand sectors are defined by end use:</p> <p>Auto, Bus/truck, Air, Marine, Residential and commercial space heat, R/C misc. heat, R/C electro-mechanical, Ind. process steam, Ind. direct heat, Ind. electro-magnetic, Nap. feedstock, Gas feedstock, Coal feedstock</p>	<p>The model calculates market shares for fuels, own and cross price elasticities of fuel use, and future energy prices.</p>	<p>Foreign and domestic oil</p> <p>Oil shale</p> <p>High and low sulphur coal</p> <p>Natural gas</p> <p>Imported gas</p> <p>Imported methanol</p> <p>Tar sands</p>	<p>"Energy network" covers:</p> <p>Resource extraction processes, Supply transportation, Primary conversion, Product transportation, Secondary conversion Distribution, End use conversion, End use demand</p>

TABLE 5 (CONT.)

MODEL	FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
<u>Stanford Research Institute, National Energy Model</u>	A financial submodel incorporates capital and operating costs and the required rate of return on equity into the supply curves. Secondary effects allow for increases in physical capital costs during periods of rapid sectoral expansion.	<ol style="list-style-type: none"> 1. The model forecasts capital requirements by process, region, and year over any time horizon. 2. Given exogenously supplied discount rates, the model forecasts varying mixes of fuel supply and demand. 3. The model can be used to measure the effect of import quantities and prices by varying the import assumptions. 	<ol style="list-style-type: none"> 1. There is no linkage between the energy sector and the economy. 2. The investment funds are expected to be forthcoming for any project which will satisfy a target rate of return.

TABLE 6
MODEL DESCRIPTION MATRIX -
WHARTON LONG TERM ANNUAL AND INDUSTRY FORECASTING MODEL

MODEL AND SCOPE	DEMAND SECTORS	DEMAND STRUCTURE AND DETAIL	SUPPLY SECTORS	SUPPLY STRUCTURE AND DETAIL
<u>Wharton Long Term Annual and Industry Forecasting Model</u> The Wharton model is based on a time series input-output model developed within the context of a macro forecasting model. The sectoral detail includes some recently added input-output data for the major energy sectors. Regionalized model solutions are not generated.	53 individual sectors	The input-output model determines the total energy demands. Fuel switching is modeled only for electric utilities.	Crude oil Natural gas Nuclear Electric power Coal	Borrowing conditions, baseline estimates of resource availability are inputs.

TABLE 6 (CONT.)

MODEL	FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
<u>Wharton Long Term Annual and Industry Forecasting Model</u>	Minimal financial detail beyond basic exogenous inputs such as tax laws and monetary policies	<p>1. Model forecasts, energy demand for 53 industrial sectors</p> <p>2. The model forecasts the investment requirements for the major energy sectors</p> <p>3. The model forecasts energy imports</p>	<p>1. The model does not provide engineering-type estimates of energy production capacity. For long-term forecasts, the supply estimates and capital requirements estimates may not be consistent.</p> <p>2. The model does not specify the necessary capacity utilization or inventory adjustments (of fuel stockpiles).</p>

TABLE 7

**MODEL DESCRIPTION MATRIX - BROOKHAVEN ENERGY SUPPLY
OPTIMIZATION MODEL (BESOM)/UNIVERSITY OF ILLINOIS INPUT-OUTPUT MODEL**

MODEL AND SCOPE	DEMAND SECTORS	DEMAND STRUCTURE AND DETAIL	SUPPLY SECTORS	SUPPLY STRUCTURE AND DETAIL
<p><u>Brookhaven Energy Supply Optimization Model (BESOM)/University of Illinois Input-Output Model</u></p> <p>The Brookhaven linear programming optimization model of the energy sector is linked to an input-output model for use in examining fuel substitution possibilities and the effect of fuel supply constraints on the economy. No regional breakdowns are provided.</p>	<p>Final demands for the 110 sectors are expressed as demand for eight energy products: coke or ore reduction feedstocks, chemical feedstocks, motive power, process heat, water heat, space heat, air conditioning, and electric power</p>	<p>Energy demand is dependent on the fuel prices and technical coefficients. Fuel-switching capabilities are implicit in the characterization of the utilizing technologies and they are determined on the basis of maximizing the efficiency of the energy system (minimizes the cost of supply).</p>	<p>Coal</p> <p>Crude oil and gas</p> <p>Shale oil</p> <p>Methane from coal</p> <p>Solvent refined coal</p> <p>Refined oil products</p> <p>Pipeline gas</p> <p>Coal combined cycle electric</p> <p>Other fossil electric</p> <p>LWR electric^a</p> <p>HTGR electric^b</p> <p>Hydroelectric</p>	<p>The energy network inputs include annual capital and operating costs, environmental considerations, and conversion efficiencies.</p> <p>Supply constraints are defined by geological information, market surveys, or engineering judgments.</p> <p>This information is included in the cost functions which form the basis of the linear programming problem.</p>

^aLWR = light water reactor.

^bHTGR = high temperature gas-cooled reactor.

TABLE 7 (CONT.)

MODEL	FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
<u>Brookhaven Energy Supply Optimization Model (DESOM)/ University of Illinois Input- Output Model</u>	Investment is modeled only as the capital expenditures necessary to move to a desired capital/output ratio.	<p>1. The model provides forecasts of capital requirements and energy demand for each of 110 sectors.</p> <p>2. Forecasts of capital requirements for the energy sector can be checked for consistency with forecasts of production.</p> <p>3. The energy system specified by Brookhaven incorporates detail on energy storage facilities. Included in the model runs are forecasts of inventory adjustments (of energy stockpiles).</p>	1. No modelling in attempted of industry financing (borrowing) requirements.

TABLE 8
MODEL DESCRIPTION MATRIX - HUDSON-JORGENSEN/BROOKHAVEN MODEL

MODEL AND SCOPE	DEMAND SECTORS	DEMAND STRUCTURE AND DETAIL	SUPPLY SECTORS	SUPPLY STRUCTURE AND DETAIL
<u>Hudson-Jorgenson/Brookhaven Model</u> This model combines a macro-economic growth model with an econometric model of inter-industry transactions and with the Brookhaven Energy Supply Optimization Model. This represents an integration of a process analysis model with an econometric model of inter-industry transactions for application to policy analyses where the technological component is significant. No regional analysis of the entire system is provided.	Final demands for the nine sectors modeled (five energy sectors, four nonenergy sectors) are expressed as demand for eight energy products: Coke or ore, Reduction feedstocks, Chemical feedstocks, Motive power, Process heat, Water heat, Space heat, Air conditioning, Electric power	Energy demands are sensitive to fuel prices, final demands for nonenergy products	Coal Crude oil and gas Shale oil Methane from coal Solvent-refined coal Refined oil products Pipeline gas Coal-combined cycle electric Other fossil electric LWR electric ^a HTGR electric ^b Hydroelectric	The energy network limits include annual capital and operating costs, environmental considerations, and conversion efficiencies. Supply constraints are defined by geological information, market surveys, or engineering judgement.

^aLWR = light water reactor.

^bHTGR = high-temperature gas-cooled reactor.

TABLE 8 (CONT.)

MODEL	FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
<u>Hudson-Jorgenson/Brookhaven Model</u>	Aggregate Investment is sensitive to the rate return to capital through changes in the technical coefficients.	<p>1. An estimate of the capital requirements of the energy sector can be derived from a given macroeconomic environment. The BESOM allocates capital in the energy sector on the basis of the least cost energy supply.</p> <p>2. The model solution provides a consistent set of fuel prices, energy product prices, and nonenergy product prices due to the linkage of the optimization model with the interindustry transactions model.</p> <p>3. The model can be used to forecast imports, energy inventory adjustments, and total energy demand.</p>	The model does not attempt to assess the financial situation of the energy sector.

TABLE 9
MODEL DESCRIPTION MATRIX - MIT REGIONAL ELECTRICITY MODEL

MODEL AND SCOPE	DEMAND SECTORS	DEMAND STRUCTURE AND DETAIL	SUPPLY SECTORS	SUPPLY STRUCTURE AND DETAIL
MIT Regional Electricity Model, MIT Energy Laboratory This model is an engineering, econometric simulation model of U.S. electricity demand and supply requirements based on simple regressions with historical data. A financial accounting submodel specifies prices and financing needs. Regional breakdowns of outputs are provided.	Residential and commercial	Econometric estimation of fuel use based on cross-sectional data. Equations which allocate demand among fuels, allow for fuel switching	Electric utilities including production, transmission, and distribution	The model simulates construction requirements, fuel choices. Exogenous inputs are fuel costs, plant construction costs, and plant operating characteristics.
	Industrial	Econometric estimation of fuel use based on cross-sectional data. The equations allocate demand among fuels and allow for fuel-switching.		

TABLE 9 (CONT.)

MODEL	FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
<u>MIT Regional Electricity Model</u>	<p>The financial submodel forecasts prices once the allowed rate of return (based on the cost of capital), capital expenditures, depreciation, and taxes are specified. The cost of capital is approximated as a weighted average of costs for the various financing instruments. An accounting model provides the necessary structure for analyses.</p>	<ol style="list-style-type: none"> 1. The model forecasts investment expenditures made to meet the forecasted demand. 2. The model forecasts electricity prices which will yield a predetermined rate of return on the utilities rate base. 	<p>Investment funds are assumed to be forthcoming for any projects satisfying the required rate of return.</p>

TABLE 10

MODEL DESCRIPTION MATRIX - ELECTRIC UTILITY SIMULATION MODEL

MODEL AND SCOPE	DEMAND SECTORS	DEMAND STRUCTURE AND DETAIL	SUPPLY SECTORS	SUPPLY STRUCTURE AND DETAIL
<u>Electric Utility Simulation</u> <u>Model, Teknekron, Inc.</u> This simulation model converts demand projections into utility construction requirements and new capital requirements. The latter are specified through a financial submodel. Regional forecasts are provided.	No disaggregation	---	Electric utilities	The model estimates construction requirements, fuel choice, and pollution control needs with engineering process models.

TABLE 10 (CONT.)

MODEL	FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
<u>Electric Utility Simulation Model</u>	The model forecasts prices, new external financing needs and earnings. The exogenous variables which need to be set are the cost of capital to utilities, regulatory policies, and tax policies. An accounting model provides the structure for this analysis.	<ol style="list-style-type: none"> 1. The model forecasts capital requirements and financing needs for the utility industry. 2. The model forecasts the electricity prices which will yield a predetermined rate of return. 	Required new financing is assumed to be forthcoming once a target rate of return is met.

TABLE 11

MODEL DESCRIPTION MATRIX - ARGONNE COAL MARKET MODEL

MODEL AND SCOPE	DEMAND SECTORS	DEMAND STRUCTURE AND DETAIL	SUPPLY SECTORS	SUPPLY STRUCTURE AND DETAIL
<u>Argonne Coal Market Model</u> The Argonne model predicts long-term regional production and interregional flows of coal.	None	---	Coal	Supply curves from the ICF coal model are fitted to linearly increasing functions to reflect resource depletion and increas- ing extraction costs, transportation costs, and treatment costs.

TABLE 11 (CONT.)

MODEL	FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
<u>Argonne Coal Market Model</u>	Capital costs are only indirectly modeled in that they are imbedded in the ICF cost functions.	The model forecasts production patterns for coal.	No forecast of capital requirements for the coal industry is provided.

TABLE 12

Model Description Matrix - DRI Energy Policy Model

MODEL AND SCOPE	DEMAND SECTORS	DEMAND STRUCTURE AND DETAIL	SUPPLY SECTORS	SUPPLY STRUCTURE AND DETAIL
<p>A full energy system econometric model of the US which incorporates regional economic activity models, the DRI Macro Model (which includes the most detailed financial sector involving flow of funds and interest rates imbedded in macro model), energy demand sector models, and primary resources supply models. Final demands by each of the primary consuming sectors is the primary model output.</p> <p>The model is econometric in nature, utilizing ordinary least squares and pooled cross-section time series analysis solved in a recursive fashion. Annual estimates are produced from the present to 1990, on a national or regional (13 regions) basis.</p> <p>The model is available to DOE currently thru DRI.</p>	a. residential	forecasts, income, housing, employment, population, vehicle registrations, fuel prices and demands for electricity and natural gas, coal and petroleum	a. natural gas	determined regionally for intra and interstate production, based on decline rates in existing fields and incremental production Alaskan, Canadian and Mexican Gas, LNG and SNG imports are included
	b. commercial	prices and demands for electricity, coal, petroleum, and natural gas	b. coal	DRI/Zimmerman Coal Model-see separate description
	c. transportation	prices and demands for gasoline, jet fuel, distillate, residual and liquefied gases	c. electric utilities	fuel demands to utilities derived given existing and planned generation capacity including nuclear and hydroelectric. Fuel costs, operating costs and capital costs are forecasted in an econometric and cash flow framework. Tax considerations and debt structure included here.
	d. industry	prices of major fuels to industry and demand by region based on production indexes for each 2-digit industry, SIC 20 to 38 as forecasted by the DRI Macro Model. Fuel-switching and fuel conversion are captured in the potential demand equations		
	e. electric utility	demand and prices of fuels used by utilities including petroleum, natural gas and coal, driven by demand for electricity of each of the consuming sectors		

TABLE 12 (CON'T).

MODEL	FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
DRI Energy Policy Model	Exists explicitly for the Electric Utility Sector, including determination of the rate base, operations and maintenance costs, non-fuel costs, capital expenditures, and balance sheet and income statement for the utility sector	<p>Linkages between the DRI Macro Model and the Coal Model make the model useful for simulating energy demands as affected by:</p> <ul style="list-style-type: none"> • the general economy • OPEC impacts • industry activity • product prices • taxes • decontrol schemes <p>In the utility sector, the future capital expenditures of the industry is explicitly forecasted, based on the activity in the demanding sectors, and as related to the US financial environment modeled in the DRI Macro Model</p>	<ul style="list-style-type: none"> • The model provides the basis for, but does not explicitly model future capital required by the residential, commercial, and industry sectors. • New technology uses must be imposed on the model exogenously

TABLE 13

Model Description Matrix - DRI/Zimmerman Coal Model

MODEL AND SCOPE	DEMAND SECTORS	DEMAND STRUCTURE AND DETAIL	SUPPLY SECTORS	SUPPLY STRUCTURE AND DETAIL
<p>A supply and distribution model integrating geological, engineering, and economic concepts in the forecasting of production, prices and shipments by quality of coal. 13 demand regions, 6 supply areas, 6 sulfur types are estimated for strip and deep-mined coal.</p> <p>¹⁾ Supply functions estimate cumulative cost functions and a linear program optimizes the distribution of different types of coal from supply regions to demand regions. The cost functions an estimate of using an engineering-based model of mining.</p> <p>It is linked to the DRI Macroeconomic Model, the DRI Energy Model and the DRI Cost Forecasting Service Models. Annually, it may be simulated to 1990.</p>	<p>Total Demand for coal in 13 regions by 5 sectors is considered</p>	<ul style="list-style-type: none"> • Electric utility • Metallurgical • Industrial • Household/commercial • Exports <p>Detail on the specification of coal demands is found in the documentation for the Energy Model. Demand from this model may be used, or specified by the user.</p>	<p>Coal supply-</p> <p>supply functions for 6 supply regions and 6 sulfur ranges, for strip and deep-mined coal</p>	<p><u>deep mining:</u></p> <p>Production costs are related to the thickness of the coal seam, geological conditions, and the quantity produced and amount remaining</p> <p><u>strip mining:</u></p> <p>Costs are related to the overburden ratio, other geological characteristics, and quantity produced and remaining</p> <p><u>allocation:</u></p> <p>A linear programming framework simulates optimal regional production by sulfur content and the optimal distribution pattern for coal, choosing between low-sulfur coal, and the desulfurizing of high-sulfur coal utilizing stack-gas scrubbing devices.</p>

¹⁾ Martin B. Zimmerman, "Modeling depletion in a mineral industry: the case of coal: Bell Journal of Economics, Spring 1977.

TABLE 13 (CON'T.)

MODEL	FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
DRI/Zimmerman Coal Model	<p>The supply curves are influenced by:</p> <ul style="list-style-type: none"> • investment cost for new mines • labor costs • equipment expenditures • scrubbing costs • reclamation costs • rate of return on equity • state taxes • federal taxes • transportation costs 	<ul style="list-style-type: none"> • assessing the future growth of coal demand within environmental constraints • evaluating the impacts of tax changes or other regulations on prices and production • sensitivity of the distribution of coal to transportation facilities for coal • evaluation of the adequacy of existing transportation facilities for coal • estimating the availability of specific qualities of coal by Btu and sulfur content to meet future needs and delivered prices of that coal • determining where and how coal will be recovered and what type of recovery equipment will be demanded 	<p>Not an entirely simultaneous demand/supply system; the demands are generated exogenous to the system; DRI iterates with the demand model before releasing the forecast. For any severe changes to the environment, it would be necessary to do this.</p>

TABLE 14
Model Description Matrix -
Temple, Baker & Sloane Regulatory Analysis Financial Model

MODEL AND SCOPE	DEMAND SECTORS	DEMAND STRUCTURE AND DETAIL	SUPPLY SECTORS	SUPPLY STRUCTURE AND DETAIL
<p>A computer-based model used for making financial projections for individual electric utilities given a set of assumptions concerning demand, capital expenditures, operating costs, and financial and regulatory policies; based on critical inputs and utilizing a tax accounting logic, it produces a pro forma balance sheet, income statement and sources and uses of funds statements. Simple trend and regression analysis is applied to certain concepts.</p> <p>Industry or regional analysis may be performed by combining results of analyses or modeling the group as a single firm.</p> <p>The model may be simulated for any desired period of times. It is available to DOE under contract with TBS.</p>	total demand for electricity	exogenous to the model	electric utilities	unlimited supply of resources, both materials and capital is assumed to be available; based on alternative inputs, this is inherent in the assumptions

TABLE 14 (CON'T).

MODEL	FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
Temple, Baker & Sloane Regulatory Analysis Financial Model	<u>Performance Module</u>	• rate cases	• data inputs necessary to run the model must be supplied; these may be hard to acquire; a good deal of judgement may have to be exercised, particularly for the exogenous forecasted figures, thereby affecting the results
	projects operations & maintenance expenses	• plant construction authorization	
	<u>Plant Module</u>	• policy alternative analysis	
	from a given capital budget, computes allowance for funds used during construction, construction work in progress, and depreciation	• external financing projection and authorization	
	<u>Aggregation Module</u>	• financial condition projection and surveillance	• certain accounting procedures are not always captured by the model, which may be fine-tuned for the individual utility if the user is aware of them but would certainly be lost when aggregation took place
	total operations expense total maintenance expense total fuel expense purchased power expenses Construction expenditures additions to plants gross plant value construction work in progress retirements depreciation	• performance evaluation • future rate projection	• capital requirements are inputs to the model
	<u>Finance Module</u>		
	determines the financing of the capital requirements and the operating revenues necessary to meet income requirements and expensed: taxes gross revenues changes in working capital common and preferred stock long-term debt net income		

TABLE 15

Model Description Matrix -
Oak Ridge Improved Engineering - Economic Model of Residential Energy

MODEL AND SCOPE	DEMAND SECTORS	DEMAND STRUCTURE AND DETAIL	SUPPLY SECTORS	SUPPLY STRUCTURE AND DETAIL
<p>This model was developed to simulate residential energy use on an annual basis from 1970 to 2000. Considerable detail on energy uses by fuel, end use, and housing type are provided. Though the model was originally designed to forecast residential on a national basis¹, it has been used for regional forecasts as well.²</p> <p>The model is recursive. Equations were estimated using ordinary least squares on time series and cross-sectional data, pooled cross-sectional time-series analysis, and three-stage least squares.</p> <p>¹ E. Hirst, et. al., <u>An Improved Engineering-Economic Model of Residential Energy Use</u>, ORNL/CON-8, April 1977.</p> <p>² J.B. Kurish and E. Hirst, <u>Residential Energy Use For the Nine Census Divisions</u>, ORNL/CON-11, April 1977.</p>	I. Residential	<p>Forecasts the following residential demand concepts for three housing types (single family homes, apartments, and mobile homes) and four fuels:</p> <p>A. <u>End-Use Fuel Demand For:</u></p> <ol style="list-style-type: none"> 1. Space Heating 2. Water Heating 3. Refrigeration 4. Food Freezing 5. Cooking 6. Air Conditioning 7. Lighting 8. Other <p>B. <u>New Equipment Expenditures & Installations by Fuel Used:</u></p> <ol style="list-style-type: none"> 1. Space Heating 2. Water Heating 3. Refrigeration 4. Food Freezing 5. Cooking 6. Air Conditioning 7. Lighting 8. Other <p>C. <u>Equipment Ownership</u></p> <ol style="list-style-type: none"> 1. Space Heating 2. Water Heating 3. Refrigeration 	<p>ELECTRICITY GAS OIL OTHER</p>	<p>Available fuel supplies for residential consumption are not explicitly forecasted, fuel prices for electricity, gas, oil and other are exogenous to the model* and presumably reflect fuel supply constraints to the residential sector.</p> <p>* Residential fuel prices currently used are forecasts from the Brookhaven National Laboratory energy system optimization model (RESOH).</p>

TABLE 15 (CON'T).
Model Description Matrix -

Oak Ridge Improved Engineering - Economic Model of Residential Energy

MODEL AND SCOPE	DEMAND SECTORS	DEMAND STRUCTURE AND DETAIL	SUPPLY SECTORS	SUPPLY STRUCTURE AND DETAIL
Oak Ridge Improved Engineering Economic Model of Residential Energy		C. <u>Equipment Ownership</u>	ELECTRICITY GAS OIL OTHER	
		4. Food Freezing		
		5. Cooking		
		6. Air Conditioning		
		7. Lighting		
		8. Other		
		D. <u>Aug. Equip. Energy Use</u>		
		1. Space Heating		
		2. Water Heating		
		3. Refrigeration		
		4. Food Freezing		
		5. Cooking		
		6. Air Conditioning		
		7. Lighting		
		8. Other		
		E. <u>Average Thermal Integrity of Homes</u>		
		1. Space Heating		
		2. Air Conditioning		
		F. <u>Equipment Usage Factors</u>		
		1. Space Heating		
		2. Water Heating		
		3. Refrigeration		
		4. Food Freezing		
		5. Cooking		
		6. Air Conditioning		
		7. Lighting		
		8. Other		
		G. <u>Housing Forecasts</u>		

TABLE 15 (CON'T).

MODEL	FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
Oak Ridge Improved Engineering Economic Model of Residential Energy	<p>Technology models, which evaluate the trade-off between appliance energy use and capital costs for "state of the art" technology, exist for the following equipment:</p> <ol style="list-style-type: none"> 1. Space Heating 2. Water Heating 3. Refrigeration and Freezing 4. Cooking 5. Air Conditioning <p>Similar models evaluate changes in household thermal integrity as a function of changes in initial cost for different housing structure design.</p>	<p>The Oakridge Model is well suited for analyzing the effect changing incomes, fuel prices, equipment prices, and technologies have on end-use residential energy consumption.</p> <p>Oakridge has used the model to evaluate a number of conservation programs, including:</p> <ol style="list-style-type: none"> 1. The energy and economic impacts of different appliance efficiency standards. 2. The effect the adoption of the ASHRAE 90-75 and alternative residential structure construction standards would have on energy demands for space heating and air conditioning. 3. The impact tax credits for retrofitting single-family homes would have on energy consumption. 4. The energy and benefits of federal R&D programs to develop improved space heating and cooling systems and high-efficiency appliances. 	<ol style="list-style-type: none"> 1. The income and price elasticities are based on an inadequate combination of fuel and equipment price data, thus the related models are poorly specified. 2. Detailed technology models (appliance energy use vs. capital cost) exist only for refrigerators and water heaters, all other energy use/capital cost relationships are based on a lean synthesis of limited literature. 3. Switches to more efficient equipment generated by a rise in income or fuel prices is exogenous to the model. 4. Fuel and appliance prices are not sensitive to changes in residential demand at all. Both such prices are exogenous to the model.

7.1 Summary Matrices of Model Data Sources

TABLE 16

MODEL DESCRIPTION MATRIX - DRI MACROECONOMIC MODEL OF THE U.S. ECONOMY

MODEL	MAJOR SECTORS	SECTORAL DETAIL
A large-scale, simultaneous econometric model of over 800 behavioral equations, with a 200 equation financial sector. It is maintained by DRI and utilized by its clients. Every month DRI publishes 3-4 forecasts and documents the findings.	consumer spending	automobiles, food, housing services clothing and shoes, gasoline furniture
	housing	housing starts, mobile home shipments inventories
	business fixed investment inventories	producers durable equipment, nonresidential structures, pollution abatement expenditures, investment in plant and business inventories, farm, nonfarm, value of inventories
	state and local governments	receipts & expenditures: personal taxes, corporate profits tax, indirect business tax, public construc- tion, transfer payments, interest, subsidies, grants- in-aid, contributions for social insurance
	imports and exports	by end-use category: food, industrial supplies, capital goods, motor vehicles, consumer goods, military goods, trade balance
	profits and incomes	corporate profits, personal income, transfer payments, wages and salaries, rental income, dividends, interest income
	employment, unemployment, labor force	unemployment for all civilian workers, married males, household heads, males, females, whites, nonwhites, teens and adults population for ages 16 and over, 16 to 19, and 18 to 64 civilian labor force and participation rate employed and unemployed totals employment by 2-digit industry

TABLE 16 (CON'T).

MODEL DESCRIPTION MATRIX - DRI MACROECONOMIC MODEL OF THE U.S. ECONOMY (Continued)

MODEL	MAJOR SECTORS	SECTORAL DETAIL
	Industrial production	approximately 75 categories of industrial production (Federal Reserve Board) indexes; capacity utilization, vendor performance
	prices and wages	CPI's: food, other commodities, services, total WPI's: industrial commodities, textiles, fuels and power, chemicals, rubber and plastic, lumber and wood, pulp and paper, metals, machinery and equipments, transportation equipment, agricultural farm products, processed food, WPI for major trading partners
	federal government	receipts and expenditures and personal tax and non tax receipts, corporate profits tax, indirect business taxes, contributions for social insurance, defense purchases, transfers to persons and foreigners, grants-in-aid, subsidies, interest, wages

TABLE 16 (CON'T).

MODEL DESCRIPTION MATRIX - DRI MACROECONOMIC MODEL OF THE U.S. ECONOMY (Continued)

FINANCIAL DETAIL	APPLICATIONS	LIMITATIONS
<ul style="list-style-type: none"> • complete flow of funds modeling for households, businesses and mortgage markets • monetary policy and money aggregates • interest rates 	<p>Fiscal and Monetary Policy Simulations</p> <p>A wide range of government legislative proposals including:</p> <ul style="list-style-type: none"> social security energy policy employment inflation budget questions tax packages housing <p>Study of Capital Markets: "The Capital Shortage: Near Term Outlook and Long Term Prospects", DRI Long Term Review, Summer, 1975.</p>	<p>The model is a demand-oriented model and although it has few limitations, cannot be expected to answer all questions without some outside modeling effort. Macro in scope, it does not reflect minor sector changes well.</p>

OAK RIDGE RESIDENTIAL ENERGY DEMAND

CONCEPT	AVAILABILITY	SOURCE
	all data is annual	
I. Housing Stock Model (both time series and cross-sectional data used in estimation)	population by age group	1951-75 Bureau of the Census, "Estimates of the Population of the United States by Age, Sex, and Race: 1970-75," <u>Current Population Reports</u> , Series P-25, No. 614, U.S. Department of Commerce, November 1975; also earlier publications. Bureau of the Census, "Marital Status and Living Arrangements: March 1975," <u>Population Characteristics</u> , Series P-20, No. 287, U.S. Department of Commerce, December 1975; also earlier issues.
	real per capita income	1951-75 Council of Economic Advisers, <u>Economic Report of the President</u> , January 1976
	housing occupancy by type of unit and age of occupancy	1970 Bureau of the Census, <u>1970 Census of Housing, Detailed Housing Characteristics, United States Summary</u> , HC(1)-D1, 1972; also 1960 and 1950 Censuses of Housing, U.S. Department of Commerce.
II. Household Fuel Demand Models. (both time series and cross-sectional data for 47 states are available for each concept)	electricity prices	1950-74 Edison Electric Institute, <u>Statistical Yearbook of the Electric Utility Industry for 1974</u> . No. 75-39. November 1975; previous issues from 1950 to 1973.
	natural gas prices	American Gas Association, <u>1974 Gas Facts</u> , 1975; previous issues from 1950 to 1973.
	fuel oil prices	1951-74 McGraw-Hill, Inc., <u>Platt's Oil Price Book and Oilmanac: 1974 Prices</u> . 51st and earlier editions. 1959-74 U.S. Department of Agriculture, <u>Agricultural Prices</u> , 1946 to 1974 Editions.
	real per capita income	1951-74 U.S. Department of Commerce, <u>Survey of Current Business</u> , Bureau of Economic Analysis, Monthly.
	heating degree days	1951-74 U.S. Department of Commerce, National Oceanic and Atmospheric Administration, "Monthly Heating Days by State and Season," November 13, 1973.

OAK RIDGE RESIDENTIAL ENERGY DEMAND (Continued)

CONCEPT	AVAILABILITY	SOURCE
mean July temperature	1950-74	U.S. Department of Commerce, Environmental Science Services Administration, <u>Climatological Data, National Summary</u> , July 1974 and earlier editions.
electricity consumption	1950-74	Edison Electric Institute, <u>Statistical Yearbook of the Electric Utility Industry for 1974</u> , No. 75-39, November 1975; previous issues from 1950 to 1973.
natural gas consumption	1950-74	American Gas Association, <u>1974 Gas Facts, 1975</u> ; previous issues from 1950 to 1973
fuel oil consumption	1951-74	Bureau of Mines, <u>Sales of Fuel Oil and Kerosene in 1974</u> , U.S. Department of the Interior, 1975 and earlier reports. American Petroleum Institute, <u>Petroleum Facts and Figures</u> , 1971 Edition
number of households per state	1950, 60, 65-68, 70	Bureau of the Census, <u>Statistical Abstract of the United States, 1950</u> , 71st Ed., U.S. Department of Commerce, 1950, for 1940 Households and Population. Bureau of the Census, <u>Population Estimates</u> , Series P-25.
III. Household Equipment Market Share Sub-Models (cross-sectional data only)		
saturation ratios of fuels by end use categories	1960, 70	U.S. Department of Commerce, Bureau of the Census, <u>1970 Census of Housing: Detailed Housing Characteristics, United States Summary</u> , HC(1)-B1, 1972; also 1960 Censuses of Housing.
saturation of room air conditioners	1960, 70	U.S. Department of Commerce, Bureau of the Census, <u>1970 Census of Housing: Detailed Housing Characteristics, United States Summary</u> , HC(1)-B1, 1972; also 1960 Censuses of Housing.
saturation of central air conditioners	1960, 70	U.S. Department of Commerce, Bureau of the Census, <u>1970 Census of Housing: Detailed Housing Characteristics, United States Summary</u> , HC(1)-B1, 1972; also 1960 Censuses of Housing.
saturation of food freezers	1960, 70	U.S. Department of Commerce, Bureau of the Census, <u>1970 Census of Housing: Detailed Housing Characteristics, United States Summary</u> , HC(1)-B1, 1972; also 1960 Censuses of Housing.
electricity prices	1970	Edison Electric Institute, <u>Statistical Yearbook of the Electric Utility Industry</u> , 1970

OAK RIDGE RESIDENTIAL ENERGY DEMAND (Continued)

CONCEPT	AVAILABILITY	SOURCE
natural gas prices	1970	American Gas Association, <u>Gas Facts</u> , 1970.
oil prices	1970	U.S. Department of Agriculture Statistical Reporting Service, <u>Agricultural Prices, 1970 Annual Summary</u> , June 1971
real per capita income	1970	U.S. Department of Commerce, Bureau of the Census, <u>Statistical Abstract of the United States</u> , 1975, July 1973
heating degree days	1931-73	U.S. Department of Commerce, National Oceanic and Atmospheric Administration, National Climatic Center, <u>Monthly Heating Degree Days by State and Season, 1931-1973</u> , November 1973
cooling degree days	1970	U.S. Department of Commerce, National Oceanic and Atmospheric Administration, <u>Climatological Data, National Summary</u> , December 1970
space heating equipment (oil) price	1974	J. G. Delene, <u>A Regional Comparison of Energy Resource Use and Cost to Consumer of Alternate Residential Heating System</u> , Oak Ridge National Laboratory, ORNL/TM-4689, November 1974.
electric range prices	1970	U.S. Department of Agriculture, Statistical Reporting Service, <u>Agricultural Prices, 1970 Annual Summary</u> , June 1971
gas range prices	1970	U.S. Department of Agriculture, Statistical Reporting Service, <u>Agricultural Prices, 1970 Annual Summary</u> , June 1971
room air conditioner prices	1970	U.S. Department of Agriculture, Statistical Reporting Service, <u>Agricultural Prices, 1970 Annual Summary</u> , June 1971
food freezer prices	1970	U.S. Department of Agriculture, Statistical Reporting Service, <u>Agricultural Prices, 1970 Annual Summary</u> , June 1971.
metropolitan cost of living index	1973	K. P. Anderson, <u>Residential Energy Use: An Econometric Analysis</u> , Rand Corporation, Report R-1297-NSF, October 1973.

OAK RIDGE RESIDENTIAL ENERGY DEMAND (Continued)

	CONCEPT	AVAILABILITY	SOURCE
	proportion of urban population	1975	U.S. Department of Commerce, Bureau of the Census, <u>Statistical Abstract of the United States, 1975</u> , July 1973.
	fraction of single housing detached units	1960, 70	U.S. Department of Commerce, Bureau of the Census, <u>1970 Census of Housing: Detailed Housing Characteristics, United States Summary, HC(1)-B1, 1972</u> ; also 1960 Censuses of Housing.
IV. Technology Sub-Models	refrigerator engineering/cost analysis	-	R. Hoskins and E. Hirst, <u>Energy and Cost Analysis of Residential Refrigerators</u> , Oak Ridge National Laboratory, ORNL/CON-6, January 1977
	gas and electric water heaters energy use/cost analysis	-	J. D. D'Acierno, R. Bertolami and E. Citao, <u>Energy Consumption in Gas and Electric Water Heaters and Ranges</u> , Oak Ridge National Laboratory, ORNL/HIT-226, February 1976. R. Hoskins and E. Hirst, <u>Energy and Cost Analysis of Residential Water Heaters</u> , ORNL/CON-10, June 1977
	household thermal integrity		J. G. Delene and J. B. Gaston, <u>A Regional Comparison of Savings from Various Residential Energy Conservation Strategies</u> , Oak Ridge National Laboratory, ORNL/TM-5146, February 1976 S. H. Dole, <u>Energy Use and Conservation in the Residential Sector: A Regional Analysis</u> , Rand Corporation. Report R-1641-NSF, June 1975 J. C. Moyers, <u>The Room Air Conditioner as an Energy Consumer</u> , Oak Ridge National Laboratory, ORNL/NSF/EP-59. October 1973 J. C. Moyers, <u>The Value of Thermal Insulation in Residential Construction: Economics and the Conservation of Energy</u> , Oak Ridge National Laboratory, ORNL/NSF/EP-9, December 1971.

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CONCEPT	LEVEL OF DETAIL	AVAILABILITY	SOURCE
		historic data used from 1974 on; inde- pendent projections for 1980, 85 & 90 used for the forecast	
demand & exports	household & com- mercial industrial transportation electricity		"U.S. Energy Use Down in 1974", News Release, Bureau of Mines "25th Annual Electrical Industry Forecast", <u>Electrical World</u> , Sept. 1974 "Coal and Oil-Shale Conversion Looks Better", <u>Oil and Gas Journal</u> , March 1974 <u>Emergency Preparedness for Interruption of Petroleum Imports</u> , National Petroleum Council, Sept. 1974
synthetic fuels	from petroleum, coal, shale		<u>Realistic View of U.S. Natural Gas Supply</u> , FPC, Dec. 1974
exploration & de- velopment costs	oil & gas		<u>U.S. Energy Outlook</u> , National Petroleum Council, 1972
electric utilities costs	generation transmission distribution nuclear fuel		<u>Electrical World</u> , Sept. 1974 <u>U.S. Energy Outlook</u> , NPC
capital markets	U.S. Government State & Local Governments Consumer Credit Home Mortgages Foreign Corporate Equity Corporate Bonds Mortgages Business Loans	historic data used from 1955-74	<u>Federal Reserve Bulletin</u> <u>Financing the Energy Industry</u> , Haas, Mitchell, and Stone, 1974, Cambridge: Ballenger Edison Electrical Institute, <u>Statistical Yearbook</u>
industry financial positions	sources & uses of funds, ex- ternal finan- cing, various ratios		Standard and Poors COMPUSTAT data files

BECHTEL CORPORATION ENERGY SUPPLY PLANNING MODEL

CONCEPT	LEVEL OF DETAIL	AVAILABILITY	SOURCE
		annual data developed for 1973, 80, 85, 90 historical observations taken from publications from 1968-on	
Facilities Resources Data Base			
(a)Construction Resource Data	25 manpower categories		Operating Divisions of Bechtel based on past construction experience, literature, and industry contacts; vendors, builders and manufacturers. Accuracy varies - some only approximations.
	41 materials & 60 equipment categories		
	6 time-phased requirement groupings		
(b)Operations Resource Data	27 manpower categories		Stanford Research Institute "Manpower, Materials, Equipment, and Utilities Required to Operate and Maintain Energy Facilities". Based on discussions and investigations by SRI, literature references and recorded industry averages. Some materials data from FPC or ICC publications.
	11 materials & equipment categories		
	3 utilities categories		
	8 energy & natural resources requirements		

BECHTEL CORPORATION ENERGY SUPPLY PLANNING MODEL (Continued)

CONCEPT	LEVEL OF DETAIL	AVAILABILITY	SOURCE
(c) Fuel Mix Data	24 'overview' variables of U.S. Energy Requirements		Bureau of Mines, Federal Power Commission and <u>Electrical World Energy Independence Act of 1975 & Related Tax Proposals</u> . FEA, (EIA) based on PIES Fitted trends and extrapolations
	20 'primary' variables of fuel demand & policy		National Petroleum Council, EIA, and extrapolations
	73 'secondary' variables capacities of supply sources		National Petroleum Council, Bureau of Mines, FEA <u>Project Independence</u> , American Gas Association, Atomic Energy Commission Reports, Federal Power Commission Reports, <u>Minerals Yearbook</u> .
(d) Energy Facility Location Coefficients	petroleum		
	<ul style="list-style-type: none"> - new onshore facilities - offshore production - refineries - import terminals 		Mineral Industry Survey, "Crude", Dept. of Interior, 1974 FEA Weekly Petroleum Statistical Report, 1974 Deepwater Port Act, Joint Committee Hearings, 1973 "Oil Shale & the Energy Crisis," U.S. Bureau of Mines U.S. Energy Outlook "Oil Shale Availability", National Petroleum Council "U.S. Port Development Requirements", Schmid & Garcia, Bechtel, Inc., 1973 Offshore Terminal Systems Concepts, Soros Associates, Inc., U.S. Dept. Commerce, Maritime Administration, Sept. 1972
	gas		
	<ul style="list-style-type: none"> - new onshore production - offshore production - LNG port facilities 		Gas Facts, American Gas Association, 1971 Oil and Gas Journal Pipeline and Gas Journal "U.S. Port Development Requirements", Schmid & Garcia, Bechtel, Inc.

BECHTEL CORPORATION ENERGY SUPPLY PLANNING MODEL (Continued)

CONCEPT	LEVEL OF DETAIL	AVAILABILITY	SOURCE
	coal		Keystone News Bulletin, December 1974
	- locations of coal mines by various types		Keystone Coal Industry Manual, McGraw-Hill, N.Y., 1973 Minerals Yearbook, "Coal", Dept. of Interior, A72
	- coal gasification & coal solvent refining facilities		
	electric power		EEI, "Statistical Yearbook"
	power plant location data for existing & planned additions		National Power Survey, FPC "FEA Considering Conversion of 53 Generating Plants," National Journal Reports, Nov. 1974 "U.S./R&D" Government Data Publications, Washington, D.C., Jan. 1975 U.S. Dept. of Interior, Final Environmental Statement for the Geothermal Leasing Program.
(e)Regional Demand	11 fuel types: crude, gasoline, distillates, other products methanol heavy fuel oil electricity high-BTU coal low-BTU coal solvent refined coal natural gas		"Crude Petroleum & Petroleum Products," Bureau of Mines, Minerals Yearbook "Crude Petroleum, Petroleum Products, and Natural Gas Liquids", Minerals Industry Surveys, Bureau of Mines Current Population Reports; Population Estimates & Projections, Dept. Commerce, Bureau of Census 55th Semi-Annual Electric Power Survey, Edison Electric Institute Electric Power Statistics, FPC Edison Electric Institute Statistical Year Book of the Electric Utility Industry "Bituminous Coal & Lignite Distribution", Minerals Industry Surveys, Bureau of Mines "Coal-Bituminous & Lignite", Bureau of Mines, Minerals Yearbook Coefficients calculated on the basis of the above sources
(f)Interregional Transportation Model-Split Coefficients	crude oil refined products heavy fuel oil coal		"Inputs to Refineries", Minerals Industry Surveys Petroleum Facts and Figures, API "Bituminous Coal and Lignite Distributions", Bureau of Mines

TEKNEKRON, INC., ELECTRIC UTILITY SIMULATION MODEL

CONCEPT	LEVEL OF DETAIL	AVAILABILITY	SOURCE
		all annual data	
A. Demand Module			
net generation purchases net interchanges resale & wholesale sales pumped storage energy size of existing generating capacity	by individual utility company	year ending 12/31/75	"Statistics of Privately Owned Electric Utilities in the U.S." "Statistics of Publicly Owned Electric Utilities in the U.S." from FRC Form I and IM magnetic tapes
monthly peak loads	by state	1970-76	1975 FPC Monthly Electric Power Statistics
yearly growth rates	by state	1970-76	Electric Reliability Council
steam electric generating units	by individual unit primary fuel type size type of cooling alternative fuel capability	12/75	"Steam Electric Air & Water Quality Control Data," year ending 12/75 Regional Reliability Council Reports Electrical World Directories
announced units of all generating types	fuel type, size, state & county, state of primary owner & percentage of ownership, year unit will come on line, primary fuel type, type of cooling	1976-86	FPC published reports pursuant to FPC Order 383-4, April 1, 1977 Regional Reliability Council Reports Electrical World Directories
conversions and curtailments	gas and oil burners unit by unit	1977	A file of orders to convert to coal per FEA data, June 1977

TEKNEKRON, INC., ELECTRIC UTILITY SIMULATION MODEL (Continued)

CONCEPT	LEVEL OF DETAIL	AVAILABILITY	SOURCE
B. Emissions Data	by county, state & Air Quality Control Region	1972	National Emissions Data System - EPA
	by county & source category	1973	
	major fuel-burning installations	1975	DOE/EPA Master Industrial County Data Base
	planned industrial boilers		American Boiler Manufacturers Association
C. Meteorological Data	Inversion & mixing height	1960-64	EPA-Holzworth Files and Teknekron's Meteorology Group
	TDF data for national weather stations	1970-76	
		1977-78	
D. Air Quality Data Bases	National Air Sampling Network	1960-77	EPA, National Air Sampling Network
E. Financial Data	individual utilities, merged to states, includes operations & maintenance, expenditures & general & administrative costs	1976	FPC Forms 1 & IM

DRI/ZIMMERMAN COAL MODEL

CONCEPT	LEVEL OF DETAIL	AVAILABILITY	SOURCE
		all annual data	
contract & captive coal	shipped produced		FPC Form 423, (FERC) and National Coal Association, <u>Steam Electric Plant Factors</u>
coal reserves	by sulfur content by thickness of seam	1976	U.S. Bureau of Mines, <u>The Reserve Base of Bituminous Coal and Anthracite for Underground Mining in the Eastern U.S.</u> , Information Circular 8655.
equipment expenditures	mining machinery and equipment	1965-76	U.S. Bureau of Mines <u>Basic Estimated Capital Investment and Operating Costs for Underground Bituminous Coal Mines</u> , Information Circulars 8632 and 8641.
coal demand	by electric utilities bituminous, by industry bituminous less coke	1965-76	U.S. Bureau of Mines "News Release" and <u>Minerals Yearbook</u>
coal exports	bituminous, by region	1965-76	Mineral Industry Surveys, Bureau of Mines and Energy Data Data Report, Department of Energy
average productivity	surface, deep and total, by state	1965-75	
production		1965-76	
value/ton, fob mine		1965-76	
employment levels		1965-75	
consumption by consumer class		1965-74	
distribution by consumer class	by supply region by demand region	1965-74	
days supply of coal by consumer class		1965-74	

DRI/ZIMMERMAN COAL MODEL (Continued)

CONCEPT	LEVEL OF DETAIL	AVAILABILITY	SOURCE
productivity costs	seam thickness mining machines shifts per day annual output days worked		State of Illinois, Department of Mines and Minerals. <u>1973 Annual Coal, Oil and Gas Report</u> , Springfield, 1973. State of Kentucky, Department of Mines and Minerals. <u>Annual Report, 1973</u> . Frankfort, 1973. State of Ohio, Department of Industrial Relations. <u>Division of Mines Report, 1973</u> . Columbus, 1973. State of Pennsylvania, Department of Environmental Resources. <u>Annual Report of Bituminous Coal Division, 1973</u> . Harrisburg, 1973. State of West Virginia, Department of Mines. <u>Directory of Mines, 1973</u> . Charleston. 1973.

Sources of Data Used In DRI Energy Model

	<u>Residential</u>	<u>Commercial</u>	<u>Household and Commercial</u>	<u>Industrial</u>	<u>Transportation</u>	<u>Electric Utilities</u>
Electricity	EEL	EEL		EEL	EEL	
Coal			BOH			FPC
Natural Gas	AGA	AGA		AGA		FPC
Nuclear Power						FPC
Hydropower						FPC
Petroleum Products						FPC
Distillate			BOH	BOH	BOH	
Residual			BOH	BOH	BOH	
Kerosine			BOH	BOH		
Liquified Gases			BOH	BOH	BOH	
Jet Fuel					BOH	
Gasoline					DOT	
Other			BOH	BOH		

AGA: American Gas Association - "Single-Family Residential Gas Appliance Usage", Gas Facts

BOH: Bureau of Mines - "Natural Gas Production & Consumption", Mineral Industry Yearbook, "News Release"

DOT: Department of Transportation - Highway Statistics

EEL: Edison Electric Institute - Statistical Yearbook of the Electric Utility Industry

FPC: Federal Power Commission - Typical Electric Bills, "All Electric Customers, Residential Customers & Average Annual kWh Use"

API: American Petroleum Institute Facts and Figures

FOSSIL1

CONCEPT	LEVEL OF DETAIL	SOURCE
Sources & Uses of Funds for the Petroleum Industry	capital expenditures dividends working capital income depreciation stock debt	Chase Manhattan Bank, <u>Financial Analysis of a Group of Petroleum Companies</u> , Energy Economics Division
Financial ratios for electric utilities	tax rates depreciation capital ratios external/internal financing target ROI	Edison Electric Institute, <u>Statistical Yearbook of the Electric Utility Industry</u>
Capital Costs	plant, O&M conversion to alternative technologies	ERDA, <u>A National Plan for Energy Research, Development and Demonstration</u> , ERDA 77-1 draft
Shale Oil Supply		FEA, <u>Project Independence Blueprint Task Force Report - Potential Future Role of Oil Shale: Prospects and Constraints</u> , Department of Interior
Return to drilling for U.S. Petroleum Resources recoverable estimates Petroleum supply		M.K. Hubbert, <u>U.S. Energy Resources: A Review as of 1972</u> , U.S. Senate Committee on Interior and Insular Affairs, Pursuant to S.Res. 45 -- A National Fuels and Energy Policy Study, Serial No. 93-40 (92-75), 1974
Recoverable resource estimates	oil, gas, coal	U.S. Geological Survey, <u>Geological Estimates of Undiscovered Recoverable Oil and Gas Resources in the U.S.</u> , Geological Survey Circular 725 National Academy of Sciences, <u>Mineral Resources and the Environment</u> , NAS, 1975
Coal supply		U.S. Bureau of Mines, <u>Strippable Reserves of Bituminous Coal and Lignite in the United States</u> , Information Circular 8531. U.S. Dept. of the Interior Washington, D.C. (1971) U.S. Bureau of Mines, <u>Cost Analyses of Model Mines for Strip Mining of Coal in the United States</u> , Information Circular 8535. U.S. Dept. of the Interior Washington, D.C. (1972)

FOSSIL1 (Continued)

CONCEPT	LEVEL OF DETAIL	SOURCE
Coal Supply		<p>U.S. Bureau of Mines, <u>Demonstrated Coal Reserve Base of the United States on January 1, 1974</u>. Mineral Industry Survey. U.S. Dept. of the Interior, Washington, D.C. (June 1974).</p> <p>Patrick A. Hamilton, et al., <u>The Reserve Base of U.S. Coals by Sulfur Content, Part 1</u>, Bureau of Mines Information Circular 8680. U.S. Dept. of Interior, Washington, D.C. (1975).</p> <p>M. B. Zimmerman, <u>The Supply of Coal in the Long Run: The Case of Eastern Deep Coal</u>, Report No. MIT-EL 75-021. M.I.T. Energy Laboratory, Cambridge, Mass. (September 1975).</p>
Financial Ratios for Coal Industry		<p>T. T. Tomimatsu and R. E. Johnson, <u>The State of the U.S. Coal Industry</u>, Bureau of Mines Information Circular 5707, 1976</p>

BAUGHMAN & JOSKOW REGIONALIZED ELECTRICITY MODEL (MIT)

CONCEPT	LEVEL OF DETAIL	AVAILABILITY	SOURCE
material balances and cost relation- ships for nuclear fuels	fuel fabrication costs reprocessing costs preparation costs conversion costs	1965-71	<u>Reactor Fuel Cycle Costs for Nuclear Power Evaluation, U.S.</u> <u>Atomic Energy Commission Report, WASH-1099, December 1971</u>
transmission and distribution requirements	structure miles substation capa- city capacity of line transformers number of meters	1965-71	<u>FPC - Statistics of Privately Owned Electric Utilities in the</u> <u>U.S.</u>
cost of service and generation	generation for the 9 census regions for: hydro, conventional steam, nuclear and internal combustion	1965-71	<u>Edison Electric Institute Statistical Yearbook</u>
electricity demand	total, for nine regions	1965-71	"Annual Statistical Report," <u>Electrical World</u>
fuel prices		1967-72	<u>Edison Electric Institute Statistical Yearbook</u>
capital cost factors	depreciation insurance costs return on invest- ment fixed capital charges	1967-72	FPC - <u>National Power Survey, Part 1</u>

ICF GAS AND OIL SUB-MODELS

MODEL	CONCEPT	AVAILABILITY	SOURCE
		all annual	
I. <u>Oil Sub-Model</u>	oil in place discoveries	56-69	National Petroleum Council, U.S. <u>Energy Outlook: Oil and Gas</u> <u>Availability.</u>
	exploratory drilling	56-69	
	primary recovery factors		
	initial oil in place	56-69	
	average well depth by region		
	secondary/tertiary recovery factors in new fields		American Petroleum Institute, <u>Quarterly Review of Drilling</u> <u>Statistics.</u>
	secondary/tertiary delay factors		
	secondary investment factors		
	gas/oil reserves added ratio		
	oil well exploratory footage	1970-76	
	average depths of producing of producing oil wells		American Petroleum Institute, <u>Reserves of Crude Oil, Natural</u> <u>Gas Liquids, and Natural Gas in</u> <u>the United States and Canada.</u>
	initial depths of wells		
	oil in place discoveries	1970-75	
	initial oil reserves		
	decline rates		
	exploratory drilling schedules on leased land		Dept. of the Interior, Bureau of Land Management, Environmental Impact Statements on OCS lots.
	average and peak oil production estimates		
	off-shore drilling costs		
	initial oil wells		<u>World Oil, 2/15/77 Issue</u>

ICF GAS AND OIL SUB-MODELS (Continued)

MODEL	CONCEPT	AVAILABILITY	SOURCE
		all annual	
II. <u>Gas Sub-Model</u>	cumulative gas reserves	56-69	National Petroleum Council, U.S. <u>Energy Outlook: Oil and Gas</u> <u>Availability, 1974.</u>
	historical gas drilling	56-69	
	average well depth		
	depletion fractions for new wells		
	cumulative gas reserves	70-75	American Petroleum Institute, <u>Reserves of Crude Oil, Natural</u> <u>Gas Liquids, and Natural Gas in</u> <u>the United States and Canada.</u>
	initial gas reserves		
	projected time pattern of exploratory drilling efforts		Department of the Interior, Bureau Land Management, Environmental Impact Statements.
	OCS drilling costs		
	historical gas drilling	70-75	American Petroleum Institute, <u>Quarterly Review of Drilling Statistics.</u>
	oil resources factor beyond 200 meter ocean depth		National Petroleum Council, <u>Ocean Petroleum Resources Report, 1974.</u>
	undiscovered gas resources		U.S. Geological Survey
	number of oil wells, gas wells, dry holes drilled and costs		<u>Joint Association Survey</u>
	initial number of gas wells		<u>World Oil, 2/15/77 Issue</u>

ICF GAS AND OIL SUB-MODELS (Continued)

MODEL	CONCEPT	AVAILABILITY	SOURCE
		all annual	
II. <u>Gas Sub-Model</u>	operating costs per well		Gruy Federal, Inc., <u>Oil and Gas Replacement Cost: Development and Production</u> , Report to DOE.
	production of gas		Bureau of Mines, <u>Report on Withdrawal and Deposits of Natural Gas in the United States</u> .
	indices of depth adjusted drilling costs	1975, 1976, 1977	IPAA Cost Study Report, May 8-10, 1977 and October 1977 update.
	OCS drilling costs		National Petroleum Council, <u>Ocean Petroleum Factors</u>
III. Oil and Gas Supply	gas plant investment initial net fixed assets intangible drilling write-off		National Petroleum Council (from Chase Manhattan Bank data)
	geological and geophysical expenditure overhead expense lease equipment expense		Joint Association Survey on Drilling Costs

ICF GAS AND OIL SUB-MODELS (Continued)

MODEL	CONCEPT	AVAILABILITY	SOURCE
		all annual	
	operating costs per well		Gruy Federal, Inc., <u>Oil and Gas Replacement Cost: Development and Production.</u>
	wells, footage drilled, costs for oil and gas wells and dry holes for 11 depth classes		1975 <u>Joint Association Survey.</u>
	cost indices for depth adjusted drilling costs	1973, 1976, 1977	Independent Petroleum Association of America Cost Study Report, May 8-10, 1977 and October 1977 update.
	oil well secondary recovery operating costs		Research by LaRue, Moore and Schafer.
	tertiary operating costs		Vello A. Kruskran, Lewin & Assoc. Vello A. Kruskran, Lewin & Assoc.
	tertiary recovery factors from old fields		Lewin & Associates, <u>The Potential Economics of Enhanced Oil Recovery</u> , Reports to DOE.
	tertiary recovery investment factors		
	off-shore drilling cost factor: atlantic		National Petroleum Council, in <u>Ocean Petroleum Factors.</u>

STANFORD RESEARCH INSTITUTE NATIONAL ENERGY MODEL

Network Locations

Sources

I. End-use Demand.

A. Residential/Commercial

1. Urban Space Heat

- a. U.S. Bureau of Mines, Mineral Industry Surveys, "Sales of Fuel Oil and Kerosene," 1974.
- b. U.S. Bureau of Mines, Mineral Industry Surveys, "Natural Gas, Annual," 1974; Monthly, January-November 1975; or "Petroleum Statement Monthly," October 1974.
- c. U.S. Bureau of Mines, Mineral Industry Surveys, "Petroleum Statement," Annual, 1974.
- d. Electrical World, September 1975.
- e. American Gas Association, Gas Facts, 1973.
- f. Federal Power Commission, "All-Electric Homes," 1974.
- g. American Gas Association, Quarterly Report of Gas Industry Operations, 1974 issues.

2. Cooking, Drying, Water Heating

- a. U.S. Bureau of Mines, Mineral Industry Surveys, "Natural Gas, Annual," 1974; Monthly, January-November 1975; or "Petroleum Statement Monthly," October 1974.
- b. Sources d. through g. under Urban Space Heat.

3. Rural Heat

- a. U.S. Bureau of Mines, Mineral Industry Surveys, "Sales of Liquefied Petroleum Gases and Ethane," 1974.
- b. Stanford Research Institute, "Patterns of Energy Consumption," 1972.
- c. Electrical World, September 1975.
- d. American Gas Association, Gas Facts, 1973..

4. Electromechanical

- a. Sources d. through f. under Urban Space Heat.
- b. Stanford Research Institute, "Patterns of Energy Consumption," 1972.

5. Air Conditioning

- a. Federal Power Commission, FPC News, various issues.
- b. California Energy Resources Conservation and Development Commission, Quarterly Fuel and Energy Summary (Second Quarter 1975).

STANFORD RESEARCH INSTITUTE NATIONAL ENERGY MODEL (Continued)

B. Industrial

1. "Dirty" Direct Heat

- a. U.S. Bureau of Mines, Mineral Industry Surveys, "Sales of Fuel Oil and Kerosene," 1974.
- b. U.S. Bureau of Mines, Mineral Industry Surveys, "Natural Gas, Annual," 1974; Monthly, January-November 1975; or "Petroleum Statement Monthly," October 1974.
- c. U.S. Bureau of Mines, Mineral Industry Surveys, "Petroleum Statement" Annual, 1974.
- d. Electrical World, September 1975.
- e. U.S. Department of Commerce, Bureau of Census, 1972 Census of Manufactures, "Fuels and Electric Energy Consumed."
- f. U.S. Department of Commerce, Bureau of Census, Annual Survey of Manufactures, "Fuels and Electric Energy Consumed," 1974.
- g. Federal Energy Administration, "Voluntary Industrial Energy Conservation," April 1976.
- h. U.S. Bureau of Mines, Minerals Yearbook, Volume 1, 1973.
- i. Federal Power Commission, "National Power Survey," Volume 1, 1970.
- j. Battelle Columbus Laboratories, "Energy Use Patterns in Metallurgical and Nonmetallic Mineral Processing (Phase 4)," PB-245 759, June 1975.

2. Indirect Heat

- a. U.S. Bureau of Mines, Mineral Industry Surveys, "Sales of Liquefied Petroleum Gases and Ethane," 1974.
- b. Sources a. through j. under "Dirty" Direct Heat.

3. Electromechanical

- a. U.S. Bureau of Mines, News Release, "Annual U.S. Energy Use Drops Again," April 5, 1976.
- b. Federal Power Commission, FPC News, various issues.
- c. Sources d. through j. under "Dirty" Direct Heat.

4. Clean Direct Heat

- a. Federal Power Commission, FPC News, various issues.
- b. Sources a. through j. under "Dirty" Direct Heat.

5. Intermediate Direct Heat

- a. Same sources as Clean Direct Heat.

STANFORD RESEARCH INSTITUTE NATIONAL ENERGY MODEL (Continued)

C. Transportation

1. Automobile
2. Truck/Bus
3. Rail
4. Marine
5. Aircraft

Sources of Data unknown.

II. Demand Region Gateways

A. Electric Power Production

Federal Power Commission, "Bulk Power Load and Supply Information," Docket R-362 (Order 383-3), FPC News Release No. 21520, June 30, 1975

Brookhaven National Laboratory, Memorandum: "Reactor Characteristics," June 1976

State of California, "Common Methodology for Preparing Forecasts of Electric Loads and Resources," State Energy Resources Conservation and Development Commission Docket No. 75-FOR-3, January 21, 1976

Falcone, C. A., "Generating Alternatives to the Year 2000 - The System Planning Viewpoint," 1975 Joint Power Generation Conference, September 30, 1975

Ebasco Services, Inc., "Fossil and Nuclear 1000 MW Central Station Power Plants Investment Estimates," Prepared for Electric Power Research Institute, September 1975

Stanford Research Institute, "Manpower, Materials, Equipment and Utilities Required to Operate and Maintain Energy Facilities," National Science Foundation Contract NSF-C-87, March 1975

Federal Power Commission, Hydroelectric Power Evaluation, Supplement No. 1, Washington, D.C., November 1969

Garber, L. L., "Effective Load Carrying Capability of Generating Units," 31 TP 66-51, IEEE Transactions on Power Apparatus and Systems, August 1966

STANFORD RESEARCH INSTITUTE NATIONAL ENERGY MODEL (Continued)

III. Refinery Regions

Stanford Research Institute, A Western Regional Energy Development Study: Economics, "Volume II--SRI Energy Model Data Base," prepared for the Council on Environmental Quality, Environmental Protection Agency, Energy Research and Development Administration, Department of the Interior, National Science Foundation under Contracts EQ5AC007 and EQ5AC008; Draft Report November 1975; Final Report November 1976

IV. Resource Regions

Shale Oil

National Petroleum Council, "An Initial Appraisal by the Oil Shale Task Group, 1971-1985," Library of Congress Card No. 72-75038, 1972

Perry, H., "Prospects for Oil Shale Development," U.S. Dept. of Interior, May 1968

Brown, C. H., Statement before the Science and Technology Committee, U.S. House of Representatives, October 8, 1975

Nuclear Fuel

Patterson, J. A., Uranium Industry Seminar, GJO-108(75) USERDA, Grand Junction, Colorado, October 1975

U.S. Atomic Energy Commission, "The Nuclear Industry--1974," Wash Report 1174-74, p. 20

Metz, Wm. D., "Laser Enrichment: Time Clarifies the Difficulty," Science March 19, 1976, p. 1162

The Energy Daily, February 16, 1976, p. 13

Geothermal

White, D. E., and Williams, D. L. (editors), "Assessment of Geothermal Resources of the United States--1975," USGS Circular 726, 1975

Ramachandran, G., Barrager, S. M., and Quinn, D. J., "Economic Analysis of Geothermal Energy Development in California," Volumes I and II (draft report), SRI, November 1976

STANFORD RESEARCH INSTITUTE NATIONAL ENERGY MODEL (Continued)

Resource Regions (continued)

Domestic Crude Oil and Natural Gas

American Gas Association, American Petroleum Institute, Canadian Petroleum Association, "Reserves of Crude Oil, Natural Gas Liquids, and Natural Gas in the United States and Canada and United States Productive Capacity as of December 31, 1974," Volumes 14-29, May 1975

U.S. Geological Survey, "Geological Estimates of Undiscovered Recoverable Oil and Gas Resources," USGS Circular 725, 1975

"Exxon Says U.S. Still Has Vast Potential," Oil and Gas Journal, March 22, 1976, p. 29

Federal Energy Administration, "Oil: Possible Levels of Future Production," Project Independence Blueprint, Final Task Force Report, November 1974

"Enhanced Recovery Surge Seen Via Price Decontrol" (Report of Interstate Oil Compact Commission to Federal Energy Administration), Oil and Gas Journal, February 24, 1975, pp. 19-21

U.S. Bureau of Mines, "Engineering Cost Study of Development Wells and Profitability Analysis of Crude Oil Production," USBM Information Circular 8561, 1972

"Depth and Producing Rate Classification of Petroleum Reservoirs in the United States, 1971," USBM Information Circular 8675A, 1976

Federal Energy Administration, "Natural Gas," Project Independence Blueprint, Final Task Force Report, 1974

Federal Power Commission, National Gas Survey, Volumes I-V, 1973

Potential Gas Agency, "Potential Supply of Natural Gas in the United States" (as of December 31, 1972), Potential Gas Committee, Mineral Resources Institute, Colorado School of Mines Foundation, Inc., Golden, Colorado

Kelley, T. E., "Alaskan Operators Solve Tough Drilling Problems," World Oil, December 1968

Franklin, L. J., "Drilling in the Northwest Australian Shelf," Proceedings of the Ninth World Petroleum Conference

STANFORD RESEARCH INSTITUTE NATIONAL ENERGY MODEL (Continued)

Resource Regions (continued)

Coal

Sheridan, E. T., "United States Coals for Coke Production," Paper presented at the Economic Commission for Europe Symposium on Developments in European and World Markets for Coking Coal and Coke, Rome, Italy, March 26-30, 1973, p. 21

U.S. Geological Survey, "Coal Resources of the United States, January 1, 1974," USGS Bulletin 1412, Washington, D.C., 1975, p. 130

U.S. Bureau of Mines, "Demonstrated Coal Reserve Base of the United States by Sulfur Category on January 1, 1974," Mineral Industry Surveys Series, May 1975, p. 7

Fuels from Biomass

Alich, J., and Inman, R. E., "Effective Utilization of Solar Energy to Produce Clean Fuel," NSF Grant No. 38723, June 1974

Alich, J., et al., "An Evaluation of the Use of Agricultural Residues as an Energy Feedstock," NSF Grant No. AER74-18615A03, July 1976

U.S. Energy Research and Development Administration, "An Evaluation of the Use of Agricultural Residues as an Energy Feedstock: An Extension of Work," Division of Solar Energy, Contract E (04-3)-115 (in progress)

APPENDIX A

FLOW CHARTS OF CAPITAL MARKET MODELS

Figure A-1. Flow chart of oil and gas sector financing.

Figure A-2. Bechtel energy supply planning model.

SIMPLIFIED FLOW CHART
OIL SUPPLY (OS) CURVE SECTION

* PVE = Present Value Equivalent

Figure A-3. ICF oil and gas model.

SIMPLIFIED FLOW CHART

NON-ASSOCIATED GAS SUPPLY (GS) CURVE SECTION

* Present Value Equivalent

Figure A-4. ICF oil and gas model (con't)

Figure A-5. SRI national energy plan, partial flow chart.

Figure A-6. Wharton long-term annual and industry forecasting model.

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graph TD
    A1[FINAL DEMANDS: FOUR NONENERGY INDUSTRIAL SECTORS, SIXTEEN ENERGY PRODUCT SECTORS (FROM CONSUMPTION MODEL).] --> IIM1[INTERINDUSTRY MODEL: FOUR NONENERGY INDUSTRIAL SECTORS, ELEVEN ENERGY RESOURCE SECTORS, TWENTY ENERGY CONVERSION PROCESSES, SIXTEEN ENERGY PRODUCT SECTORS.]
    B1[TECHNICAL COEFFICIENTS: FOUR NON-ENERGY INDUSTRIAL SECTORS (FROM PRODUCTION MODEL), ELEVEN ENERGY RESOURCE SECTORS, TWENTY ENERGY CONVERSION PROCESSES, SIXTEEN ENERGY PRODUCT SECTORS (FROM LINEAR PROGRAMMING MODEL).] --> IIM1
    C1[INDUSTRIAL PRICES, ENERGY RESOURCE PRICES, ENERGY CONVERSION UNIT COSTS, ENERGY PRODUCT PRICES: FOUR NONENERGY INDUSTRIAL SECTORS (FROM PRODUCTION MODEL), ELEVEN ENERGY RESOURCE SECTORS, TWENTY ENERGY CONVERSION PROCESSES, SIXTEEN ENERGY PRODUCT SECTORS (FROM LINEAR PROGRAMMING MODEL).] --> IIM1
    IIM1 --> ITF[INTERINDUSTRY TRANSACTIONS, FINAL DEMANDS, PRIMARY INPUTS IN CURRENT AND CONSTANT PRICES: FOUR NONENERGY INDUSTRIAL SECTORS, ELEVEN ENERGY RESOURCE SECTORS, TWENTY ENERGY CONVERSION PROCESSES, SIXTEEN ENERGY PRODUCT SECTORS.]
    ITF --> ET1[ENERGY TRANSACTIONS: ELEVEN ENERGY RESOURCE SECTORS (TO LINEAR PROGRAMMING MODEL).]
    ITF --> ET2[ENERGY TRANSACTIONS: SIXTEEN ENERGY PRODUCT SECTORS (TO LINEAR PROGRAMMING MODEL).]
    ITF --> PPI1[PRICES OF PRIMARY INPUTS, NONENERGY INDUSTRIAL PRICES, PRODUCTIVITY LEVELS: TWENTY ENERGY CONVERSION PROCESSES (FROM DATA INPUT AND PRODUCTION MODEL).]
    PPI1 --> UCC[UNIT CONVERSION COSTS: TWENTY ENERGY CONVERSION PROCESSES.]
    UCC --> LPM[LINEAR PROGRAMMING MODEL: TWENTY ENERGY CONVERSION PROCESSES, TWENTY-SEVEN SUPPLY AND DEMAND CONSTRAINTS.]
    ET1 --> LPM
    ET2 --> LPM
    ET2 --> EPD[ENERGY PRODUCT DEMANDS: SIXTEEN ENERGY PRODUCTS.]
    EPD --> LPM
    LPM --> ERS[ENERGY RESOURCE AND ENERGY PRODUCT PRICES: ELEVEN ENERGY RESOURCES, TWENTY ENERGY CONVERSION PROCESSES, SIXTEEN ENERGY PRODUCTS (TO PRODUCTION AND INTERINDUSTRY MODELS).]
    ERS --> C[CONSUMPTION MODEL: INDIRECT UTILITY FUNCTION FOR HOUSEHOLD SECTOR.]
    ERS --> PPI2[PRICES OF PRIMARY INPUTS, IMPORTS, CAPITAL SERVICES, LABOR SERVICES (DATA INPUT).]
    PPI2 --> PM[PRODUCTION MODEL: PRICE POSSIBILITY FRONTIERS FOR FOUR NONENERGY INDUSTRIAL SECTORS.]
    PPI2 --> LPM
    PM --> LPM
    PM --> IP1[INDUSTRIAL PRICES: FOUR NONENERGY INDUSTRIAL SECTORS (TO INTERINDUSTRY MODEL AND LINEAR PROGRAMMING MODEL).]
    IP1 --> LPM
    PM --> PPL[PRODUCTIVITY LEVELS: FOUR NONENERGY INDUSTRIAL SECTORS (DATA INPUT).]
    PPL --> LPM
    PM --> TC1[TECHNICAL COEFFICIENTS: ELEVEN ENERGY RESOURCE SECTORS, TWENTY ENERGY CONVERSION PROCESSES, SIXTEEN ENERGY PRODUCT SECTORS (TO INTERINDUSTRY MODEL).]
    TC1 --> LPM
    TC1 --> B1
    TC1 --> TC2[TECHNICAL COEFFICIENTS: FOUR NONENERGY INDUSTRIAL SECTORS (TO INTERINDUSTRY MODEL).]
    TC2 --> LPM
    TC2 --> B2[GROSS PRIVATE DOMESTIC INVESTMENT, GOVERNMENT PURCHASES OF GOODS AND SERVICES, EXPORTS: FOUR NONENERGY INDUSTRIAL SECTORS, SIXTEEN ENERGY PRODUCTS (DATA INPUT).]
    B2 --> LPM
    LPM --> EP1[ENERGY PRICES: FIVE FUEL TYPES.]
    EP1 --> CM[CONSUMPTION MODEL: INDIRECT UTILITY FUNCTION FOR HOUSEHOLD SECTOR.]
    CM --> PC[PERSONAL CONSUMPTION EXPENDITURES: FOUR NONENERGY INDUSTRIAL SECTORS, SIXTEEN ENERGY PRODUCTS.]
    PC --> FD[FINAL DEMANDS: FOUR NON-ENERGY INDUSTRIAL SECTORS, SIXTEEN ENERGY PRODUCTS (TO INTERINDUSTRY MODEL).]
    FD --> A1
  
```

The flowchart illustrates the Energy Conversion Model, showing the integration of various economic and technical data into a linear programming model for energy conversion processes. The model is structured as follows:

- Input Data (Top):**
 - Final Demands (A):** Four nonenergy industrial sectors, sixteen energy product sectors (from consumption model).
 - Technical Coefficients (B):** Four non-energy industrial sectors (from production model), eleven energy resource sectors, twenty energy conversion processes, sixteen energy product sectors (from linear programming model).
 - Industrial Prices, Energy Resource Prices, Energy Conversion Unit Costs, Energy Product Prices (C):** Four nonenergy industrial sectors (from production model), eleven energy resource sectors, twenty energy conversion processes, sixteen energy product sectors (from linear programming model).
- Intermediate Models and Data:**
 - Interindustry Model:** Four nonenergy industrial sectors, eleven energy resource sectors, twenty energy conversion processes, sixteen energy product sectors.
 - Interindustry Transactions, Final Demands, Primary Inputs in Current and Constant Prices:** Four nonenergy industrial sectors, eleven energy resource sectors, twenty energy conversion processes, sixteen energy product sectors.
 - Energy Transactions:**
 - Eleven energy resource sectors (to linear programming model).
 - Sixteen energy product sectors (to linear programming model).
 - Prices of Primary Inputs, Nonenergy Industrial Prices, Productivity Levels:** Twenty energy conversion processes (from data input and production model).
 - Unit Conversion Costs:** Twenty energy conversion processes.
 - Linear Programming Model:** Twenty energy conversion processes, twenty-seven supply and demand constraints.
 - Energy Product Demands:** Sixteen energy products.
 - Energy Resource and Energy Product Prices:** Eleven energy resources, twenty energy conversion processes, sixteen energy products (to production and interindustry models).
 - Prices of Primary Inputs, Imports, Capital Services, Labor Services (Data Input):** Data input for the production model.
 - Production Model:** Price possibility frontiers for four nonenergy industrial sectors.
 - Technical Coefficients:**
 - Eleven energy resource sectors, twenty energy conversion processes, sixteen energy product sectors (to interindustry model).
 - Four nonenergy industrial sectors (to interindustry model).
 - Productivity Levels:** Four nonenergy industrial sectors (data input).
 - Industrial Prices:** Four nonenergy industrial sectors (to interindustry model and linear programming model).
 - Energy Prices:** Five fuel types.
 - Consumption Model:** Indirect utility function for household sector.
 - Personal Consumption Expenditures:** Four nonenergy industrial sectors, sixteen energy products.
 - Final Demands:** Four non-energy industrial sectors, sixteen energy products (to interindustry model).
 - Gross Private Domestic Investment, Government Purchases of Goods and Services, Exports:** Four nonenergy industrial sectors, sixteen energy products (data input).
- Output and Feedback (Bottom):**
 - The **Linear Programming Model** outputs **Energy Prices** and **Energy Transactions**.
 - The **Consumption Model** outputs **Personal Consumption Expenditures**.
 - The **Production Model** outputs **Technical Coefficients** and **Productivity Levels**.
 - The **Final Demands** are fed back into the **Final Demands** input box.

Figure A-7. Hudson Jorgenson/Brookhaven model.

Figure A-8. MIT regional electricity model.

Figure A-10. Teknekrom electric utility simulation model (con't)

Financial Module

Figure A-11. Teknekrom electric utility simulation model (con't)

Figure A-9. Teknekron electric utility simulation model.

Financial Module

Figure A-11. Teknekrom electric utility simulation model (con't)

Figure A-10. Teknekrom electric utility simulation model (con't)

Figure A-12. DRI Energy Model

Parameters
(specified by the user)

1. Regional demand forecasts
2. Regional sulfur emission standards
3. Transportation costs
4. Reclamation costs
5. Scrubbing effectiveness and costs
6. Federal & State taxes
7. Input cost forecasts
8. Rate of return
9. Productivity parameters

Supply Model

Estimates Cumulative
Marginal Cost Functions
for Each Sulfur
Category & in Each
Supply Region

Optimization Model

Finds the Least Cost Manner in Which
Regional Demands as Well as Regional Emission
Standards can be Satisfied by the Supply Regions

Coal Model Results

- A. Price Information
 1. Marginal mine-mouth prices (source prices) by sulfur category and by supply region.
 2. Marginal delivered prices (destination prices) by sulfur category and by demand region.
- B. Production Information
 1. Regional production rates by sulfur category.
 2. Allocation of coal from supply to demand regions by sulfur category.
 3. Regional breakdown to strip- and deep-mined coal.
- C. Other Information
 1. Impact of changes in regional demands and in emission standards.
 2. Sensitivity analysis and parametric programming.

Figure A-13. DRI/Zimmerman Coal Model

Figure A-14. Temple, Barker and Sloane, Inc.
Regulatory Analysis Financial Model

Figure A-15. Oak Ridge National Lab
Residential Energy Use Model

FINANC

Figure A-16. DRI Macro Model

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