International Institute for
Applied Systems Analysis
IIASA www.iiasa.ac.at

A Review of Energy Models: No. 2 - July 1975

Charpentier, J.-P.

IIASA Research Report
October 1975

RR-75-35

A REVIEW OF ENERGY MODELS:

No. 2 - July 1975

Jean-Pierre Charpentier

A REVIEW OF ENERGY MODELS:

No. 2 - July 1975

Jean-Pierre Charpentier

With Contributions by*:

J.M. Beaujean	INSTN, Institut National des Sciences Techniques et Nucléaires	Gif-sur-Yvette, France
S. Rath-Nagel	Kernforschungsanlage	Jülich, F.R.G.
W. Weisz	Rechnungszentrum der Universität	Vienna, Austria

---

*The authors are much indebted to G. Baecher for his help, in particular with the models dealing with energy resources; to Maria Sachs for her editorial assistance, without which the review might never have appeared; and to Anne Weingaertner for her very faithful secretarial support.

TABLE OF CONTENTS

Foreword

Following our first review of energy models in 1974, we received a number of letters encouraging us to continue. Economists and energeticians understood the interest inherent in this synthetic approach to energy modeling, whose main goal was to provide and disseminate all information and methodologies at present available in the energy field.

We have thus collected further models so as to extend our survey of research carried out in various institutes. (For the full model collection, both reviews should be consulted.) If, through these reviews, authors make contact with one another--and we know that this has often occurred--then most of our objective will have been reached.

We are especially indebted to those of you who helped in this exchange of information by writing to us or visiting us to explain their work; and to the many who provided us with summaries of their models.

We hope that, on the occasion of Review No. 3 next year, authors will again send us their models and their own summaries. This avoids possible misinterpretation and greatly improves the quality of the review.

Some have suggested a kind of "Michelin Guide" to energy models, giving quality stars to rank them. We decided, however, that the dangers of too subjective a judgment outweighed the possible advantages of such a ranking. Moreover, since the models have different aims and view the problems in different forms, any ranking would be somewhat arbitrary.

As in the first review, bibliographical details of the models are given in Appendix A. Appendix B provides the addresses of all those with whom we have been in active contact, including but not confined to model authors. Some authors have kindly sent us corrections for the models treated in our first review; these are given in Appendix C.

Without repeating what was said in the first review, we would like to draw attention to certain models in both reviews that address the most frequent questions in the energy field. Before doing so, let us recall the classification we adopted:

Model Classification

Areas of Application		National	International
Energy system (energy is the main problem)	One kind of fuel	A 38*	B 1*
	Several kinds of fuel	C 22*	D 3*
Linkage between energy and general economy		E 10*	F 1*

In Class A (one energy form in a given country), we found a tremendous number of models. It is practically impossible to give an overview of these, because all the industrial models aim at quite specific targets.

*Number of models in this class (Review No. 2).

This year, we have incorporated in Class A models dealing with the estimation of raw energy resources: coal, gas, fuel oil, and uranium. Because of its importance, this area will give birth to many models in forthcoming years; and already we can present many interesting approaches integrating subjective probabilities and geological considerations.

In Class B (one energy form at the international level), the models developed by R.J. Deam of Queen Mary College, UK, and by H. Houthakker and M. Kennedy of Harvard University, USA, remain the most relevant. In both models, the world fuel oil market is divided into a number of regions whose production, transport, and refining are taken into account. The Deam model uses linear programming to minimize the total expenditure for a given demand level. The Houthakker-Kennedy model simulates a market that the authors supposed optimal, described by equations that can be interpreted as first-order conditions of a quadratic programming problem defining a competitive market. Both models are still being developed but can nevertheless be used now for studying different policies.

Class C (different forms of energy for a given country) is as large in number as it is important in theme. The class essentially studies the possibilities of substitution among different forms of energy, either on the primary supply side or on the final use side. One of the most relevant models in this category is still that of K. Hoffman of Brookhaven National Laboratory, USA, using linear programming. For a given year it investigates the best linkage between thirteen given supply sectors and fifteen given demand sectors. The criterion is minimization of the total expenditure. The constraints are related to the levels of demand, supply, and pollution (SO_x, CO_x, NO_x particulates, radioactive and thermal wastes). Hoffman is at present working on a dynamization of his model.

Linked to this model class is the work being carried on by W. Häfele and his team at IIASA in a study of the transition from fossil to other fuels in a given economy. The first publication on this subject came out in June 1974: "Strategies for a Transition from Fossil to Nuclear Fuels" by W. Häfele and A.S. Manne. Extensions of the model will incorporate other energy supply options such as solar and geothermal. The objective is to minimize, by linear programming, the present value of costs incurred annually during each three-year period over a seventy-five-year horizon. It is interesting to note that two kinds of model have been developed where the final demands for energy are either taken to be exogenous, or are endogenous since they depend upon the costs of supply. In a model where the demands are responsive to price, the objective function is the maximization of the money value of consumers' utility less the costs of meeting the final demand. (If q is the quantity of energy, then the utility function of the consumer is $u(q) = aq^b + c$, where a,b,c, are estimated through a series of assumptions about the demand curves.)

It is not useful to describe in detail the models of Class D (different fuels at the international level), or that in Class F (energy as part of global and international models), since very few models have been developed in these areas. Even if energy is a major problem, it is only one problem within a complex system that humanity has to forecast and to solve. It is therefore logical that energy is considered within a larger framework of global and world studies. The Club of Rome initiated such studies, and now five or six others are in progress around the world. Unfortunately the energy area is often considered only cursorily.

It is worth mentioning the only model in Class F, the ISPRA model, which links the energy sector to the general economy of the E.E.C.

Now let us look at Class E where energy is studied by linkage to other national economic questions. Without doubt, this class is the most important, despite the fact that most of the models are still being developed. The energy area has such a great impact on all other economic problems that the linkage between energy and economics seems essential.

In this connection, I should especially like to mention the work by Dale Jorgenson, Harvard University, USA, on the quantitative aspects of this topic Jorgenson dynamized the input-output matrix by using production functions that include both technical progress and price effects. This study is a good one for treating the energy demand aspect which, in most other models, is either exogenously treated, or endogenously integrated using simple elasticity coefficients that many are beginning to consider somewhat inefficient for forecasting problems.

The Jorgenson model is formulated for the analysis of relationships between energy utilization and economic activity. Its most distinctive feature is the incorporation of energy demand and supply in a single analytical framework. A second important innovation is the analysis of the relationship between energy demand and supply and US economic growth.

The first component of the Jorgenson model is the Long-Term Growth Model which provides projections of aggregate US consumption, investment, government final demand, and the prices of primary input: labor and capital. The second component is based upon an inter-industry structure incorporating transactions not only between producers and final users, but also between producer purchases of primary inputs and transactions among different production sectors. The basic element is a model of producer behavior (one for each producing sector) that determines the sector input requirements and output price on the basis of other prices, levels of technological efficiency, and production coefficients. This information is then integrated, and the sectoral interdependencies are analyzed by means of the input-output technique.

Let us briefly consider the models in both reviews from a quantitative point of view. First, the total number of models is 144 (75 this year against 69 last year). The distribution between eastern and western countries is far better this year; the proportion is roughly 1 to 3. The USSR is still underrepresented, but our contacts with the USSR Academy of Sciences suggest that this will be rectified shortly, which will improve the east-west balance we are striving for.

Second, the number of countries covered has increased from 17 to 24, so that this review gives a wider spread of energy models.

We have also computed the frequency of some model characteristics. It turns out that there exists a balance between forecasting and normative models. It is worth noting that the eastern countries are more oriented toward normative methodology. As for modelling techniques, linear programming and simulation using econometric equations are the most used (38% each). The remaining techniques, e.g. I/O analysis, dynamic programming, etc., comprise only 24%.

If we now look at the time frame, we notice a remarkable balance:

Short term ($\leq$ 5 years)	34%
Medium term ($\leq$ 20 years)	34%
Long term ($\geq$ 20 years)	32%

Since the energy crisis occurred two years ago, this balance would have been quite surprising: one would have expected long-term models (i.e. to 2050) to have been dropped in favor of medium-term models, since in energy problems the medium term is tomorrow. In fact, of course, most of the models we present were built before or during the crisis. Are we going to notice any change next year?

To extend our service, we are storing abstracts of the models in the IIASA computer*, so as to permit model selection by various criteria. Our service will be easy to use. Suppose that one is interested in forecasting models on energy demand that use dynamic programming; one then computes--or asks us to compute-- 1.1; 2.2.3; 8.5 , and obtains for all those models the authors, references, and abstracts.

The key words to be used are listed in the following pages. Like any classification, the one we have chosen has its imperfections, but we considered it the most suitable for our purpose.

---

*We are very much indebted to the energy systems group of the Nuclear Research Center, Jülich (FRG), for providing us with a computer program.

Energy Models: Key-Word Classification

1. Overall Aim

   1.1 Forecasting model
   1.2 Normative model
   1.3 Others

2. Demand

   2.1 Total
   2.2 Sector

      2.2.1 Energy sector only
      2.2.2 Industry sector (without energy sector)
      2.2.3 Transport sector
      2.2.4 Household sector
      2.2.5 Commercial and services sector
      2.2.6 Agriculture sector

3. Supply

4. Reserves (see also item 8)

5. Relationship Between:

   5.1 Demand and supply
   5.2 Demand and reserve
   5.3 Supply and reserve
   5.4 Demand, supply and reserve
   5.5 Substitution among fuels
   5.6 Energy and environment

6. Interdependency Between Energy Sector and Other Economic Sectors

7. Model Type

   7.1 Static
   7.2 Dynamic
   7.3 Cybernetic
   7.4 Deterministic
   7.5 Stochastic

8. Modelling Techniques

   8.1 Regression analysis
   8.2 Simulation
   8.3 I/O matrices
   8.4 Linear programming
   8.5 Dynamic programming

      8.5.1 Bellman technique
      8.5.2 Pontryagin technique
      8.5.3 Others

   8.6 Game theory
   8.7 Graphs and networks
   8.8 Others

9. Energy Carriers

    9.1 Non-specified
    9.2 Fuel oil
        9.2.1 Tar sand and shale oil
    9.3 Gas
    9.4 Coal
        9.4.1 Lignite
        9.4.2 Others
    9.5 Hydraulic
    9.6 Nuclear
        9.6.1 Uranium
        9.6.2 Thorium
        9.6.3 Plutonium
        9.6.4 Others (Lithium, etc.)
    9.7 Solar
    9.8 Wind
    9.9 Tidal Geothermal
    9.10 Geothermal
    9.11 Heat carriers
    9.12 Electricity
    9.13 Hydrogen
    9.14 Synthetic fuels (Methanol, etc.)
    9.15 Others

10. Fuel Type

    10.1 Primary
    10.2 Secondary

11. Location

    11.1 Global (worldwide)
    11.2 International
    11.3 National
        11.3.1 Austria
        11.3.2 Belgium
        11.3.3 Bulgaria
        11.3.4 Canada
        11.3.5 Cyprus
        11.3.6 C.S.S.R.
        11.3.7 Denmark
        11.3.8 Federal Republic of Germany
        11.3.9 Finland
        11.3.10 France
        11.3.11 German Democratic Republic
        11.3.12 Greece
        11.3.13 Hungary
        11.3.14 Iceland
        11.3.15 Ireland
        11.3.16 Israel
        11.3.17 Italy
        11.3.18 Japan
        11.3.19 Luxemburg
        11.3.20 Malta
        11.3.21 Netherlands
        11.3.22 Norway
        11.3.23 Poland
        11.3.24 Portugal
        11.3.25 Rumania
        11.3.26 Spain

11.3.27 Sweden
11.3.28 Switzerland
11.3.29 Thailand
11.3.30 Turkey
11.3.31 United Kingdom
11.3.32 United States of America
11.3.33 U.S.S.R.
11.3.34 Yugoslavia
11.3.35 International Organizations
11.3.36 Others

11.4 Regional

12. Time

12.1 Horizon

12.1.1 Short-term (up to 5 years)
12.1.2 Medium-term (under 20 years)
12.1.3 Long-term (over 20 years)

12.2 Lag-time structure

12.2.1 Discrete
12.2.2 Continuous

CLASS A MODELS

AUSTRIA

The Model	K. Fessl, A. Kalliauer and G. Schiller, Österreichische Elektrizitätwirtschaft-AG, Vienna, 1974. Optimization in the Planning of Power Plant Extensions.
Subject and Goal	Given an existing system of thermal and hydraulic electric power plants, the planning of its extension should be optimized so as to meet the long-term requirements and minimize overall costs.
System Described	More than half of the electricity generating system consists of hydraulic power plants, including river power stations and storage power stations to satisfy winter demand. There is also an increasing number of thermal power plants. The system must be expanded to meet future requirements. Electricity exchange with foreign countries must also be taken into account.
Area – Time	Long-term planning.
Area – Space	Austria as a whole (applicable to countries with similar electricity production structure).
Modelling Techniques	The model consists of two dependent though separate programs. 1) Selection of the optimal extension project, using dynamic programming, in 4 steps: -All technically unsuitable possibilities are discarded, -To obtain the total-probability function for the availability, the availability densities of each new power plant are gathered step by step; all "states of the system" with breakdown probabilities above a threshold are discarded; the breakdown probability weighted by a cost factor is retained for each project, -Simulation of the operational costs of each "state of the system", -A stepwise approach year by year: starting from the existing system, each possible state is assigned a monetary value plus the investments for the new elements built during the year. Using dynamic programming, project variants are classified in ascending order of costs. 2) Operational investigation, using non-linear optimization: -The thermal subsystem is optimized by dynamic programming to show the lowest fuel cost for every possible power plant, -The hydraulic subsystem is used to supply the additional power, if available, -The whole system is optimized using the gradient projection method; this is done for each extension variant. The classification of both investigations should be compared to find the best variant.
Input Data	<u>Physical</u> -Data on the power plants, -Data on the storage system, -Failure probabilities, -Limitations imposed on the power plants. <u>Economic</u> -Demand for electricity, -Financial data, -Operational costs for each plant.
Output Data	Classification of the overall projects; for each project, power plants needed, operational data, and matrix of costs.
Observations	Some aspects of the model are still to be improved.

Summary not reviewed by the authors of the model.

AUSTRIA

The Model	R. Lehner, STEWEAG, Graz, 1973. Planning for the Power Station Extension.
Subject and Goal	According to the projected electricity demands, finding the optimum extension program with sufficient supply security, and the most economic management of the power plants.
System Described	The electricity producing system consists of hydraulic power plants including storage stations. Up to ten thermic power plants may be included in the computations. Electricity purchase from abroad is also taken into account.
Area — Time	10-15 years.
Area — Space	Austria (regional).
Modelling Techniques	The model uses linear programming to compute the operational function. The optimization period is one month.
Input Data	Physical -Electricity demand in the form of 3 kinds of daily diagrams (working day, Saturday, Sunday), -Hydraulic energy supply for each month (3 sorts of year are considered: dry, normal, wet), -Electricity production of river power stations, -Storage capacities, -Minimum and maximum load and maximum speed of load change of thermal power stations, -Limited electricity supply from abroad. Economic -Fixed and operational costs, -Costs of electricity bought outside the region.
Output Data	Physical -Optimum operation of each plant, -Sum of energy produced. Economic: Costs of operation.
Observations	This model has been developed for extension and operational planning.

Summary not reviewed by the author of the model.

CANADA

The Model	K.J. Roy and R.E. Roadifer, Geological Survey of Canada, Edmonton, Alberta, 1975[1,2]. Probabilistic Approach to Estimation of Fossil Fuel Reserves.
Subject and Goal	Probabilistic estimates of total petroleum resources within an oil field.
System Described	Probabilistic size distribution of possible oil reservoirs.
Area – Time	Not specified.
Area – Space	Any oil field.
Modelling Techniques	Subjective probability estimates by expert geologists of geometric properties of oil reservoirs. For each geometric factor the subjective probability is aggregated by the Delphi method, and the Monte Carlo method is used to aggregate the factors into a global estimate of oil reserves.
Input Data	Geological and geophysical exploration data for the oil field studied. The information is used by a set of experts for supplying subjective probabilities.
Output Data	Probabilistic estimates of oil fuel reserves.
Observations	-

Summary not reviewed by the authors of the model.

CANADA

The Model		J.T. Ryan, University of Alberta, Edmonton, Alberta, 1973. Analysis of Crude Oil Discovery Rate in Alberta.
Subject and Goal		To estimate the oil resources of Alberta.
System Described		The system deals with deterministic time-series forecasts of oil production on a play by play basis.
Area	Time	Not specified.
	Space	Given locales for regional estimates.
Modelling Techniques		Fitting of saturation curves for each play. The basic assumption is that the rate of discovery of oil in a play is proportional to the undiscovered oil in the play and to the knowledge of the existence of the play. The saturation curves using new field wildcasts as independent variables have a basis in such theory.
Input Data		Time series of cumulative oil discoveries on a play by play basis. The cumulative new field wildcasts are used as independent variables.
Output Data		Deterministic time-series forecasts of oil reserves from known plays.
Observations		The model does not include economic variables, nor the probability of finding new plays.

Summary not reviewed by the author of the model.

CANADA

The Model	E.R. Stoian, Operations Research Branch, National Energy Board, Ottawa, 1973-1974[3]. Crude Oil and Natural Gas Transshipment Models.
Subject and Goal	To develop a multidisciplinary approach to: -Assessing significant changes in oil supply and demand in North America, -Designing strategies for Canadian competitive developments, -Determining system reaction to a new market, -Assessing the marketing penetration zone of a new high-cost source of supply and identifying any possible future oil distribution routes.
System Described	Interconnected crude oil pipeline subsystems in North America, essentially for macro-investigations.
Area — Time	Not specified, long-term.
Area — Space	North America as a whole.
Modelling Techniques	The model is based on network analysis and operations research. The basic flow network has 65 nodes and 145 arcs. It can be used in two modes: -All capacity constraints on arcs are fixed. The model acts as a behavioural or descriptive analytic model and may be used for the study of effects of flows, quantity or quota control, and predictions and forecasts. -All capacity constraints are relaxed. The model is then used to investigate price and shipment tariff structures, as well as import-free schedules in a normative or prescriptive rather than predictive manner.
Input Data	-Supply price of oil, -Productive capacity of each source node, -Costs of shipping oil between two points at the extremity of an arc, -Shipment capacity of each arc, -Demand to be met at each market node.
Output Data	-Quantity of supply by source, -Flow rate and utilization of capacity of each arc, -Incremental costs or true worth to the system of an extra barrel/day of crude oil at a given location. Remarkable insights were obtained by observing how this sensitive "incremental" cost index responds to changes in the environment.
Observations	The model permits detailed examination of: -The opportunity costs to the North American system caused by trade-offs of Canadian and foreign imports, -Cost differences to individual refinery centers, -The impact of the Prudhoe Bay project if connected to potential markets by various routes.

Summary not reviewed by the author of the model.

C.S.S.R.

The Model	E. Goldberger and V. Kraus, Research Institute for Fuel and Energy Economics, Prague, 1974. Rational Earning of Domestic Sources of Solid Fuel.
Subject and Goal	Optimum investment policy in solid fuel system development; optimum plan for volume and structure of solid fuel production and its delivery to territorially specified consumers within that framework.
System Described	The model investigates possible development variants of actual and future solid fuel producers, (volume and structure) with respect to location of both production and consumption.
Area — Time	From 1976 to 2000.
Area — Space	CSSR as a whole.
Modelling Techniques	Linear programming model including Boolean variables. The latter are related to each supply sector. The continuous variables represent volume, kind of solid fuel, and area where they are consumed. There are three kinds of constraints: producer capacity, consumer demand, and investment and labor volume available. The objective function is the discounted cost (investment, production, transportation).
Input Data	Physical -Solid fuel suppliers and variants of their development, by time series, -Solid fuel consumers, by time series, -Technical coefficients related to possible new production of solid fuel, -Volume of labor available in the given time interval. Economic -Fixed cost (investment) of each new development in solid fuel production, -Variable cost (depending on volume of production) related to each new development, -Transportation cost for each path connecting producer and consumer, -Volume of investment available in the given time interval.
Output Data	Physical -Developments to be realized, -Volume and structure of production and transportation of solid fuels considered. Economic: Related minimal cost.
Observations	The integration of Boolean variables in linear programming models requires some aggregation to make the problem tractable.

Summary supplied by the authors of the model.

C.S.S.R.

The Model		M. Imrich Lencz et al., Power Rese..ch Institute of Czechoslovakia, Prague, 1975(4). Electric Consumption Models.
Subject and Goal		Due to forecasting uncertainties, the author uses a set of methods for the long term (up to 1980-1990). This multi-model approach combines an international comparison over the long term (1980-2030) with normative scenarios related to consumption of electricity and heat.
System Described		Energy consumption split into the following sectors: -Manufacturing industry and building industry, -Transportation, -Agriculture, -Non-productive sphere. Two system approaches are envisaged: -Investigation of the internal structure and the internal and external relationships of energy consumption, in order to explain the system behavior, -Mathematical and statistical approach in which the system is considered as a black box.
Area	Time	Long term (up to 2030).
	Space	C.S.S.R. as a whole.
Modelling Techniques		In the first approach, three methods were used: -Analysis of time series, -One-dimensional correlation, -Multi-dimensional correlation. The authors take into consideration the influence of internal and external factors affecting energy consumption, such as demographic, economic and climatic factors. The second approach is a derived Delphi method. Thirty-five experts were questioned on the long-term development of the electric power system. The basic features of the procedures applied were the following: use of questionnaires, iterative procedure for results, and statistical evaluation of the obtained answers. International comparisons were made using Felix's curves.
Input Data		First approach: Population, manpower, GNP, final consumption, means of production, number of cold days, per capita consumption per year. Second approach: Delphi method.
Output Data		First approach: Electricity consumption over time, up to 2000. Second approach: Statistical evaluation of the Delphi answers for the consumption of electricity and for the consumption of heat. Special emphasis had been put on total energy consumption using Felix's curves.
Observations		Behavioral equations and Delphi questionnaires are not given in this report.

Summary not reviewed by the authors of the model.

FRANCE

The Model	A. Breton and F. Falgarone, Electricité de France, Paris, 1973[5]. Optimal Management of Hydro Reservoirs.
Subject and Goal	To set up a new forecast-orientated energy system management, using uniform data for either local or national decision making.
System Described	Hydraulic and thermal production plants; the hydro electricity sub-system is disaggregated into valley sub-systems (see M1 below) operated by (M2); all sub-systems are integrated in (M3).
Area — Time	Weekly results over a year.
Area — Space	France.
Modelling Techniques	The model is composed of three sub-models, of which two are linear programs and one is applied control theory. (M1) Valley sub-system (LP) - determines, for a given level of output, the optimal location of water in the valley under operating constraints and gives all energetic characteristics; (M2) All sub-systems are operated through control theory such that they give the evolution curve of stock on which operating profit is maximum, subject to constraints such as minimum stock and maximum flow, according to the energy characteristics of this sub-system determined by M1. (M3) Maximizes the means (LP) of production of the entire system over a year by balancing hydro and thermal plants such as to fulfill the demand at every time point.
Input Data	A great many physical and economic data.
Output Data	M1 output data feed M2 which in turn feed M3, only M3 output data are given here: Physical -Operating decision for every coming week, -Evolution of water stock. Economic: Marginal costs of all operating sub-systems over a week.

Summary supplied (in French) by the authors of the model.

FRANCE

The Model	Electricité de France, Fontenay-aux-Roses, 1974[6]. Availability of Hydraulic and Thermal Supply System.
Subject and Goal	To simulate nuclear, thermal on hydraulic production under uncertainty, with the aim of estimating operation-failure costs.
System Described	Production and consumption of electricity.
Area — Time	Static model for one year, divided into 52 periods.
Area — Space	France as a whole.
Modelling Techniques	Linear programming. The objective functions are of two kinds: -Minimizing potential energy failures of a lake, -Optimizing some management criteria over a period. Constraints are physical and economic. Consumption and thermal and hydraulic production are randomized.
Input Data	Physical description of set of fuel-oil and nuclear plants; Weekly consumption; Mean operating costs; Mean failure costs.
Output Data	Physical -Hydraulic balance, -Thermal balance, -Consumption peak balance, -Mean utilization power, -Cumulative balance of production and consumption. Economic -Marginal costs of thermal production.
Observations	Model equations and links between sub-models are not described.

Summary supplied (in French) by the author of the model.

G.D.R.

The Model	Ogreb-Institut für Kraftwerke, Cottbus, 1973. Energy Economy of the G.D.R. - Electric Power Generation Optimization.
Subject and Goal	Calculation of an optimum structure for power generation plants to meet demand which minimizes the economic costs under given constraints. The model includes all electric power generation plants, existing and to be constructed. It deals with two problems: balancing the electric load, and optimizing power plant structure. For the first problem all electric power generation systems are considered; for the second, only condensation, nuclear and peak-load power plants.
System Described	Condensation, nuclear, gas turbine, pump storage, heating and industrial power plants (power transmission is not included). The calculation is made given the electric energy demand and power generation in heating and industrial power plants. The system is defined by fuel-balance equations and equations for electric load curves.
Area — Time	A time horizon of 5-15 years, separated into intervals of a year or more.
Area — Space	Electric power generation of the G.D.R.
Modelling Techniques	Linear programming model. The dynamic behavior in the mathematical static model is represented by: -The matrix with multiple defined lines and columns according to the time steps, -The objective function with discounted costs per time interval for one unique point of time. The objective function is of the same form as for the optimization model for the coal industry (see p. 20).
Input Data	The variables of the model are the power plants, by block size and siting area. The lines (balance equations) deal with fuels, electric output (by different load stages), electric capacity and availability of power plants. Required information: Technological -Load duration of electric power generation block per hour, -Fuel input (by energy carrier), -Self-demand for electric energy, -Coefficients for availability of power plants. Economic -Cost of investment (for plants under construction and new plants), -Wages, -Material and other costs, -Costs for floating capital supply (for plants under construction and new plants), -Costs for the import of fuels, -Planned lifetime of new scheduled plants. Other -Electric energy demand, by load stage, -Capacity limits of power plants, -Required capacity in the system, -Electricity generated in heating and industrial power plants, -Availability of power plants.
Output Data	Optimum structure of electric power plants by determining optimum input of existing and planned utilities for the different load stages; optimum input of utilities to meet the peak load; optimum program for shutting down the power plants; demand for fuels.
Observations	The model's mathematical character is static, but it can be used for dynamic calculations in time intervals according to the objective function and the matrix. If the model is used as a submodel of a larger system of the energy economy the coefficients of the objective function should not include fuel costs.

Summary supplied (in German) by the author of the model.

G.D.R.

The Model	Brennstoffinstitut, Freiberg/Sa., 1973. Energy Economy of the G.D.R. - Strategy of Gas Supply Structure.
Subject and Goal	Optimization of the given gas demand (domestic and foreign natural and artificial gas) in the G.D.R. for an optimum network construction under technological and economic constraints. All gas production plants, existing and scheduled, are included, as is the import of natural gas.
System Described	The model includes plants for lignite briquette gasification under pressure, splitting of rich or liquid gas, production of bituminous coal gas and of rich gas out of petrol, gas storage, domestic natural gas production, double trail supply, gas transport and distribution and import of natural gas. The system is limited by the given gas demand of G.D.R. (separated into consumer concentration densities and load stages), import facilities and domestic production of natural gas, and the system capacities for transport and distribution of gas. The system is defined by fuel-balance equations and equations for technological conditions.
Area — Time	A time horizon of 5-15 years, separated into intervals of a year or more.
Area — Space	Gas production of the G.D.R.
Modelling Techniques	Linear programming model. The dynamic behavior in the mathematical static model is represented by the matrix with multiple defined lines and columns according to the time steps, and the objective function with discounted costs per interval of time for one unique point of time. The objective function is of the same form as for the optimization model for the coal industry (see p. 20).
Input Data	The variables of the model consist of the plants for gas supply and distribution and the consumer concentration density; the lines, of fuel-balance equations and equations for gas transport and distribution and technological conditions. Required information: <u>Technological</u> -Fuel input, -Output of gas and coupled products, -Coefficients for transport and distribution, -Coefficients for adaptation of gas at the consumer's location. <u>Economic</u> -Cost of investment (for plants under construction and new plants), -Wages, -Material and other costs, -Costs for floating capital supply (for plants under construction and new plants), -Costs for the import of fuel, -Planned lifetime of new scheduled plants. <u>Other</u>: Limitations in capacity; gas demand as a function of consumer concentration density and load stage.
Output Data	The model provides the optimum structure of production plants by determining size and utilization of installed and planned capacity, production per day and per year, amount of coupled products produced, demand for fuel input, and cross-section results for gas production and consumer concentration densities.
Observations	The model's mathematical character is static, but it can be used for dynamic calculations in time intervals according to the objective function and the matrix. If the model is used as a submodel of a larger system of the energy economy the coefficients of the objective function should not include fuel costs.

Summary supplied (in German) by the author of the model.

G.D.R.

The Model	Energy Economy of the G.D.R. - Coal Industry Production and Supply Optimization.
Subject and Goal	Optimum structure of production and supply relations as a function of production facilities and regional demand, embedding costs (production, conversion and distribution of raw lignite).
System Described	The model includes open cast mines operating or being prepared for production, resource areas, briquette plants, electric power plants of the coal industry and lignite coke oven plants. It is limited to large-scale consumers. The interdependencies of consumers and plants producing and converting coal are represented by the fuel-balance equations.
Area — Time	A time horizon of 5-20 years, separated into intervals of a year or more.
Area — Space	Coal industry of the G.D.R.
Modelling Techniques	Linear programming model. The dynamic behavior in the mathematical static model is represented in the matrix, with multiple defined lines and columns according to the time steps; and the objective function, with discounted costs per time interval for one unique point of time. The objective function is an equation which minimizes economic costs in the form of: $$aw = I \cdot q^n \cdot \frac{q-1}{q^n-1} + U(q-1) + l \cdot q_k + m$$ with aw = average cost per year, I = cost of investment, U = supply of floating capital, l = wages, m = material and other costs (except wages and depreciation), q = accumulation factor, q_k = consumption factor.
Input Data	The variables (columns) of the model consist of open cast mines or resource areas, briquette plants, industry power plants, lignite coke oven plants, defined large-scale coal consumers and consumer concentration densities with their potential supply relations; the lines, of equations for fuel balance, technological conditions, and meeting energy demand. Required information: Technological -Fuel input, -Output, -Coefficients representing the balance of production and consumption. Economic -Cost of investment (for plants under construction and new plants), -Wages, -Material and other costs, -Costs for floating capital supply (for plants under construction and new plants), -Costs for the import of fuels, -Costs for the transport of raw lignite from the mine to the consumer, -Planned lifetime of scheduled plants. Other: Limitations in capacity for different plants, and demand of large-scale and regionally concentrated consumers for coal, both in absolute figures.
Output Data	The calculation of the model provides: the optimum load factor of existing production capacities according to given regional demand; available production capacity not required for meeting the demand according to the demand structure; economically feasible preparation or opening of new production capacities; calculation of optimum supply relations between producer and consumer; load cycle of industry power plants according to the optimal structure; and economic costs of different supply structures.
Observations	The model's mathematical character is static but it can be used for dynamic calculations in time intervals according to the objective function and the matrix. The costs for producing and converting coal should be counted once only, generally at the mine site. If the model is used as a submodel of a larger system of the energy economy, the coefficients of the objective function should not include fuel costs from other sectors.

Summary supplied (in German) by the author of the model.

G.D.R.

The Model	Erdölarbeitungsindustrie, Schwedt, 1973. Energy Economy of the G.D.R. - Optimization of Oil Industry.
Subject and Goal	Calculation of the optimum structure of oil processing with respect to the siting of other energy supply plants (steam, electric energy, hydrogen, synthetic gas, etc.), for processing of fuel from oil and lignite tar.
System Described	The model includes all oil plants and processing plants (industrial power, synthetic gas, etc.) by process, technology and load cycle. The interdependencies are given by fuel-balance equations. The system limits are the given demand for liquid fuels, non-energetic demand, amount of imported oil and natural gas, and amount of lignite tar supplied.
Area — Time	A time horizon of 5-15 years, separated into intervals of a year or more.
Area — Space	Oil industry of the G.D.R.
Modelling Techniques	Linear programming model. The dynamic behavior in the mathematical static model is represented by: -The matrix with multiple defined lines and columns according to the time steps, -The objective function with discounted costs per time interval for one unique point of time. The objective function is of the same form as for the optimization model for the coal industry (see p. 20).
Input Data	The variables (columns) consist of the oil and processing plants, by process, technology and load cycle; the industrial power plants and production plants for hydrogen, synthetic gas and other fuels. The lines consist of fuels (including certain by-products) and conditions for the technological interdependicies of the plants. Required information (in absolute figures): Technological -Fuel input (including by-products), -Fuel output (including by-products), -Coefficients representing technological interdependencies of different plants. Economic -Cost of investment (for plants under construction and new plants), -Wages, -Material and other costs, -Costs for floating capital supply (for plants under construction and new plants), -Costs for import of fuels, -Planned lifetime of scheduled plants. Other -Demand for liquid fuels, -Non-energetic demand, -Demand for synthetic gas for ammonia and methanol synthesis.
Output Data	-Optimum structure of the oil processing industry, -Optimum structure of synthetic gas production, -Optimum structure of liquid fuels in accordance with the interdependencies, -Optimized structure of other energy conversion plants, -Optimized demand for oil, natural gas and fuels supplied by other sectors, -Economic costs of optimum supply structure.
Observations	The model's mathematical character is static, but it can be used for dynamic calculations in time intervals according to the objective function and the matrix. If the model is used as a submodel of a larger system of the energy economy, the coefficients of the objective function should not include fuel costs.

Summary provided (in German) by the author of the model

G.D.R.

The Model	Ogreb-Institut für Kraftwerke, Vetschau, 1973[7]. Energy Economy of the G.D.R. - Short-Term Electric Power Management.
Subject and Goal	Within the planning of long-term development patterns of the "Uniform Electro Energy System" (EES), the model aims at determining and analysing power plant operation. Given different EES structures and technological, regional and sociological constraints, the following information should be generated with reference to the unregulated load curve of electric energy demand: development of operation procedure of all power plant types as a function of load duration, regulation requirement and interruption management; technological and economic requirements of new plant types; determination of percentage of electricity generated by single power plants relative to that generated in the entire system, as a function of economic criteria; required fuel demand.
System Described	The model includes the complete system of electric energy generation--i.e. conventional thermal, nuclear, heating, industry and peak load power plants, divided into groups classified by different characteristics (electricity transmission is excluded.)
Area — Time	Characteristic load cycles of electric energy demand per week (reference period: average load cycles Thursday 8 p.m. - Monday 11 p.m., load charge per hour). One year is represented using 12 characteristic load cycles/week.
Area — Space	Electricity generation in the G.D.R.
Modelling Techniques	The discrete and integer optimization problem for calculating an optimum plant configuration at discrete time periods is solved by "heuristic" program using the "branch and bound" method. The variables to be calculated are the intermission capacity as given by technology, and the numbers of units in overhaul. The constraints are: maximum number of units which may be in overhaul, and minimum number which must be in operation per power plant, and the electric capacity balance. Pump storage plant operation is optimized applying the gradient method of non-linear optimization. The constraints are the limitations of machine capacity (turbine or pump storage). The objective function minimizes fuel costs per hour within a given period using the cost increment method.
Input Data	<u>Technological</u> -Unregulated load curve of electricity demand according to cycles/week (100 figures per hour) for the characteristic yearly time periods and the number of balance days (separated into weekday, Friday, Saturday, Sunday, Monday), -Technological and regional constraints of power plants, -Out-of-action sequence of power plants, -Available capacity for the characteristic time periods, -Characteristics of the calorific value of fuels, -Technological data of pump storage plants (efficiency, turbine/pump ratio, capacity of basins). <u>Economic</u>: Cost of different fuel types.
Output Data	<u>Technological</u> -Out-of-action strategy of the system, -Per-hour installed capacity of power plants, -Electric energy supply at any given time and place, -Load charge per hour of power plants during different time periods, -Fuel demand of power plants as function of amount, type and time. <u>Economic</u>: Fuel cost of EES and of power plants (separated due to time sequence).
Observations	The information and program area of the system comprises 4 relatively autonomous parts: calculation of the available capacity per time unit; optimization of operation mode of pump storage plants in connection with the optimum out-of-action and reserve strategy of power plants; optimization of operation mode according to the fuel cost increment method; balancing and output programs for different objects.

Summary provided (in German) by the author of the model.

G.D.R.

The Model		Ingenieurburebau für Rationalisierung in der Braunkohleindustrie, Grossräschen, 1971(8). Energy Economy of the G.D.R. - Simulation of Rail-Operated Extraction in Lignite Open Mines.
Subject and Goal		The model describes the complicated operating procedures of a rail-operated lignite open mine and may be used for planning problems and analysis of projects. It provides information (e.g. on use of machinery and rails, bottle-necks and critical points in the railway system) needed for efficient management of open mining.
System Described		A lignite open mine is separated into the extraction and tipping and the transportation area. The former includes dredges and tip machines; the latter comprises the whole movable rail system.
Area	Time	A period ranging from 3 months to a year; can also be used for medium- or long-term planning.
	Space	Any lignite open mine.
Modelling Techniques		Simulation model, the mine operation procedures per unit time are simulated by means of stochastic distribution.
Input Data		-Data on stops (dimension in space, shape of stop), -Information on dredges and tip machines (machine condition, distribution curves of operation and overhaul periods, percentage of total production), -Data on trains (load conditions, transport time and distance, -Information on the rail system (waggon type, stochastic distribution of time and distance over the network).
Output Data		-Coefficients of machinery, -Operation and overhaul periods, -Waiting time, -Number of trains loaded and unloaded, -Information on operation procedure of machinery.
Observations		The advantage of the model is the short simulation time, compared with other simulation models which may be used for only a single open mine.

Summary provided (in German) by the author of the model.

G.D.R.

The Model	Staatliches Unternehmen der Elektroenergieversorgung, Berlin, 1973[9]. Energy Economy of the G.D.R. - Siting of Nuclear Power Stations.
Subject and Goal	Determining the optimum siting of nuclear power stations.
System Described	The model includes existing power stations, scheduled conventional and nuclear power stations, existing and scheduled transformation stations and transmission lines of the national network. The network is represented by a system of knots and junction lines. The generation and transformation capacities and the demand are attached to the knots and the transmission lines to the junction lines. The important technological and economic conditions of the network system and region are included.
Area — Time	A time horizon of 15-20 years, separated into intervals of a year or more.
Area — Space	The electricity supply system of a nation's total area, separated into partial areas.
Modelling Techniques	The model is a multi-period optimization system based upon mixed integer (zero-one) optimization (a special form of linear optimization). The degree of aggregation is limited by the algorithm of resolution and computer capacity computation equipment used.
Input Data	The variables (columns) of the model are: -Nuclear power capacity to be built per site, -Transformation capacity to be managed per site, -Transmission capacity to be built between knots, -Capacity demand of knots, -Capacity demand of transmission lines. The constraints (lines) are related to energy balance conditions and to siting possibilities. Required information: Technological -Electric capacity demand, per region and time, -Conventional electric power capacity available, per region and time, -Technological coefficients of transformation and transmission equipment, -Limitations in nuclear power capacity per site with respect to environmental conditions (population, cooling water, emission concentration, etc.) Economic -Specific costs of investment (for plants under construction and new plants), -Specific wages, -Specific material and other costs (except fuel costs), -Specific costs of floating capital supply (for plants under construction and new plants), -Planned lifetime of scheduled plants. Other -Load capacity limits of existing or scheduled transformation and transmission equipment, -Increase of nuclear power capacity during planning period per interval of time.
Observations	The siting model provides the optimum results for: -The sites of nuclear power plants and transformation stations as well as the transmission lines, -The optimum capacity of nuclear power and transformation stations to be built per site and the number of transmission lines between regions, -The capacity load factor of all regional structured supply systems as a function of time.

Summary provided (in German) by the author of the model.

GREECE

The Model		C. Delis, Public Power Corporation, Athens, 1973. Short-Term Forecasting Models for Electricity.
Subject and Goal		Estimating the electricity demand of the coming months.
System Described		Model I : Trend model with auto-correlated random variables for forecasting electricity production in the next 1-12 months. Model II: Two-random-variables model for forecasting household electricity consumption in the next 1-12 months.
Area	Time	1-12 months.
	Space	Greece as a whole.
Modelling Techniques		The formal statement of the models is as follows: Model I : $x_{(t)} = y_{(t)} + (u)_{(t)}$ $y_{(t)} = y_{(t\hat{-}1)} + m_r$ $u_{(t)} = u_{(t+1)} + e_t$ The electricity demand at time t consists of one systematic component $y_{(t)}$ and one random component $u_{(t)}$. The variation of the former from period to period is due to the influence of trend and seasonal factors. The random component $u_{(t)}$ follows a Markov process of order 1 (auto-regressive process). p = auto-correlation coefficient of the process $e_{(t)}$ = normal random variable. Parameters $m_1, m_2, \ldots, m_{12}$ and y_o are estimated by the least-squares method after transformation to take account of the fact that the $u_{(t)}$ are not independent. Model II: $x_{(t)} = y_{(t)} + u_{(t)}$ $y_{(t)} = y_{(t-1)} + m_r + v_{(t)}$ The $u_{(t)}$ and $v_{(t)}$ follow the normal distribution of zero-average and standard deviation σ_u and σ_v respectively; estimation by Maximum Likelihood Method.
Input Data		Time series data concerning, for Model I, monthly electricity production, and for Model II monthly household electricity consumption.
Output Data		Seasonal variation coefficients.

Summary supplied by the author of the model.

GREECE

The Model	C. Delis, Public Power Corporation, Athens, 1975. Public Power Corporation Financing Model.
Subject and Goal	The model supplies the corporation's cash flow for the next decade and indicates the financial results of changes in investment, prices, taxes, etc.
System Described	The flows of revenues and expenditures as well as the capital requirements and the sources of financing.
Area — Time	1975-1980
Area — Space	The corporation as a whole.
Modelling Techniques	Simulation model using econometric equations for the projection of various items (sales, etc.).
Input Data	-Rage of growth of the gross national product, -Rate of growth of the index of industrial production, -Rate of growth of household consumption expenditure, -Index of salaries and wages, -Fuel prices, -Income and price elasticities, -Investments by category, -Rate of growth of production, -Fuel consumption in tons, -Calorific value of fuels, -Fixed assets at the beginning of the first year and depreciation coefficients by category, -Expected evolution of basic prices of electricity, -Upper limits of certain categories of loans, -Rate of interest and duration of loans, -Balance sheet and income statement, -Items in the basic year.
Output Data	Physical: Volume of sales, number of employees. Economic: Cash flow; evolution of sales prices; financial equilibrium.
Observations	The choice of generating units, of the date of commission and of the operation of the system is based on other models, the outputs of which are used as inputs for the model in question.

Summary supplied by the author of the model.

GREECE

The Model		A. Samaras and C. Stelakatos, Public Power Corporation, Athens, 1975. ENAL: Generation Simulation Model.
Subject and Goal		Simulating the generation of thermal and hydroelectric units in relation to demand.
System Described		This model defines the energy production, maintenance reserve, and fuel consumption of each unit for each month.
Area	Time	For medium- and long-term planning.
	Space	Greece; up to 150 thermal and hydro units and up to 30 fuels.
Modelling Techniques		Allocation of thermal units into monthly load duration curves according to their cost or a given loading order. A version of this program uses the Booth method to allocate the thermal units.
Input Data		-Form of load duration curves, -Available quantities of fuels (if restricted), -Characteristics of each unit and date of its commissioning, -Energy and demand (MW) for every year.
Output Data		Monthly and annual load duration curves, maintenance for each unit, energy produced by each unit, rotating and static reserve and fuel quantities.

Summary supplied by the authors of the model.

ISRAEL

The Model	J. Vardi, Ministry of Development, Tel Aviv, 1973 (10). Optimal Planning of Electrical Energy Generation Systems.
Subject and Goal	Optimal Investment planning to determine: -Types of generating facilities to be installed in the electricity system at each point in time, -Optimal size of units of each type at each point in time, -Optimal reserve required by the system, -Optimal geographic location for power plants from the point of view of equilibrium of the system and of ecology, -Optimal timing of introducing each unit. The model should also be capable of evaluating the impact of changes.
System Described	The Israeli electricity supply system. Nuclear power plant possibilities are also considered. In the short term, the problem is one of resource allocation; in the long term, one of minimizing the overall cost of investment and operation.
Area — Time	Short and medium term (less than 10 years), and long term.
Area — Space	Israel as a whole.
Modelling Techniques	A simulation model (SM) was built for the short and medium term, and a linear programming (LPM) one for the long term. The former computes, for any given type and capacity of power plant and any given reserve capacity, the associated distribution of costs and shortages. The LPM minimizes the total discounted costs of investments and operation. Constraints are: -Output from each plant is equal to or less than available capacity, -Electricity demand must be satisfied at all points in time, -The total installed capacity is greater than the peak demand by some safety margin at all times. The two models are linked through the load duration curve.
Input Data	SM : Description of each power plant, weekly power demand, dates of initial operation of each plant. LPM: Discounted investment plus the sum of the fixed costs to be incurred per megawatt of capacity; discounted costs associated with every operating unit; load duration curve.
Output Data	SM : The weekly program schedules: -power supply, distribution of shortages, -accumulated costs, -load duration curve of demand. LPM: Determines the generating capacity of each type to be added to the system and the optimal utilization at each time period.

Summary not reviewed by the author of the model.

ITALY

The Model		P.L. Noferi et al., Ente Nazionale per l'Energia Elettrica, Milan, 1971-1972[13,14]. SICRET: Electrical System Network Planning.
Subject and Goal		The model estimates the reliability of a large high-voltage network in order to investigate possible new investment in power plants or lines.
System Described		Electrical system (generation and transmission).
Area	Time	One year.
	Space	Italy as a whole (no more than approximately 100 nodes).
Modelling Techniques		The Monte Carlo method is used to simulate system behavior for one year, with special regard to the probabilistically defined load demand and outrage of lines, transformers and generators. Hourly dispatching is computed so as to minimize energy curtailments; the energy that cannot be supplied due to overloaded lines or insufficient generation is evaluated; the energy not supplied is then summed up for all the hours in the year.
Input Data		Each line or transformer is characterized by its probability of failure and its capacity, i.e. a limit on its transfer capability. Each generating plant is linked to a node and influences security through its rate of failure. The load demand is given for each node.
Output Data		As a final result of the computations the amount of energy curtailment for the whole system and for each node is determined. New investments are then deduced.
Observations		The model is a basic facility for electrical system planning studies.

Summary supplied by the authors of the model.

ITALY

The Model	L. Paris and M. Valtorta; G. Manzoni et al., Ente Nazionale per l'Energia Elettrica, Milan, 1968-1972[11,12]. Electrical System Generation Planning.
Subject and Goal	The model evaluates the long-term expansion of an electric power generation system, including hydro, thermal and peak (gas turbine and pumped-storage) units. It answers mainly the question what size and type of units are to be installed and when, in order to reach one of the following goals: -To keep available generation reserve above a given level; to reduce below a certain value the risk of not having enough generation to meet demand; -To minimize the weighted sum of capital and risk costs for each year.
System Described	The power system is described as a "busbar" to which all generating units and loads are connected; units are classified by type (hydro, thermal, run-of-river, pumped storage, gas turbine) and characteristics (size and availability index). It is assumed that all hydro plants are supplied by the same reservoir, the inflow to which depends on the "hydrological year". Annual peak load is given, with the associated indices for deriving monthly and daily peak loads and the load-duration curve of working and weekend days.
Area — Time	A period of 20 years.
Area — Space	Electric power generation systems comparable in size and complexity with the ENEL (Ente Nazionale Energia Elettrica) system in Italy.
Modelling Techniques	A detailed simulation is made of the generation system during expansion, in which the installation of new units is planned at the beginning of each year and the operation is such, within each year, as to minimize costs and risk indices week by week. The program includes computation of risk indices using probabilistic procedures to account for unit availability, water inflows, random load fluctuations and reservoir operation policy. Other parts are devoted to maintenance scheduling and rotating reserve evaluation.
Input Data	-Yearly peak loads for all the years to be studied; -Uncertainty in load forecast, defined by a standard deviation value; -Weekly load duration curves per unit of annual peak load; -List of generating units in existence at the beginning of the study, and ordered sequence of units to be installed; -Characteristics of each type of generating unit (size, technical and economic performance, installation costs, availability); -Reservoir characteristics (dimension, water inflow, etc.).
Output Data	-For each year, costs of investment, fuel, maintenance and risk; -Yearly list of new units to be installed.
Observations	This model yields an overall generation plan, without reference to sites.

Summary supplied by the authors of the model.

NETHERLANDS

The Model		J.W. Brinck, International Resources Consultants B.V., Alkmaar, 1975. Uranium Resources Assessment with MIMIC.
Subject and Goal		Regional estimate of specific types of mineral resources and development of reserve based on economic variables.
System Described		Regional probability distribution of mineral concentration based on assumption of special frequency. Description of economic environment of mineral discovery and exploitation.
Area	Time	Not specified.
	Space	Unspecified - regional to global.
Modelling Techniques		Mix of probability distribution assumption on mineral concentration and economic analysis of cost of recovery, related to market prices.
Input Data		Empirical estimations of mineral concentration parameters. Cost of exploration and production as a function of size, grade, specification of mineral resources.
Output Data		Probabilistic distribution of deposit size and grade. Metal price as a function of concentration.
Observations		The description of the model is not sufficiently detailed to give a clear idea of the modelling technique used.

Summary not reviewed by the author of the model.

NETHERLANDS

The Model	Peter R. Odell and K.E. Rosing, Erasmus University, Rotterdam, 1975 [15] Simulation of Oil Extraction.
Subject and Goal	Estimation of time stream of oil production for the North Sea.
System Described	Oil discovery and production in the North Sea.
Area — Time	Present up to 2030.
Area — Space	North Sea area.
Modelling Techniques	Simulation model which assumes rate of drilling and discovery as an input variable. Extensive sensitivity analysis to obtain the required input variables.
Input Data	The number of wells drilled per year for the first 20 years is assumed to be known. The probability of success with each well for each year is also an input, as is the probability of finding different-sized reservoirs.
Output Data	Probabilistic time stream forecast of oil production.
Observations	This study is more an analysis of sensitivity to different parameters than a model.

Summary not reviewed by the authors of the model.

PORTUGAL

The Model	A. Leite Garcia et al., Companhia Portuguesa de Electricidade, Lisbon, 1974[16]. Simulation of the Hydro and Thermal Electricity Production System: VALOR AGUA.
Subject and Goal	To set up a data bank for analysis of combined technologies for localization of production units and for price setting; to manage the hydroelectricity resources; to allocate means during peak periods.
System Described	Production and transport of electricity in Portugal, divided into two parts: -The electricity supply network with 21 knots, 6 consumption centers, and 8 types of thermal plants, -The hydroelectricity network with 28 knots, 21 hydrological reservoirs, 21 electric plants and 8 pumping stations.
Area — Time	Short term (month divided into 100 periods) and long term (time not specified).
Area — Space	Portugal as a whole.
Modelling Techniques	For the short term, the objective function is the monthly operating expenditures. Given a set of hypotheses on water stock levels, initial conditions are assigned to the parameters. The optimum is obtained by applying the Kuhn and Tucker theorem. For the long term, dynamic programming. The objective function is the mathematical mean of discounted operating costs over the time frame.
Input Data	Technical characteristics of all thermal and hydro plants; electrical and hydro networks; consumption (in the form of load curves); hydrologic conditions and marginal cost of each thermal plant.
Output Data	-Marginal value curves of the water stock in the set of reservoirs. -Load curve of thermal electricity production with respect to variable costs. -Thermal or hydroelectric production, pumping and consumption. -Payoff of each plant type.
Observations	VALOR AGUA consists of four sub-models related to specific goals, e.g. management of water reservoirs.

Summary supplied (in French) by the authors of the model.

PORTUGAL

The Model	Companhia Portuguesa de Electricidade, Lisbon, 1973. EVOFI: Economic-Financial Equilibrium of the Companhia Portuguesa de Electricidade.
Subject and Goal	Analysis of alternative financial policies for an electric public utility by simulation of the long-term economic and financial evolution of the company. Parametric variation of the ratios defining alternative policies allows the identification of areas of consistency between short-term and long-term objectives.
System Described	The model uses the estimation of reserves as a function of the dominant constraints and fixes the amount of indebtedness for financing policy. Explicit assumptions are made regarding the evolution of the general and specific price index.
Area — Time	Up to 20 years.
Area — Space	Portugal as a whole.
Modelling Techniques	Linear programming. The model is designed both to study the feasibility of a fixed price and to determine the price level implicit in certain contractual provisions, expressed in terms of a minimum rate of return on net capital or minimum operating surplus (as a function of the finance required for investment). The financial policies are divided into two categories, constrained to either short-term equilibrium (depreciation and transfer of reserves up to a given proportion of indebtedness) or long term-equilibrium, expressed as a maximum ratio of loans to social capital (and reserves).
Input Data	-Demand: time series of electricity sales to distribution networks and special consumers at base-year prices. -Investment program: investment in buildings, equipment and other assets at base-year prices; rate of commissioning of plants under construction; coefficients specific for each type of asset. -Expenditures on current account (base-year prices): fuel; purchases of electricity; wages,salaries and other current expenditures (base-year value and average annual rate of growth). -Balance sheet, operating account and flow of funds for the base year. -Assumed time series for general price index and relative prices for items 1, 2, 3 above. -Stock and financial market parameters: average rate of interest on loans; average share yields (including related taxes); ratio of amortization to outstanding debt. -Range of variation of financial policy parameters and contractual provisions, including depreciation coefficients.
Output Data	-Tables with specification of parametric variation of financial policies and contractual provisions studied. -Tables with annual operating accounts, balance sheets and flow-of-funds summaries supplemented by rates of change of the main items, financial ratios and structure of some aggregates (net assets, liabilities, financing of investment). -Graphical illustration and comparison of sets of alternative policies and contractual provisions: average price of electricity, operating net surplus of statutory capital income, rate of return on net assets, financial structure and financing of investment.
Observations	Some of the exogenous variables are the output of forecasting models ("sales of electricity" and "wages, salaries and other current expenditures") or optimization simulation models ("fuel changes"; see model VALOR AGUA, p. 33).

Summary supplied by the authors of the model.

SWEDEN

The Model	Göran Bergendahl, University of Gothenburg, 1974-1975[17]. Electricity Production, Pricing and Investment.
Subject and Goal	To determine the Swedish electric power system such as to meet demand for either lowest cost or highest social surplus. The model gives only a simplified projection of the electric power system. It allows for the effect of preparing nuclear power plants.
System Described	As investments are scheduled up to 1976, the 1st year will be 1977; it is assumed that investments are introduced each 5th year only. Average demand is assumed constant in the 5-year periods. The investment schedule for hydro-power plants is given. The other plant types are: nuclear power plants, base-load fossil plants, peak-load fossil plants, gas turbines. The demand flexibility is given by a piecewise linear approximation of the value of consumer advantages, defining the benefits as a function of demand. The load duration curve is reduced to fixed demand in 5 time segments.
Area — Time	The years of interest are 1977, 1982, 1987, etc.
Area — Space	The electricity power system of Sweden.
Modelling Techniques	Using LP the model finds the solution minimizing the total discounted costs over the 3 periods for a given demand. Six kinds of constraints constitute the set of feasible solutions for investment, capacity and electricity supply. The costs to be minimized are those of: -Producing 1 unit of energy (kWh) (per plant type, time segment and time period); -Operating (and maintaining) 1 unit of power (kW) (per plant during 1 time period); -Investment in 1 unit of power (kW) for 1 plant type to be available at the beginning of the time period. The constraints that must be satisfied are: -Demand, less than the production at all power plants, per time segment; -Production per time segment less than the total amount of available capacity (product of maximum number of hours of operation and capacity by time segment); -Product of reserve capacity factor (policy parameter) and the production in all power plants per time segment less than total amount of available capacity; -Restrictions which guarantee an even production rate for nuclear and base-load fossil-fueled plants only; -Total annual amount of energy produced at hydro-plants less than the upper bound of hydroproduction; -Production in kWh during the summer interval greater than the minimum production caused by non-variable water power; -Restrictions on nuclear expansion; -Restrictions on growth of demand.
Input Data	Power production as scheduled for 1977; given investment schedule for hydro-plants; estimated demand per time segment or the consumers' values (per kWh) of changing consumption from the projected demand; availability of production per time segment and plant type; minimum hydro-production for summer-time segments and for the different time periods; cost of production, operation and investment in different types of plant.
Output Data	Nameplate capacities in MW for different plants and time periods (investment is simply the difference between capacities in each year); energy production (in TWh) for each time segment of a year and each time period for the 5 plant types; capacity utilization in percentage of available capacity during each time segment; wholesale prices for each time segment set to marginal costs of producing 1 additional unit of energy (given as Sw. Crs./kWh).
Observations	The model takes no account of size and location problems of each plant. The demand flexibility is determined only by the price, but it allows for studying the effect of nuclear investment constraints and demand rationing on price discrimination.

Summary supplied by the author of the model.

U.S.A.

The Model	F.G. Adams, University of Pennsylvania, Philadelphia, Penn., and J.M. Griffin, University of Houston, Houston, Texas, 1972[46]. Economic LP Model of the U.S. Petroleum Refining Industry.
Subject and Goal	To simulate and forecast U.S. petroleum refining activities. The main characteristic of the model is that it links statistically estimated behavior equations with an engineering LP model. It intends to provide a medium-term perspective over the business cycle and serve as a framework for long-term policies. It can also be used as a tool for simulation studies under alternative assumptions about economic policies.
System Described	The U.S. petroleum refining industry on an aggregated scale. The structural specifications are: -domestic product demands of crude oil, asphalt, distillation kerosene and lubricants, -inventory adjustments within a year, -imports and exports of products, -supply determination, -price determination.
Area — Time	The sampling period was 1955-1968 and projections were obtained for 1970 up to 1975.
Area — Space	U.S. as a whole.
Modelling Techniques	Both econometric techniques and LP were used, the former to specify behavioral equations of products demands, product price, technical adjustment. The ordinary least-squares method has been applied to the data. The structure of the model is as follows: The Wharton Long Term Industry Model of the U.S. Economy (Preston and Ross, University of Pennsylvania; in press) determines the economic setting in which the petroleum model operates. Given the stocks of petroleum-consuming equipment, economic activity determines product demands. A simple inventory adjustment to normal levels is assumed. Imports and exports of products are exogenous. Given product demand inventory adjustments and net imports, the requirements for the major petroleum products are determined, and become endogenous constraints in the linear programming. Other inputs are the capacities of various types of refining equipment available and crude oil prices, both of which are treated as exogenous. Crude oil supplies are assumed to be adjusted to satisfy refining needs. Constraints in the LP model include product quality specifications, process capacities, and product output requirements. The objective function is then set to minimize the cost of producing these outputs. The LP solution determines the volume of crude oil inputs required, the capacity utilization measures, total operating costs, and the outputs of byproducts, e.g., residual fuel oil. Then products prices are determined on the basis of a markup over crude cost, utilization of capacity, inventory levels, and a general inflation measure. By subtracting operating costs as calculated by the LP from a measure of gross revenue, an estimate of net operating revenue is obtained.
Input Data	-List of prices, -Ratio of domestically produced cars, -Total highway mileage, -Commercial fleet of aircraft, -Heating needs per day, -Stock of oil burners, -GNP and value added in manufacturing and mining, -Load factor, -Technical coefficients of production, -Import and exports (exogenous).
Output Data	-Domestic demands of gasoline, kerosene, distillate, lubricants, asphalts, -Refinery inputs and outputs of crude oil, gasoline, kerosene, distillate, lubricants, asphalt, petrochemical feedstocks, aviation gasoline, military jet fuel, -Byproduct outputs of residual fuel, still gas, coke, -Prices of most fuels listed above, -Revenue and costs for petroleum refining industry).
Observations	Sample period simulation gave rise to mean absolute errors less than 2.5% for output products and 5% for prices.

Summary not reviewed by the author of the model.

U.S.A.

The Model		Robert E. Brooks, Massachusetts Institute of Technology, Cambridge, Mass., 1975 (50). GASNET - Production, Transmission, and Demand for Natural Gas.
Subject and Goal		To analyze the effects of FPC regulation in the natural gas industry by comparing results of alternative regulatory policies toward gas producers and pipelines as predicted by varying input policy parameters to GASNET.
System Described		The natural gas system of the U.S. with special emphasis on the interstate transmission network.
Area	Time	1966-1980.
	Space	U.S.A. as a whole.
Modelling Techniques		GASNET consists of a series of optimization models using quadratic programming, separable linear programming, and linearization techniques for programs with non-linear constraints. The models are basically network models with price-dependent supply and demand functions whose parameters are estimated econometrically. Each regulatory policy is modelled by a pricing mechanism (generally non-linear) which provides the link between wellhead and consumer prices within the program. The 40 largest interstate pipeline companies are represented in the model whose network submodel consists of about 300 nodes and 900 arcs. The entire model measures about 800 rows and 1500 columns as a linear program. A set of FORTRAN programs handle the input and output data manipulation. This model can be easily linked with the MacAvoy-Pindyck supply model or other supply models to provide a dynamic forecasting model of the U.S. natural gas system under alternative supply scenarios and FPC regulatory policies. Alternative demand formulations can also be used.
Input Data		Estimated coefficients for supply and demand equations; transmission variable costs; transmission capital costs; pipeline depreciation rates; pipeline losses; pipeline capacities; exogenous demand growth rate (for forecasts); production decline rate (or complete supply model); pipeline capital plant growth rate; pipeline capacity growth rate pipeline rate of return, and wellhead price ceilings on new contracts (policy variables for forecasts).
Output Data		The model determines optimal production levels, allocation patterns, prices, demands, and excess demands by minimizing a linear combination of excess demands and (negative) pipeline profits subject to rate of return constraints, mass balance constraints, and the supply and demand relations. The model operates by optimizing separately for each consecutive forecast year. Input data for year T may, however, be dependent on forecast results for year T-1.
Observations		Supply and demand functions can be general (invertible) functions of price and other exogenous variables. Regulatory pricing mechanisms are used in place of marginal cost pricing.

Summary supplied by the author of the model.

U.S.A.

The Model		DeVerle P. Harris, Pennsylvania State University, University Park, Penn., 1970 (18). Simulation of Natural Resource Estimation.
Subject and Goal		Statistical estimates of mineral wells and their spatial distribution in partially explored regions.
System Described		The total value of all economic resources in a given region is investigated.
Area	Time	No specific time.
	Space	Homogenous geological region.
Modelling Techniques		Multiple linear regression using a variety of geological variables (e.g. age and type of rock, degree of fracturing, etc.).
Input Data		Values of regional variables for the region considered, and data for an intensively explored calibration region. For a given region, data have to be disaggregated by quadrate.
Output Data		Estimation through regression of total mineral value on a quadrate basis.
Observations		The model includes a mix of economic and geological influences.

Summary not reviewed by the author of the model.

U.S.A.

The Model		DeVerle P. Harris, Pennsylvania State University, University Park, Penn., 1973. Subjective Probability Appraisal of Metal Endowment of Northern Sonora.
Subject and Goal		To find probabilistic estimates of total mineral deposits on a quadrate basis for partly explored regions.
System Described		Total value of all economic mineral resources for a given region.
Area	Time	Not specified.
	Space	Northern Sonora-Mexico; can be used for any region.
Modelling Techniques and Input Data		Direct subjective estimates given by geology experts were aggregated by the Delphi technique. The basic assumption was that probability of dis-discovery is affected by the amount of cover (glacial alluvial, etc.), type of terrain, size of deposit, and intensity of search. A questionnaire was designed in which three tonnage categories were defined: 1-5 million tons, 5-50 million tons, and 50 million tons or more. The explorationist then defined three types of terrain and three kinds of cover (one of them being no cover) for which costs and efficiency varied considerably. For each of the 27 conditions obtained, the explorationist specifies a probability of discovery for each of three levels of expenditure (low, expected, and high).
Output Data		Probabilistic estimate of mineral wells by quadrates.
Observations		-

Summary not reviewed by the author of the model.

U.S.A.

The Model J.D. Khazzoom, McGill University, Montreal, Quebec, 1974.

Econometric Model of Natural Gas Supply in the United States.

Subject and Goal To analyze exploration policy with respect to ceiling price of gas. The results for gas discoveries are reported for different assumed gas prices, because the drilling decision is induced by the price signal.

Area — Time 1970-1984.

Area — Space 21 U.S. districts.

Modelling Techniques The model is based on the following four time-lag econometric equations.

Two discovery equations:

Linear type

$$ND_t = \mu_o + \mu_1 \sum_{i=1}^{2} C_{t-i} + \mu_2 \sum_{i=1}^{2} P^o_{t-i} + \mu_3 \sum_{i=1}^{2} P^L_{t-i} + \mu_4 \sum_{i=1}^{2} ND_{t-i} + \omega_t$$

Quadratic type

$$ND_t = \mu'_o + \mu'_1 \sum_{i=1}^{2} C_{t-i} + \mu'_2 \left(\sum_{i=1}^{2} C_{t-i}\right)^2 + \mu'_3 \sum_{i=1}^{2} P^o_{t-i} + \mu'_4 \left(\sum_{i=1}^{2} P^o_{t-i}\right)^2$$

$$+ \mu'_5 \sum_{i=1}^{2} P^L_{t-i} + \mu'_6 \left(\sum_{i=1}^{2} P^L_{t-i}\right)^2 + \mu'_7 \sum_{i=1}^{2} ND_{t-i} + \omega'_t \; .$$

Two extension and revision equations:

Linear type

$$XR_t = \pi_o + \pi_1 C_t + \pi_2 P^o_t + \pi_3 P^L_t + \pi_4 ND_{t-1} + \pi_5 XR_{t-1} + \xi_t$$

Quadratic type

$$XR_t = \pi'_o + \pi'_1 C_t + \pi'_2 C^2_t + \pi'_3 P^o_t + \pi'_4 (P^o_t)^2 + \pi'_5 P^L_t + \pi'_6 (P^L_t)^2 + \pi'_7 ND_{t-1}$$

$$+ \pi'_8 XR_{t-1} + \xi'_t \; .$$

C_t = ceiling price of gas at time t,

P^o_t = price of oil at time t,

P^i_t = price of natural liquid gas at time t,

w_t, w^i_t, ξ_t, ξ^i_t statistical residues.

An abridged version of the first equation is used to estimate discovery response to gas price:

$$ND_t = \beta(C_{t-1} + C_{t-2}) + \delta(ND_{t-1} + ND_{t-2}) \; .$$

Input Data The parameters were estimated on 1961-1969 data. The main data are: C_t, P^o_t, P^i_t.

Output Data

- Estimated coefficients for the linear and quadratic equations for ND_t and XR_t,
- Simulation of the effect of a 1¢ increase in gas price or discovery cost.
- Determination of the appropriate level of ceiling price to stimulate discoveries to a point where the ratio of discoveries to production reaches x% at any given point in time.

Observations The model relies on the determination of the ceiling price. One should thus estimate the expected gas requirements for the nation as a whole. The author uses projections published by the Future Requirements Committee. His work on gas demand is in progress (see p. 54).

Summary not reviewed by the author of the model.

U.S.A.

The Model	M. King Hubbert, U.S. Senate, Washington, D.C., 1974. U.S. Energy Resources, a Review as of 1972.
Subject and Goal	To forecast fuel oil production in the U.S.A., the author tries to obtain a time stream function of oil production. His particular goal is to determine the present status of exploration and production.
System Described	U.S. oil fields as a whole (no breakdown into different areas).
Area — Time	Unspecified - asymptotic view.
Area — Space	U.S.A. as a whole.
Modelling Techniques	Time series extrapolation using logistic curves. Instead of using time series, the author modified the abscissae and substituted cumulative exploratory drilling for time.
Input Data	Past time series of proved reserves and production. Past time series of cumulative exploratory drilling.
Output Data	Time series extrapolations of production. Deterministic estimates of total resources (ultimate total resources).
Observations	This model is purely deterministic. It does not separate economic and geological variables.

Summary not reviewed by the author of the model.

U.S.A.

The Model		Decision Sciences Corporation, Jenkintown, Penn., 1971. Total Energy Resource Analysis (T.E.R.A.).
Subject and Goal		Designed to assist the American Gas Association in evaluating policy issues relative to the supply and demand of natural gas. In fact TERA is a set of models which investigate natural gas as well as other forms of energy in order to evaluate interactions and competitive aspects of energy supply, demand and prices.
System Described		TERA is broken down into 7 interacting sub-models: demand forecasting, energy market share, supply forecasting, price structure, regulation and prices, supply-demand interaction model, gas industry. The last is the most detailed, consisting of financial requirements, energy efficiency, pollution, peak demands and storage capacity. Extensive studies have been made to obtain an efficient dissaggregation into regions and sectors.
Area	Time	No horizon specified.
	Space	USA as a whole.
Modelling Techniques		Simulation models that combine econometric and structural considerations, designed in a comprehensive flexible structure so as to allow a wide variety of studies using different assumptions or scenarios.
Input Data		An important task for implementing TERA has been the building of a data bank that is continuously updated. Data are provided by federal census figures, and others are generated by the model itself.
Output Data		-Forecast of total energy demand nationally and regionally by consumer sector, -Allocation of energy demand by sector and fuel, -Supply of gas from all domestic sources, -Effect of price regulation.

Summary not reviewed by the authors of the model.

FRANCE-U.S.A.

The Model		M. Allais, Ecole Nationale Supérieure des Mines, Paris, 1957; Gordon M. Kaufman et al., Massachusetts Institute of Technology, Cambridge, Mass., 1971-1975 (28,29,30). Three Stochastic Models for Fuel Oil Reserve Estimation.
Subject and Goal		In all three approaches, to estimate the probability of mineral resources for a given region. The ultimate aim is to formulate a probability density function of resources.
System Described		All three models are related to homogeneous geologic regions or to an oil field play (geographical collection of petroleum reservoirs situated in the same geological structure).
Area	Time	Not specified.
	Space	Any mineral field; in Allais, the Sahara as whole, and in Kaufman and Bradley, an area 100 x 100 km.
Modelling Techniques		Statistical influence based on sampling theory. Parametric influences with an assumed probabilistic model.
Input Data		The basic assumption is the volume distribution of minerals. The log-normal law is generally adopted; the Kaufman approach needs in addition, the time sequence of discovery.
Output Data		The main output data are: -The probability density function of total resources within the region, -The probability function of the size of the body.
Observations		All models assumed a log normality of size distribution. Allais and Kaufman and Bradley assume a probability function of spatial distribution. Kaufman uses a Bayesian approach allowing inclusion of subjective probabilities. All three models are purely geological: no economic information is included.

Summary not reviewed by the authors of the model.

YUGOSLAVIA

The Model	H. Požar and J. Keglević, University of Zagreb, 1973[19]. Utilization of Storage Basins of Hydro Power Plants.
Subject and Goal	Optimal filling and emptying of the storage basins of hydro power plants; achieving minimal cost of fuel in thermal power plants and penalty cost for load loss during a year.
System Described	The cost of fuel in thermal power plants and the penalty cost for load loss approximate monotonously the rising curve related to the total power committed. Storage basins are treated separately, each with its average monthly (ten-day, weekly) inflow for a past multi-year period. Demands are given in monthly (ten-day, weekly) load curves. Demand is considered as satisfied if all characteristics of the load curve are satisfied.
Area — Time	One year.
Area — Space	Applicable to treatment of the storage hydro power plants of a whole country.
Modelling Techniques	The gradient method of progressive approach has been used. The hydrologic period considered is divided into intervals. The cost gradients within such a period are equalized by the iterative process, paying attention to connection of the intervals (i.e. the appearance and disappearance of the limit states in the storage basin). At the end of the iterative process the optimal state in each storage basin is obtained for the entire hydrologic period considered. The correlative connections that can be used for practical determination of the emptying and filling of the storage basin can then be established.
Input Data	Physical -Demands: Monthly (ten-day, weekly) maximal load, total energy and "constant" energy. -Hydro power plants: Installed power, degree of utilization, size of storage basin, the fall, average monthly (ten-day, weekly) water discharge through the turbine for a multi-year hydrologic period. -Thermal power plants: Input power, load factor. Economic: Cost of fuel in thermal power plants dependent on the installed power; penalty cost for load loss.
Output Data	Physical: Regulated water discharge through the turbine of each storage hydro power plant, dependent on the inflow; quantity of water in the storage basin and necessary output of thermal energy in the electroenergetic system; possible output in hydro power plants at optimal utilization of storage basins. Economic: Cost of fuel and penalty cost for load loss.

Summary supplied by the authors of the model.

YUGOSLAVIA

The Model	H. Požar et al., University of Zagreb, Zagreb, 1972-1973[20,21]. Electricity System.
Subject and Goal	Structure and utilization of the thermoenergetic system related to foreseen consumption and to the hydro power plant system. Different ways of construction and utilization of that system can be compared on the basis of fuel cost and penalty cost for load loss.
System Described	The electroenergetic system is modelled with: -Maximal and constant power consumption; -Maximal power and energy output of hydro power plants; -Availability and total and constant output of each thermal power plant or single unit.
Area — Time	One year.
Area — Space	A given region of any size.
Modelling Techniques	Simulation on technique. The demand for power and output of the thermal plant for each month of a period of 30-40 years is determined from the estimated consumption and the maximal power and energy output of the hydro power plant.
Input Data	Physical -Consumption for each month of the year; -Amounts related to possible output of hydro power plants for each month and each year; -Existing thermal power plants and characteristics of new thermal power plants; -Constant consumers; -Necessary rotating reserve from thermal and hydro power plants. Economic -Fuel costs in a single thermal power plant; -Penalty costs for load loss per unit of consumption by group of consumer.
Output Data	Physical -Total and constant output of thermal power plants; -Outages and unutilized power of hydro power plants; -Reduction of power, energy and constant energy; -Rotating reserve of the system; -Total power of units in periodic overhaul; -Output of each thermal power plant; -Optimal timing of periodic overhaul for each power plant. Economic -Total fuel costs in the thermal power plants; -Penalty cost for load loss by consumer groups; -Fuel cost for each thermal power plant.
Observations	All output data are given in each case on a monthly and yearly basis.

Summary supplied by the authors of the model.

YUGOSLAVIA

The Model	H. Požar and G. Granić, University of Zagreb, Zagreb, 1974 (22). Influence of Pumped Storage Plants on Electric Power Systems.
Subject and Goal	Optimal operation of pumped storage plants; achieving the minimal constant costs of the system, cost of fuel in thermal power plants and penalty cost for load loss.
System Described	The system is defined by the demand and the state of completion of hydro and thermal power plants, plus data on characteristics of new types of thermal power plants to be constructed and on those of pumped storage plants.
Area — Time	One year, divided into months or weeks.
Area — Space	Not specified.
Modelling Techniques	Hydrologic conditions in the year considered are extrapolated on the basis of past data (30-40 years). Electro-energetic balances are made on a monthly basis. The pumped storage hydro plants are sequentially put in operation, whereby the optimal duration of operation is determined for each. The criterion of optimal operation is minimum construction and operation cost of new thermal power plants (including penalty cost for load loss). The construction of thermal power plants necessary to meet consumer demand is determined iteratively.
Input Data	Physical -Consumption: For each period, maximal load and total energy. -Hydro power plants: Installed power; average energy production over a number of years for various hydrologic conditions. -Thermal power plants: Available power and load factors. -Pumped storage plants: The number of plants, duration of maximal power utilization in turbine operation, useful volume of the upper storage basin, water head, necessary water discharge through the turbine for the entire plant and for each unit, and natural inflow to the upper basin of each plant. Economic: Cost of fuel in thermal power plants, penalty cost for load loss; investment and operation costs for the network and the hydro, thermal and pumped storage plants.
Output Data	Physical: Optimal operation of pumped storage plants, output and consumption of pumped storage plants, construction program and output of thermal power plants. Economic: Total cost of fuel in thermal power plants, penalty cost for load loss, total investments and operation costs, and hence price of one kWh.

Summary supplied by the authors of the model.

CLASS B MODELS

FRANCE

The Model	Commissariat a l'Energie Atomique, 1973. CRESUS: Survey of Nuclear Fuel Market.
Subject and Goal	For the commercial sector, comparing future requirements to those already met; this provides the possibility of appraising new potential markets. For the industrial sector, assessment of the market as one of the elements that will lead to decisions in real time for prospecting, mining and opening plants.
System Described	-Estimation of the different requirements at each step of the fuel cycle, with a path of a month, a year, or more. -Influence of the parameters, and of the scenarios of development of nuclear reactors, on consumption. -Statistics on the world nuclear reactor program. -Economic studies (fuel management and average cost of fuel).
Area — Time	Defined in real time.
Area — Space	The world as a whole.
Modelling Techniques	-Simulation which reprocesses the elementary data, characterizing the market and the operations of the various types of reactors and calculating the requirements step by step. -Development of breeders according to the availability of plutonium. -Sorting and extracting of reactors from the file for several parameters: size, type, year of construction, country, etc. For easy assessment of the influence of nuclear market parameters, the model is conversational (APL).
Input Data	-A first file containing information on all the nuclear reactors. -A second file with technical information on the consumption of each type of reactor. -Technical parameters (timing between operations in the fuel cycle, waste level of enrichment plants, etc.).
Output Data	-Schedule for any period and with any designed path of the quantity of uranium, separation working units, etc., for one or more countries. -Cost of the fuel cycle. -Fuel management: timetable of quantities and expenses.

Summary supplied by the authors of the model.

CLASS C MODELS

AUSTRIA

The Model	Karl Musil, Österreichisches Institut für Wirtschaftsforschung, Vienna, 1974. Energy Forecast Model.
Subject and Goal	Estimation of medium- and short-term energy demand and determination of the demand structure. The model was developed as a tool for energy policy decisions both for the government and for the energy industry.
System Described	The energy demand structure is represented as a function of economic development. This allows analysis of consequences of alternative decisions for economic development. The model is demand-oriented. Energy price has not been taken into account, so that substitution processes cannot be described by a market mechanism. The model provides a forecast of energy demand, divided into sectors according to the organization and classification of energy balances as prepared by the Institute.
Area — Time	Medium- and short-term forecasting (1980, 1985).
Area — Space	Austria as a whole.
Modelling Techniques	Three tools for forecasting are used: -Extrapolation of relations between energy consumption and exogenous variables. Regression analysis techniques are applied; -Information on the technological, sociological and economic embedding. -Forecasts provided by other groups.
Input Data	Economic -Simulation of economic growth rates in different sectors using I/O methods, -Estimated GNP and industrial production, -Value added and income, used as exogeneous variables for determining energy consumption in the transport and household sectors. Technological -Specific electricity consumption of the aluminium processing industry, -Specific coke consumption of the metallurgical industry. Data provided by other groups -Data for the energy conversion sector, e.g. production structure of electricity, -Foreign trade figures, -Technological coefficients, -Scheduled changes in capacities.
Output Data	The main output data are the energy consumption, per energy carrier, in: -Industry (sectors: chemical, food, textile, paper processing, building materials, aluminium processing, metallurgical and residual industry), -Transport sector (railway, road and other traffic), -Residential and commercial sector (electricity and other fuels), -Transmission losses (gas, electricity), -Non-energy use, -Conversion sector (electricity, coke ovens, refineries).
Observations	The model uses common techniques, but is very detailed. Estimation of the energy demand structure of energy carriers has been split into substitutable and non-substitutable parts.

Summary not reviewed by the author of the model.

CANADA

The Model	J.D. Khazzoom, Mc Gill University, Montreal, Quebec, 1975[(23)]. Free and Captive Energy Demand.
Subject and Goal	To estimate and simulate energy demand. The author splits energy demand into two parts: -A captive demand which is incompressible and whose level is determined by prior investments, and which is very stable over time, -A free demand independent of past commitments and responsive to change in economic conditions, which fluctuates.
System Described	The energy sector of Canada, traditionally split into three sectors: commercial, residential, and industrial. The fuels considered are oil, electricity and coal. Studies had been carried out for six major provinces: British Columbia, Alberta, Saskatneshewan, Ontario, Quebec, and Manitoba.
Area — Time	Simulations run up to 1982.
Area — Space	All of Canada, by province.
Modelling Techniques	The model uses econometric techniques and proceeds in two steps. First, the author tries to explain the free demand of a fuel in a given sector with respect to: -The industrial price of the fuel (PF), -The price of the F fuel substitutes (PS), -The manufacturing output (MA). The relation to be adjusted is: (1) $D_t = f[PF_t \mid PS_t, MA]$. As f(•) is not known and unobservable, it is approximated by a Taylor series with first- and second-order terms. Thus: (2) $\Delta D_t = \alpha_o + \alpha_1 \left(\frac{PF}{PS}\right)_t + \alpha_2 \left(\frac{PF}{PS}\right)_t + \alpha_3 MA_t + \alpha_4 MA_t^2 + \alpha_5 \left(\frac{PF}{PS}\right)_t - MA_t$, where (α_i, i = 1,5) are the coefficients to be estimated. Second, the author studies the effect of prices on demand. To obtain a dynamic equation, one substitutes $\frac{1}{2}(PF_t + PF_{t-1})$ into PF_t and can thus simulate demand over time according to price increase.
Input Data	The prices of fuels and electricity; the production of sectors. The coefficients of equation (1) were estimated over the period 1960-1980.
Output Data	First step: -Industrial sector: gas demand, -Residential sector: demand for natural gas, electricity, oil, -Commercial sector: gas demand. Second step: -Industrial sector: simulation of gas demand in Quebec, Ontario, Alberta, -Manufacturing demand for electricity in Canada, -Industrial demand for coal in Canada, -Mining demand in Canada, -Electricity demand in the residential and commercial market.
Observations	Other demands are being investigated. The econometric model of the demand for energy in Canada used by the author has not yet been published.

Summary not reviewed by the author of the model.

CANADA

The Model	R. Hamilton, University of Calgary, Alberta, 1975. Energy Prospects in the O.E.C.D. Area to 1985.
Subject and Goal	To forecast the energy supply and demand up to 1985 under various assumptions.
System Described	The energy market of the U.S., Canada, OECD Europe, Japan, Australia and New Zealand. The sectors considered were: residential/commercial, industrial, transportation, non-energy oil, specific energy sectors (primary and intermediate fuels).
Area — Time	1980-1985.
Area — Space	Any OECD country.
Modelling Techniques	Two-step procedure. 1. A basic case is set up. Three sets of energy balances are estimated for 1980 and 1985 for each of the following countries and regions: United States, Canada, OECD Europe, EEC, and Japan. These are: -A set of base projections relying to a large extent on forecasts constructed by member country governments and corresponding to the energy situation prior to October 1973; -A set or projections corresponding to a price of $6 (in constant 1972 U.S. dollars) f.o.b. at the Persian Gulf per barrel of Arabian crude oil; -A set of projections corresponding to a crude oil price of $9. 2. Two price alternatives gave birth to $6 and $9 projections derived from the following procedure: -Prices were estimated for the various forms of energy used in OECD countries for each of the three cases; -Demand elasticities were used to determine the reduction in the quantity of energy demanded in response to higher prices compared to the base case. Estimates were made for the quantity of each type of energy expected to be produced in the $6 and $9 cases; -Adjustments were made in the allocation of different forms of energy among consuming sectors in order to satisfy various technical and policy constraints; -Oil imports were derived mainly as residuals. The base projections were derived largely from member country forecasts. Their most important feature is that either they take no explicit account of prices at all or thev are based on price expectations which prevailed before October 1973. Some projections were made to examine the sensitivity of various assumptions related to: -Price demand elasticity, -Substitutability for other fuels, -Conjuction of both.
Observations	The elasticities were not derived by econometric means but selected on the basis of judgment after examining existing econometric studies. In this study energy conversion factors are clearly specified.

Summary not reviewed by the author of the model.

FINLAND

The Model	Seppo Salo et al., Helsinki University of Technology, and Tor Nyman, IBM Finland, Helsinki, 1974. Simulation Model of the Finnish Energy Economy.
Subject and Goal	The scope of the model is the Finnish energy service within the aggregated national economy. The model is intended as an instrument for studying the effects of: -Various alternative energy policies; -Exogenous factors uncontrollable by domestic decision makers on the Finnish energy service and economy.
System Described	The model is concerned with: -The flows and stocks of different sorts of energy from suppliers via converters to consumers; -Aggregated production, exports, imports and consumption of consumer products, investment products and raw materials; -Book-keeping of the use of labour and financial resources.
Area — Time	Time continuous dynamic model (1960-1985).
Area — Space	Finland as a whole.
Modelling Techniques	Simulation model using systems dynamics. The evolution of various inventories and capacities is described by first-order differential equations; and flow rates, prices, building rates of capacities, etc., by ordinary equations as functions of the system state.
Input Data	Energy forms considered are crude oil, heavy oil fractions, medium and light oil fractions, coal, natural gas, electric power (produced by oil, coal, fuelwood and peat, nuclear reactions, hydropotential), fuelwood and peat, and heat (for district heating). Energy consumers considered are the industrial and agricultural production sectors, electric power and district heating production sectors, service activities and public administration and households. Characteristics of energy forms and behaviour of consumers are described by data in the form of constants, time series and coupling and elasticity functions. These data describe implemented policies, initial values, delays, consumption structures, efficiency coefficients, prices, etc.
Output Data	The output gives the evolution pattern of those system state variables chosen by the user. The adp application of the model produces plotted and/or numerical output. These patterns are used to study the dynamic behaviour of the system.
Observations	The model is intended as a tool for decision making, planning and control at the macro-level of energy economy. In order to get more valid aggregated coupling and elasticity functions and other data, this model should be supported by some submodels having narrower scope and describing smaller areas. The models would then form a hierarchial structure.

Summary supplied by the authors of the model.

G D.R.

The Model	Institut für Energetik, Leipzig, 1973. Energy Economy of the G.D.R. - Central Coordination Model.
Subject and Goal	Calculation of an optimum structure of energy demand and supply with respect to domestic fuel resources and fuel import facilities, using the results of all the submodels: models of the sectors electricity, gas, coal, and oil industry, substitution optimization model, regional structure optimization model. The coordination model determines the structure for every submodel; these result in an overall optimum economic fuel and plant structure. The use of the coordination model to link the submodels requires homogeneity in the principles of construction (linear multi-period model), in time and in economic area. To coordinate the submodels, a mathematical-economic algorithm is used, developed in particular for the model of the energy economy.
System Described	In coordinating the submodels, the central coordination model includes the whole sector of energy supply and most parts of the energy demand which can be optimized. The limits of the system are the energy demand (which is optimized or balanced in any of the submodels), fuel import, investment possibilities, and other economic constraints.
Area — Time	A time horizon of 5-15 years, separated into intervals of a year or more.
Area — Space	Energy supply and use in the G.D.R.
Modelling Techniques	Linear programming model. As a linkage system between the submodels of the energy economy, the model has a special construction: part of its columns consist of vectors in absolute values, and others of specific coefficients. The dynamic behavior in the LP model is represented in: -The matrix with multiple defined lines for time-dependent balances and multiple defined columns for the specific variables, -The objective function with discounted costs for fuel import for one unique point of time. The economic value of columns in absolute values is determined by the output of the submodels.
Input Data	The variables (columns) of the model consist of the calculated optimum structure modes of the different sectors (absolute figures), the fuel import (specific figures), and "fictitious" variables (production, consumption) to compensate the inflexibility of the model. The lines consist of balance equations for fuels (produced, supplied or used) and for economic constraints (investments etc.), and the conditions for linking the submodels. Required inputs: <u>Technological</u> -Produced fuel quantities of the sector per energy carrier and per time interval, -Supplied fuel quantities of the sector per energy carrier and per time interval, -Fuel input quantities from other sectors per energy carrier and per time interval, -Demand for economic resources per time interval, -Coefficients to compensate the inflexibility of the model. <u>Economic</u> -Total costs of different structures of the submodels, -Specific costs for fuel import, -Specific costs for "fictitious" production or consumption of fuels. <u>Other</u>: Energy demand, limitations of economic resources, limitations of fuel import.
Output Data	Optimum structure of energy demand and supply according to the given constraints. The structure is separated into specific structures of every sector; together, these form an optimum structure of the whole energy system without necessarily being optimum for each sector.
Observations	The central coordination model is an instrument for linking several submodels and hence can be used only as an integrated part of the entire energy economy system.

Summary supplied (in German) by the author of the model.

G.D.R.

The Model	Energieversorgungsbetriebe, Leipzig, 1974. Energy Economy of the G.D.R. - Regional Structure Optimization Model.
Subject and Goal	Calculation of an optimum structure of regional energy supply. Various ways of meeting the energy demand for the household and commercial sectors, and for heat processes at low temperatures, are represented.
System Described	The optimization refers to the energy demand of new or rebuilt units (e.g. houses, municipal institutions). Existing demand which does not change is included as a summary vector for balancing only. The limits of the system consist of the given regional energy demand (according to the number of houses, municipal institutions, industrial processes at low temperatures, etc.), the available resources and the constraints within the region (labor force, hydrological limits, siting problems, investment facilities, environmental aspects, etc.).
Area — Time	A time horizon of 5-15 years, separated into intervals of a year or more.
Area — Space	Defined region of the G.D.R. (administrative area, combination of two or at most three districts).
Modelling Techniques	Linear programming model. The dynamic behavior in the mathematical static model is represented by: -The matrix with multiple defined lines and columns according to the time steps, -The objective function with discounted costs per time interval for one unique point of time. -The objective function is an equation which minimizes economic costs in the form of: $aw = I \cdot q^n \cdot \frac{q-1}{q^n-1} + U(q-1) + l \cdot q_k + m$ with: aw = average cost per year, I = cost of investment, U = supply of floating capital, l = wages, m = material and other costs (except wages and depreciation), q = accumulation factor, q_k = consumption factor.
Input Data	The variables (columns) of the model deal with the heating power plants, heating plants and supply systems required to meet the energy demand, and the lines with the fuels for the regional energy supply, heat balance equations and technological conditions. Required information (in absolute values): Technological -Fuel input (per energy carrier) in heating power plants, heating plants and different supply systems, -Energy consumption of heating power plants and heating plants, -Coefficients for the electricity generation of heating power plants, -Coefficients related to the technical conditions of energy demand. Economic -Costs of investment (for new plants and plants under construction), -Wages, -Material and other costs, -Costs for floating capital supply (for new plants and plants under construction), -Costs for transportation of fuels from producers' to consumers' locations, -Planned lifetime of scheduled plants. Other -Energy demand of households, divided by region and by new or rebuilt housing, -Energy demand for the commercial sector and for processes at low temperatures, -Limitations in capacity of heating power and heating plants, -Limitations of the regional energy supply input.
Output Data	The model calculates the optimum structure of supply systems to meet the energy demand in the household and commercial sectors and for heat processes at low temperatures; another output is the optimized regional demand for fuels.
Observations	The model's mathematical character is static but it can be used for dynamic calculations in time intervals according to the objective function and the matrix. If the model is used as a submodel of a larger system of the energy economy as a whole, the coefficients of the objective function should not include fuel costs. The model may also be used for smaller regions (towns, city districts).

Summary supplied (in German) by the author of the model.

G.D.R.

The Model	Institut für Energetik, Leipzig, 1972. Energy Economy of the G.D.R. - Central Production Optimization Model.
Subject and Goal	Optimization of fuel structure for given energy demand and calculation of an economically effective structure of plants producing and converting fuel. The model describes practical choices for an optimum strategy of energy needs by representing the energy production plants and their interdependencies.
System Described	The model includes in an aggregated form all plants for production and conversion of coal and for production of electric energy, liquid fuels and heat distribution, and gas supply, as well as energy transport. The model considers plants in operation, in construction, and planned, interrelated by balance equations for the energy carriers and functions for technological constraints.
Area — Time	A time horizon of 15-20 years, separated into intervals of a year or more.
Area — Space	Energy economy of the G.D.R.
Modelling Techniques	Linear programming model. The dynamic behavior in the mathematical static model is represented in: -The matrix with multiple defined lines and columns according to the time steps, -The objective function with discounted costs per time interval for one unique point of time. The objective function is of the same form as for the regional structure optimization model (see p. 58).
Input Data	The variables (columns) of the model data with lignite open mining, briquette plants, distilling ovens, coke ovens, condensation power plants, nuclear power plants, heating and industrial power plants, pump storage power plants, gas turbine power plants, gas producing plants, oil refining plants and fuel import. The lines deal with the energy carriers and the technological linkage of different plants. Required information (in absolute values; the specific variables are related to the plants' main products): <u>Technological</u> -The plant's specific consumption of different fuels, -The plant's specific output of different fuels, -Coefficients for the technological linkage between plants. <u>Economic</u> -Cost of investment (for plants under construction and new plants), -Wages, -Material and other costs (except fuel costs), -Costs of floating capital supply (for plants under construction and new plants), -Costs for import of fuels, -Planned lifetime of scheduled plants. <u>Other</u> -Demand for energy for processes outside the system described, -Limitations in production capacity of different plants, -Limitations in import facilities of fuel.
Output Data	Optimum structure of energy production and conversion facilities, and structure of required imports for meeting energy demand. Several balances (primary energy, production and consumption, investment, etc.) are made.
Observations	The model's mathematical character is static, but it can be used for dynamic calculations in time intervals according to the objective function and the matrix.

Summary supplied (in German) by the author of the model.

G.D.R.

The Model		Institut für Energetik, Leipzig, 1973. Energy Economy of the G.D.R. - Reproduction Model.
Subject and Goal		The repro-model calculates the economic coefficients of the reproduction process of the energy economy, in particular effectivity coefficients of a optimum structure. The main characteristic is plant production. Another important figure for the price calculation is the specific expense per energy carrier.
System Described		Energy economy with its main sectors, including the supply network for electricity, and artificial and natural gas (domestic and imported).
Area	Time	A time horizon of 5-15 years.
	Space	Energy economy of the G.D.R.
Modelling Techniques		The model consists of a matrix system without optimization aspects. It uses the matrix of an optimization model and the vector of the system's optimum solution. Using information on system efficiency, the efficiency and reproduction figures are calculated iteratively by applying a special algorithm.
Input Data		The variables derive from those of the system optimization model. The lines of the model consist of balance equations for fuels and economic variables (depreciation, capital, wages, costs of investment, etc.). Required information: Technological -Coefficients of energy consumption per plant. Economic -Capital, depreciation value per plant, -Costs of investment per plant, -Wages per plant, -Other management costs, -Supply or charge prices per fuel, -Reproduction factors per fuel. Other: Capacity or production according to the system optimization model, per plant.
Output Data		The following results are calculated with an iteration procedure: -Prime costs per fuel, -Absolute prime costs per fuel and plant or combination of plants, -Proceeds per fuel, -Absolute proceeds per fuel and plant or combination of plants, -Costs per fuel, -Capital per fuel and plant or combination of plants, -Outcome per plant or combination of plants, -Qualitative coefficients per plant or combination of plants.

Summary supplied (in German) by the author of the model.

G.D.R.

The Model	Institut für Energetik, Leipzig, 1974. Energy Economy of the G.D.R. - Substitution Optimization Model.
Subject and Goal	Calculation of optimum regional energy demand for energy-intensive non-energetic production and supply processes with a given amount and structure of production and supply. The model reflects the substitutable energy demand of large scale consumers. Regional energy supply (household and commercial) is not considered.
System Described	The model includes large-scale consumers: production plants of non-energetic processes in the chemical, metallurgical, mechanical engineering, light industry, building, agricultural and food sectors, represented by objects (plants) or processes. According to the substitution facilities, the model includes all possible variations (technologies) of fuel use for non-energetic processes. The optimum demand structure is calculated, given the amount of non-energetic products and supply goals and the fuel resources available.
Area — Time	A time horizon of 15-20 years, separated into intervals of a year or more.
Area — Space	Energy use in the G.D.R.
Modelling Techniques	Linear programming model. The dynamic behavior in the mathematical static model is represented in: -The matrix with multiple defined lines and columns according to the time steps, -The objective function with discounted costs per time interval for one unique point of time. The objective function is of the same form as for the regional structure optimization model (see p. 58).
Input Data	The variables (columns) of the model are energy use processes of the system sectors. The lines (balance equations) consist of energy carriers, the technological linkage of objects and processes, and the equations for the given non-energetic production and supply. Required information (in absolute values; the specific variables are related to a unit of the production and supply goals): <u>Technological</u> -Energy input (per fuel) with reference to the technology of the production plant, -Coefficients for meeting of non-energetic production and supply goals, -Coefficients for the technological linkage of different objects and processes. <u>Economic</u> -Investment costs (for new plants and plants under construction), -Wages, -Material and other costs, -Costs of floating capital supply (for new plants and plants under construction), -Lifetime of scheduled plants. <u>Other</u> -Size of the production and supply goals, -Limitations in production facilities, -Limitations of available fuels.
Output Data	Optimum structure of technologies for meeting given production and supply goals according to given fuel resources, and structure of energy demand for meeting these goals. The value of the objective function represents the system costs for using the fuels.
Observations	The model's mathematical character is static, but it can be used for dynamic calculations in time intervals according to the objective function and the matrix. If the model is used as a submodel of a larger system of the energy economy, the coefficients of the objective function should not include fuel costs.

Summary supplied (in German) by the author of the model.

GREECE

The Model		C. Aronis and A. Diavolitsis, Center of Planning and Economic Research (KEPE), Athens, 1975. Model for Planning Energy Development in Greece.
Subject and Goal		The model is intended as a tool for long-term overall energy development planning in Greece, and is based on minimization of the total cost of production, transportation, distribution and usage of existing and future final energy forms. The energy forms considered are: electricity, processed lignite, gasoline, diesel, fuel oil, kerosene and city gas. Natural gas, solar energy, and geothermal energy will be considered later.
System Described		The main components of the model are: demand sub-system; generators of cost curves at the supply level; supply sub-system--optimization; generators of cost matrices at users' level; allocation sub-system--optimization; overall static optimum; routine tracing of an optimal path by linking static optima.
Area	Time	Static model which can be applied to any time horizon, with a likely upper limit of approx. 20 years due to forecasting limitations.
	Space	Point model applying to Greece as a whole.
Model Components		1) <u>Demand sub-system</u>: An econometric model estimating total yearly demand for retrievable* energy by consumption sector and/or usage, measured in units of equivalence. Multiple regression analysis is used, with the sector's yearly product (value), the average fuel price per unit of energy retrieved, and time as the main prediction variables. An attempt is made to determine the segments of sectoral demand which, without heavy incentives, are likely to remain loyal to existing energy forms (inelastic). Elasticity depends mainly on the value and age of users' existing equipment. 2) <u>Generators of cost curves at the supply level</u>: Routines are designed for total, marginal and average cost of production and transportation of final energy forms as a function of the total quantities supplied. This cost is based on optimal selection (location, size, technology, etc.) and scheduling of production units and transportation networks. The cost of electricity is being related to the shape of the load duration curve. A special routine has been designed for scheduling power stations to odd-shaped L.D.C's. Inputs are the capital and operating costs of existing and candidate production units and transportation networks, broken down into national and foreign currency components, possibly adding social cost. A comprehensive weighted unit cost will be produced. 3) <u>Supply sub-system--optimization</u>: Using marginal analysis, the optimal (minimum cost) mix of final energy forms to be produced are derived, subject to constraints such as resource capacity, budget, etc. Inputs are: marginal/average supply cost curves, total "inelastic" demand of consumable energy by final energy form, and total "elastic" demand of consumable energy. 4) <u>Generators of cost matrices at users' level</u>: Routines to compute the unit cost of retrievable* energy by final energy form and consumption sector, brokendown into national, foreign currency and possibly social cost components. Inputs are: supply cost, corresponding to the optimal supply quantities; distribution cost; capital cost of users' equipment; and usage efficiency rate (ratio of energy retrieved/energy consumed). 5) <u>Allocation sub-system--optimization</u>: Using LP (TRANSPORTATION ALGORITHM), the optimal allocation of final energy forms to the various sectors (usages) is derived. The algorithm is run in terms of retrievable* energy and all the parameters are adjusted accordingly. Inputs are: demand of retrievable* energy by sector (usage); optimal supply mix of consumable energy, converted into retrievable energy; and unit cost of retrievable energy, by energy form and consumption sector (usage)(cost of matrix at users' level). 6) <u>Overall static optimum</u>: In the allocation sub-system, the initial (optimal) supply constraints are relaxed step-wise, producing a marginal improvement in the "allocation" objective function and a marginal disimprovement in the "supply" O.F. The process is continued for as long as it results in an overall marginal improvement. 7) <u>Routine tracing of an optimal path by linking all static optima</u>: The "static" optimal allocation matrix produced for a particular year corresponds to a specific investment programme, to satisfy the demand for that year. An optimal path for the planning period can be derived by: dividing the planning horizon into 5-year periods and determining the static optimum at the final year of each; and linking all static optima with each other. A linkage of static optimum t to static optima (t-5) and (t+5) sets additional constraints which relate to "existing" and "available" investments. The optimal path minimizes the objective function of the planning period, while taking those additional constraints into consideration.
Observations		The model is still in the development stage.

*Retrievable energy = consumable energy minus usage losses.

Summary supplied by the authors of the model.

HUNGARY

The Model	K. Kelemen and A. Vári, Systems Engineering Institute INFILOR, Budapest, 1973(24). Simulation Model for Petroleum and Gas.
Subject and Goal	Consistency of decisions affecting the structure of the Hungarian oil and gas industry. The model investigates how different policies affect the satisfaction of fuel demands and the profits of the Trust.
System Described	The model describes exploitation of crude oil and natural gas and allocation to the refineries and gas works; allocation of raw materials for different products; and production of final goods. In fact the model simulates the flow of material between different factories controlled by the Head Office.
Area — Time	1974-1984, by quarter of year.
Area — Space	Crude oil and gas for Hungary as a whole.
Modelling Techniques	Simulation model; system divided into production, transportation, and storage subsystems and a control system. Event-oriented scheduling.
Input Data	Physical -Time series parameters describing: raw material resources, technological coefficients and manufacturing capacities of each conversion unit, and transportation and storage capacities. The following are included: Several crude oil and natural gas resources; several refineries, gas works and carbonic acid resources and factories; transportation facilities (tube, ship, railway, tank-car); storage facilities (underground container, tank). -Time series exogenous data describing the 31 demand categories, which include different kinds of petrol, fuel oil, bitumen, lubricants, PB gas, gasoline, natural gas, coal gas and carbonic acid. Seasonal fluctuation of each demand category is taken into account. Economic For each raw material, intermediate and final product: -Final consumer prices, import and export-prices; per unit production costs (excluding cost of raw materials); per unit transportation and storage costs.
Output Data	Physical For each quarter, the quantity of: -Exploited and converted products, -Imported and exported products, -Inventories of raw materials and products, -Materials not to be distributed because of shortage in transportation facilities. Economic For each quarter, by product: -Cost of production, transportation and stocking, -Income resulting from domestic use and export.
Observations	Prices and demands are now considered exogenous; linkage with a higher-level model of the Hungarian energy system could furnish the above data. Data describing the preferences of the Head Office in allocating raw materials, transportation and storage facilities could be generated by short-term optimization models.

Summary supplied by the authors of the model.

HUNGARY

The Model	F. Rabâr, Laboratory for Information Processing, Budapest, 1969[25]. Investment Policy in the Energy Economy.
Subject and Goal	Investigating the consistency and consequences of any proposed investment policy in the Hungarian energy economy. Following all the changes generated, the model is suitable for quantifying the effects of any investment policy or single decision.
System Described	The system to be modelled consists of 3 characteristic subsystems: production, conversion and consumption. Prices result from automatic adjustment to supply and demand. Exports and imports are included.
Area — Time	Dynamic model based on fixed time increments over 16 years.
Area — Space	Hungarian energy economy.
Modelling Techniques	The model is a discrete event simulator and the processes are sequences of discrete events. The state changes take place at specific points of the simulated time. The model contains 29 demand categories and 21 kinds of energy.
Input Data	Physical Consumption subsystem: -Useful energy demand by substitution patterns and consumption regions at time t; -Efficiency ratios for converting from a certain kind of energy to useful energy. The demand categories are: coal, natural gas, coal gas, refinery products, building-industrial, energetic and private applications. Production subsystem: resources of raw materials, production capacities and technological coefficients of the characteristic types of energy conversion. The following raw materials and products are concerned: coal of different quality, coke, crude oil, petrol, fuel oil, goudron, bitumen, PB gas, lubricants, natural gas, coal gas. Economic -Per unit production costs (excluding raw material costs which are generated endogenously), -The fixed costs of the customers, -Starting price of the different types of energy, -Export and import prices.
Output Data	Physical For each quarter of the year: -Quantity of production by type of energy, -Import requirements, -Export possibilities, -Level of supply from the different types of energy. Economic -Total production costs, -Accumulated production costs up to the time horizon, -Income from sales, -Cost/benefit ratio and net present value calculated from the cost incurred and the income generated up to the time horizon.
Observations	There is no transport in the model.

Summary supplied by the author of the model.

ITALY

The Model	F. Boselli, Ente Nazionale per l'Energia Elettrica, Rome, 1973[26]. Cobb-Douglas Production Function for Forecasting Energy Consumption.
Subject and Goal	Large model for checking assumptions on the overall energy supply, related to projections of some macroeconomic variables of the Italian system.
System Described	The model is based on introducing the energy supply into a Cobb-Douglas production equation, which establishes a functional relationship among the national product, the main production factors (employed man-power and capital funds) and technological progress, interpreted as a trend variable. Energy is alternatively considered as a production factor or an autonomous variable. This amounts to setting: $\alpha + \beta + \gamma = 1$ or $\alpha + \beta = 1$ (no constraint on γ) in the basic equation $Q = A\ e^{\delta t} L^{\alpha} K^{\beta} E^{\gamma}$, where Q = net product; e^t = time variable associated with technological progress, having rate δ; L = number of workers; K = amount of capital funds; E = energy supplied to end-users.
Area – Time	1953-1970 for historical series of statistical data; 1980 for forecasting.
Area – Space	Italy.
Modelling Techniques	Multiple regressions on logarithms of variables.
Input Data	Historical series Q/L, K/L, E/L and E, for Q and K expressed with constant price values. To compute the total energy required in 1980, several assumptions are considered, based on combining different alternatives for national product (yearly average rise at 5% and 4%), invested capital (development based on a 1.5 and 2 capital/product incremental rate), 1980 employed man-power (20 million and 25 million), technological progress (development 1970-1980 at the same rate as in the past or at 0.8 and 0.5 of past rate).
Output Data	Total requirements of energy supplied to end-users in 1980, subject to the assumptions made on the macroeconomical variables considered.

Summary supplied by the author of the model.

U.K.

The Model	Department of Applied Economics, University of Cambridge, Cambridge, 1968[27]. Demand for Fuel, 1948-1975.
Subject and Goal	To explore the possibilities of a system of sector models, each with its separate structure and task but all linked through a central model of the national economy. At each stage of calculation the energy model provides information about the fuel and power complex and the main model provides revised information about the rest of the economy. The models are used to project energy demands to 1975 on different assumptions and to make some estimates of the pattern of supplies in 1972.
System Described	Three models are described: -A model of intermediate energy demand, to explain for the various branches of industry the changes that took place, principally the substitution of oil for coal; -A model of the demand for fuels by private and public consumers; -A model which explores the balance of supply and demand, to estimate the activity levels which would be required of different branches of fuel production if the demands were to be met given the constraints imposed on the fuel and power industries by current government policies.
Area — Time	1948-1975.
Area — Space	United Kingdom as a whole.
Modelling Techniques	The first two models use econometric equations to explain the energy demand. In the first, a general method has been worked out which can be applied to a wide range of industries. For some other cases, the mean of observations, or some simple trends, are used. The starting point of the supply model calculations is a provisional set of commodity outputs calculated by the main model from given sets of final demands and industrial input structures. The input structures of the various industries remain unchanged, except in the gas and electricity industries, where several processes are distinguished, each being assigned a weight proportional to its contribution to the total output of the industry. The purpose of the model is to revise these weights, thus changing the input structure of the multiple-process industries and leading to revised output levels of all commodities. At each successive round of the calculations the revision tends to become smaller until a balanced system is obtained.
Input Data	Five energy forms are considered: coal, oil, coke, gas and electricity. There are 18 industrial branches and 5 fuel commodities. In the gas and electricity industry 8 processes are distinguished. The input data are: -The input of fuel i into industry j, -The gross output of industry j, measured in £ (1960) and a physical unit, -The input of fuel i per unit of output of industry j, -The average price of fuel i, -The annual average temperature, -The household demand for each fuel, -The total consumer expenditure per head, -The matrix of commodity inputs into industries, and that of industry outputs of commodities, -The vector of final demands for commodities.
Output Data	The estimations of coefficients of the econometric equations. Forecasts of the input of fuel i per unit of output of industry j to 1975. Household consumption of fuels in 1972. Balances of fuel demands and supplies in 1972.
Observations	The role of the prices is very important in this model. The projections of energy demand and supply depend on the rate at which North Sea gas penetrates the fuel market. In the next phase, the supply side of the model will be examined thoroughly.

Summary not reviewed by the authors of the model.

U.S.A.

The Model	Kent P. Anderson, Rand Corporation, Santa Monica, 1971(31). Toward Econometric Estimation of Industrial Energy Demand.
Subject and Goal	To explain the possibilities of the estimating techniques used (rather than obtain results directly applicable to policy making problems).
System Described	U.S. metal industry sector as a whole. This is a non-homogeneous sector for two reasons: -Firms use different technologies, -Most are multiproduct firms. Because of lack of data, different demand equations could not be adjusted for homogeneous sub-systems. However, an attempt was made to determine to what extent the coefficients of the estimated demand equations can be used for long-term elasticities (reflecting intra-firm adjustments).
Area — Time	Long term.
Area — Space	U.S. metal industry sector, by state.
Modelling Techniques	Ordinary least-squares (OLS) and two-stage least-squares (TSLS). The demand equations are assumed to be of the following form:

$$E_i^s = \varepsilon_{io} \cdot P_1^{s\,\varepsilon_{i1}} \; P_2^{s\,\varepsilon_{i2}} \cdot \cdots \cdot P_5^{s\,\varepsilon_{i5}} \cdot w^{s\,\varepsilon_{iw}} \cdot v^{s\,\varepsilon_{iv}} \cdot e^{\varepsilon_{it} \cdot t} \cdot u_i^s \qquad (i = 1,\ldots,5)$$

$$p_i^s = \mu_{io} \cdot y_i^{s\,\mu_{iy}} \cdot X_i^{s\,\mu_{ix}} \cdot z_i^s \qquad (i = 1,\ldots,5)$$

where:

- ε_{ij} and γ_{ik} are the estimated coefficients (elasticities),
- V^s value added by primary metal production in state s,
- i type of input (coal, coke, gas, oil, electricity),
- p_i^s current average market prices,
- w^s average wage rate of primary metal production markets,
- e^{ε} log constant,
- u_i^s, Z_i^s stochastic error term S
- X_i^s level of aggregate industry purchases,
- Y_i^s average price paid by all manufacturers outside the primary metal industry.

Input Data	The principal sources of data where the 1958-1963 Census of Manufacturers and the 1962 Annual Survey of Manufacturers. The sample contains 60 observations, 31 states in 1956 and 29 in 1962. Explanatory variables are given above.
Output Data	The main output data are the prices and demands of coal, coke, gas, oil and electricity.
Observations	As stated, there is no reason why the elasticities estimated with the aggregate demand should be constant in the long term. They are probably underestimated, since: -The estimates are made while some firms are still adjusting to price variation, -The elasticity of response to price change will increase (in absolute value) due to the influence of inter-product substitution and the effect of technical substitution among the inputs used for each type of product. However, an attempt was made to take these biased effects into account.

Summary not reviewed by the author of the model.

U.S.A.

The Model	L.D. Chapman and T.D. Mount, Cornell University, Ithaca, New York, 1974[32]. Electricity and Environmental Quality in the U.S.
Subject and Goal	To estimate the adverse effects of emissions on premature mortality and respiratory disease. This required estimating the demand for electricity and sulfur exhaust coefficients according to production level.
System Described	Electricity demand in the U.S. for three consumer classes: commercial, residential and industrial. The fuels considered are oil, natural gas, coal and electricity.
Area — Time	1975-1995; 1980 is the reference year for econometrical effects.
Area — Space	U.S. as a whole for the demand equations, U.S. disaggregated into 9 regions for the environmental effects of sulfur.
Modelling Techniques	1. Demand equation: coefficients have been adapted with generalized least-squares estimates. The demand equation is assumed to be log-linear. Forecasts are based on the time-lag equation: $$Y_t - Y_{t-1} = (1 - \lambda)(Y_t^* - Y_{t-1})$$ where: Y_t is the actual level of the demand, Y_t^* is the desired, but unobserved, level. Y_t^* is assumed to be $\alpha + \beta X_t$, where: X_t is the logarithm of income, β is the long-run elasticity, α, β, λ are unknown parameters. 2. A three-step procedure is used to determine the environmental effects: -Determine the size and composition of population exposed to emission, -Determine the relationship between increased emission of sulfur oxides and the probability distribution of different concentration of sulfates, -Determine the threshold concentration of sulfates and the response to higher concentrations for major respiratory diseases.
Input Data	Demand equation: -Number of customers, -Income per capita, -Prices of electricity, natural gas, oil, coal, electric, equipment, -GNP. Environmental effects: forecasts of levels of sulfur oxides emitted for 1980, and of generation, are exogeneous; they are derived from the CM model published by NERC in 1973.
Output Data	Long-run elasticities, Effect of increasing the price of electricity on the short-run response demand, Environmental effects such as: -Premature mortality, -Increased attacks of asthma, -Increase in days of aggregated heart and lung disease, -Increase in cases of aggregated respiratory disease in children, -Increase in cases of chronic respiratory disease for smokers and non-smokers.
Observations	The specification of the demand equation is not explicitly given in this report.

Summary not reviewed by the authors of the model.

U.S.A.

The Model		Wesley K. Foell, University of Wisconsin, Madison, Wisconsin, 1974[33]. Regional Energy System Planning and Policy Analysis.
Subject and Goal		The WISconsin and Energy Model (WISE) treats the Wisconsin energy system within a multi-dimensional framework that describes energy demand, conversion, transport and usage, taking account of technological, economic and environmental considerations. The primary goal of the model is improved energy system planning and policy analysis.
System Described		The model can be viewed as a large energy information system, designed to provide guidance for a wide range of energy-related decisions faced by individuals, the private sector, and government institutions at the state or regional level. Although the model has been developed primarily for those types of policy analysis appropriate to the state of Wisconsin, it is in general applicable to many other states and regions with similar characteristics.
Area	Time	Variable; the model is best suited to long-term planning and has been applied to the study of alternative futures through the years 2000 and 2025.
	Space	Any state or region; has been applied to several states in the U.S., and is being applied to the German Democratic Republic and the Rhône-Alpes region in France.
Modelling Techniques		The system model consists of a family of submodels, many of them capable of being implemented separately or coupled in a total simulation mode. The techniques used in the submodels include correlation (econometrics), simulation, non-linear discrete-variable engineering and physical descriptions. The models provide a systematic framework for investigation of a wide range of alternative energy futures. The family of models is structured within an interactive simulation command program which provides easy user access to input and output in a variety of information packages.
Input Data		Thirteen submodels currently from the heart of the WISE model, including: energy demand models according to economic sector and by physical process; energy supply models which focus primarily on electricity conversion, transmission and distribution (since Wisconsin has no sources of primary fuels within the state); a set of environmental input models which relate impact within and outside the system to energy use within the region; socio-economic models treating population, land use, and economic activity. Representative socio-economic Inputs: population growth rates, trends in industrial value added by two-digit SIC, expenditures and retail sales, population densities in sub-areas, energy costs for primary fuels. Representative physical inputs: growth rates in area of commercial buildings, energy efficiencies of various transportation modes, climatic factors, energy intensities of industrial processes. Representative environmental inputs: pollutant control characteristics, origin of fuels, population characteristics of the region.
Output Data		Energy demands by process, economic sector, and fuel; capacity and costs of required electricity facilities; environmental impact within and outside the regions, including a spectrum of emissions, concentrations, and health effects.
Observations		The model is continually evolving. It is currently being refined to include: optimization techniques (linear programming) within certain demand and supply submodels; techniques using subjective probabilities to better define and describe alternative energy futures.

Summary supplied by the author of the model.

U.S.A.

The Model	J.H. Hollomon, B. Raz and R. Treitel, Massachusetts Institute of Technology, Cambridge, Mass., 1975(34). Nuclear Power vs. Oil Imports.
Subject and Goal	Analysis of the energy cost of electricity production. The choice of growth rates for the nuclear power installed capacity is evaluated and the efficiency of nuclear power generation with respect to the displacement of oil is discussed.
System Described	The nuclear power system mainly; the model focuses on the flows of fossil fuels and electricity entering and coming out of the electricity production system.
Area — Time	1974-1995.
Area — Space	USA as a whole.
Modelling Techniques	Simulation and sensitivity analysis. The model simulates the "net energy" of the nuclear power system as a function of time and of various exponential rates of growth of the installed nuclear capacity. The net energy is defined as the balance of energy inputs and outputs as a result of detailed accounting applied to the energy production process. Some sensitivity analyses are also conducted to cope with the very uncertain nature of the energy inputs.
Input Data	-Lead time for construction and lifetime of a nominal 1000 MWe nuclear power plant, -Capacity factor, distribution losses, and energy required to prepare the nuclear fuels and operate the various plants, -Energy inputs required for the construction of a nuclear plant.
Output Data	For several scenarios the model gives the yearly net power output of the nuclear power system and the yearly amount of oil displaced by the implementation of the construction and production program.
Observations	Although the model shows that there is an exponential rate of growth that maximizes the net energy output and/or the oil displacement, the main purpose of the authors is to comment upon the alternatives the decision-makers face.

Summary supplied by the authors of the model.

U.S.A.

The Model		D. Reister and C.E. Whittle, Institute for Energy Analysis, Oak Ridge, Tennessee, 1974 (35). Long Range U.S. Energy Model.
Subject and Goal		To study the range of possible future energy supplies and demands according to different assumptions about technological development for the period 1985-2040, by analyzing complex scenarios of supply and of demand.
System Described		The model includes the supply functions for electricity, liquids, gases and solids as energy carriers generated by existing and projected techniques. The demand function is the sum of the demands for the different carriers by the industrial, residential and commercial, and transportation sectors.
Area	Time	1985-2040.
	Space	U.S.A.
Modelling Techniques		Simulation of normative scenarios for the production of different energy carriers based on projections for resources and techniques. Some of these scenarios are added to give "superscenarios" for the overall supply function according to assumptions on the development of new techniques. For the demand side, scenarios for different energy carrier mixes used by the different sectors are drawn independently of supply studies. "Superscenarios" issuing from addition of the scenarios for all the sectors are finally compared to the supply superscenarios.
Input Data		Physical -Estimates of the energy resource bases for coal, petroleum, natural gas liquids, natural gas, shale oil, uranium, thorium, hydroelectricity, geothermal heat, solar energy, regional water supplies and energy from organic wastes, -Known and projected techniques for energy carrier production, -Assumptions on future energy demand. Economic: Projection for the demand activities. Political: Possible moratorium on nuclear power plants.
Output Data		Energy equivalent of each of the produced energy carriers. Demands for the different energy carriers.
Observations		This model is an easily computable one giving results which show the long-range demand and supply possibilities.

Summary not reviewed by the author of the model.

U.S.A.

The Model		P.F. Schweizer, C.G. Love and J. Hunter Gilles, Westinghouse Electric Co., Pittsburgh, Penn., 1973[36]. Regional Energy Policy Model.
Subject and Goal		To examine the supply, demand and price of primary energy sources and electricity subject to assumptions about future policies and technology changes. The type of factors that could be examined are: -New technology, -Environmental restrictions, -Import quotas, -Energy conservation measures, -Rationing, -Regulations or taxes that force substitution, -Price increase.
System Described		The system is composed of 4 primary energy sources (coal, oil, nat. gas, nuclear) and 4 end-use sectors: industrial, electric utilities, transportation, residential/commercial.
Area	Time	From 1971 to 1985 with 1 year time lag.
	Space	USA as a whole.
Modelling Techniques		Macroeconomics using linear programming. The model is composed of a main allocation model (EAM) and an auxiliary conversion industry model (CIM). The EAM uses the mathematical techniques of linear programming to match supply with demand when possible. When shortages occur, specified algorithms are used to determine appropriate substitutes. Some parameters are subject to change due to the technology and the policy concerned. CIM accepts non-primary end-use demand, and with conversion formulas and efficiencies returns this demand to the EAM as a primary fuel demand.
Input Data		Supply, demand and price of each fuel for each market and sector.
Output Data		Under each policy assumptions and from 1970 to 1985 the main results are: -Energy consumption of each fuel in each sector, -Graph display of substitutes and shortages. Three policies are envisaged: P1: uses unlimited oil and gas imports and a moderate coal industry growth of 4% per year. P2: restricts oil and gas imports; a moderate coal industry growth (4%) and the substitution of most potential shortages (80%) with electricity. P3: as P2, but coal industry growth is assumed to be 6% per year.
Observations		Time lag structure is $Y(t+1) = G_d Y(t)$ and $X(t+1) = G_s X(t)$, where G_d and G_s are respectively growth rates of demand and supply. These are assumed to be constant over time.

Summary not reviewed by the authors of the model.

YUGOSLAVIA

The Model	H. Požar, University of Zagreb, Zagreb, 1973 (37). Determination of Optimal Energetic Structure.
Subject and Goal	Optimal structure of the output and distribution of primary forms of energy.
System Described	The economic system is modelled with: -A series of linear equations for all areas considered and all types of consumers in which the unknown quantities represent the possible output and the constants the determined demands; -A series of linear equations for minimal and maximal output values of single energy forms and limitations in transport; -The objective function (e.g. total cost of the system), which is the optimal value. The equation of total costs, total investments and total expenditure in foreign currency are included in the objective function. Different iterations are done to generate various parameters.
Area: Time	One year, but a series of years can be investigated.
Area: Space	Any area, divided into several parts.
Modelling Techniques	Linear programming.
Input Data	Physical -Level of demand for single consumers, by kind of energy and area; -Limit of energy supply, by energy form; -Limit of energy transport, by energy form; -Load factor and loss, by energy form. Economic -Costs of transport, by energy form; -Prices in foreign currency for energy procured abroad by energy form.
Output Data	Physical -Necessary quantity of energy, by form, for each kind of consumer. Economic -Total costs of output, transport and purchase, by energy form; -Total investments for construction; -Total costs in foreign currency of the purchase abroad of energy, by energy form.
Observations	The model is continuous in time.

Summary supplied by the author of the model.

I.I.A.S.A.

The Model	W. Haefele and A.S. Manne, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1974. Strategies for a Transition from Fossil to Nuclear Fuels.
Subject and Goal	To understand the basic features of the fossil to nuclear fuel transition, as the first step of a more general model dealing with the comparison of different large scale energy options over the next 30-50 years.
System Described	This model investigates what is feasible in several hypothetical "model societies" --countries of the technology level of the U.S., Japan and Western Europe. Starting from today's situation where virtually all demands for primary energy are met by fossil fuels, the study focuses on timing the introduction of new technologies, based in this first model on nuclear fission. The asymptotic reactor configuration is achieved by linkage of fast breeder reactors and high temperature reactors. The FBR supplies electricity and the HTR hydrogen for non-electric energy. Part of the FBR breeding factor is used to convert thorium 232 into U233 used in the HTR. The following aspects are explored: -The limited reserves of oil and gas, -The limited reserves of low-cost uranium, -The limited industrial capacity for construction of nuclear reactors, -The limited financial resources available to the energy supplying sector.
Area — Time	1970-2030.
Area — Space	A "model society"; could be applied with specific data to any developed country.
Modelling Techniques	Linear programming. At each point of time of a 75-year planning horizon, the fossil and nuclear energy supply activities are chosen so as to meet the final demands at minimum discounted cost, subject to technological and behavioral constraints.
Input Data	<u>Demand</u>: Three versions of demand can be investigated: -Growth from 10 kwth/capita in 1970 to 20 kwth/capita after 2015, -Growth at constant increasing rate, -Endogeneous demand which depends on price of energy and on time trends related to aggregated income; the discounted utility of consumption minus the cost is maximized. The price elasticities used are -0.5 for electricity and -0.3 for non-electricity. <u>Supply</u>: -Economic data: the main annual and inventory requirements for all kinds of plant considered are needed. a) Kind of plant--those using fossil fuels (coal and fuel oil or gas); and nuclear, LWR, HTR, FBR. b) Example of inventory data for nuclear plants--annual and inventory requirement in natural uranium; annual and inventory requirement in separative work; P_u and U233 annual production and requirement; thermal efficiency. -Economic data: annual and capital investment costs for all kinds of plants. -Data related to reserves: the availability of fuel resources (oil, gas, oil shale, coal and uranium). The estimates for fossil fuel come from the U.S. Geological Survey. For uranium, the authors assumed 2 million metric tons of low-cost uranium ($15/lb), and no upper limit is imposed for high-cost material ($50/lb). -Data related to industrial constraints: the yearly upper bounds on reactor construction rates are a major behavioral input constraint for the diffusion rate of new technologies.
Output Data	The main output is focused on timing of new technologies, taking a perspective sufficiently long to allow for the eventual exhaustion of oil and gas resources. The model allows careful study of the interactions between technology assessment, demand-growth patterns and resource availability.
Observations	The model is to be completed with a more sophisticated demand model, and new technological options (solar, geothermal, coal liquefaction and gasification).

Summary not reviewed by the authors of the model.

CLASS D MODELS

U.S.A.

The Model	W.D. Nordhaus, Yale University, New Haven, Conn., 1973[38]. Allocation of Energy Resources.
Subject and Goal	The author first discusses the efficiency of market forces in determining the prices of energy resources, using the theory of general economic equilibrium for that purpose. He then proposes a model to determine the efficient allocation of energy resource over time.
System Described	The energy system of the non-communist world on a highly aggregated level: the resource variables are petroleum, oil shale, coal, nuclear fuel, natural gas. The demand is broken down into the following categories: electricity, process heat, residential heat, substitutable transport, non-substitutable transport. In the supply mining model many different processes (technologies) are involved: refining, coal gasification and liquefaction, breeder reactors, electric automobile, hydrogen fueled automobile etc. The author introduces the concept of backstop technology--a "set of processes which: i) are capable of meeting the demand requirements and ii) have virtually an infinite resource base". This concept permits him to avoid fixing of a horizon to the model.
Area – Time	1970 to infinite, broken down into 9 time periods: 1970, 1980, 1990, 2000, 2010, 2020, 2045, 2070, 2120 to infinite.
Area – Space	Non-communist world broken down into 5 regions: USA, Japan, Western Europe, Persian Gulf and North Africa, and the rest of the world.
Modelling Techniques	Linear programming and sensitivity analysis. Given demands, resource availabilities and technologies, the model calculates the optimal path that minimizes the costs of meeting the demand. The demand model assumes that there is no responsiveness of final demand to price, and that fuels are perfectly substitutable for meeting demand requirements. The energy sector is linked to the rest of the economy by assuming that the prices of labor and capital, as well as the interest rate, are not affected by the energy sector.
Input Data	Physical: Resource availability for recoverable energy resources, the different sector demands for each region and each period. Economic: Costs of extraction, transportation and processing for each fuel in each region; rate of interest. The paper describes in great detail how these data are constructed.
Output Data	-The optimal path, i.e. for each period, each region and each sector demand the set of fuels and processing technologies; -The shadow prices of scarce resources which can be interpreted as rent or royalty; -The fuel prices, considered as the sum of shadow prices and costs of extraction.
Observations	The linearity of the objective function, the inelasticity of the demand functions and simplified linkage with the rest of the economy, the assumption of free trade and the high level of aggregation are in fact over-simplifications. Nevertheless, the model permits the author to develop very interesting comments on the present evolution of our energy system. He gives also conclusions about the implications of the results for energy policy, e.g. evaluation of the costs of an autarky policy for the U.S.

Summary reviewed by the author of the model.

I.A.E.A.

The Model	International Atomic Energy Agency, Vienna, Austria, 1975 (39; see also 40,41). WASP - The IAEA Computer Code for Electricity System Expansion Planning.
Subject and Goal	Development of the economically optimal electricity-generation expansion plan for an interconnected grid, subject to extra-economic user-imposed constraints. Considers normal and emergency hydro, pumped storage, and up to 5 types of (fossil and nuclear) thermal plants.
System Described	The original WASP computer program (see (40,41)), developed in support of the 14-country IAEA Market Survey for Nuclear Power in Developing Countries, is an extensive revision of the SAGE computer program of the Tennessee Valley Authority. An improved WASP-II version is described in the first reference above. In addition to the Market Survey application, WASP has been and is being used, by IAEA and by the countries themselves, for individual country nuclear power planning studies.
Area — Time	Study horizon from 1 to 30 years, with each year divisible into 1 to 12 periods. The periods can have different peak demands, load duration curves and hydro characteristics.
Area — Space	Has been used by or for Argentina, Bangladesh, Brazil*, Chile, Egypt, FRG*, Greece*, Indonesia, Jamaica, Rep. of Korea, Malaysia*, Mexico*, Pakistan*, Philippines, Singapore, Thailand*, Turkey*, TVA (USA)*, and the Inter-American Development Bank*. (Asterisks indicate countries or organizations which have acquired WASP from IAEA.)
Modelling Techniques	Probabilistic simulation and dynamic programming. WASP consists of 6 modular programs: -A program to describe the forecast peak loads and load duration curves for the system; -A program to describe the "fixed" system (existing system plus all additions or retirements which are firmly scheduled). Up to 100 station types, each with up to 99 identical units, can be considered. Hydro, emergency hydro, and pumped storage are each treated as a single composite plant. Up to 5 hydrological conditions, with their associated probabilities, can be considered for each period in the year; -A program to describe the "variable" system, up to 20 expansion candidate plant types which could be used to expand the system. Hydro and pumped storage are each counted as a single plant type, each with up to 20 ranked candidate projects; -A program to generate all alternative expansion configurations, subject to user-imposed constraints, which can meet the loads forecast; -A program to determine whether a particular configuration has been simulated and, if not, to simulate system operation and add the information generated to the simulation file. This module uses probabilistic simulation techniques to estimate energy generation by each plant and corresponding production costs, loss-of-load probability, and unsatisfied energy demand; -A program to determine the lowest-cost schedule for adding new units to the system over the period of interest. The objective function of this (dynamic programming) optimization is the present-worth discounted value of all operating costs plus all capital investment costs of the added variable system plants, less a salvage-value credit at the horizon for the remaining economic life of these plants. The first 3 modules are independent. The other 3 modules use, in addition to their own input, data files created by preceding modules. WASP-I has a 7th module, a report generator program which produces a summary report of the first 6 modules plus a breakdown of annual expenditure requirements for the optimal solution. The WASP-II report generator is not operational as of March 1975.
Input Data	The user enters details of the load forecast and the fixed and variable systems. Any extra-economic constraints on expansion planning are imposed in Modules 4 and/or 6. Present-worth discount rates, escalation rates on capital and operating costs (by fuel type), plant capital costs and working capital requirements for fuel are supplied in Module 6. Independent auxiliary programs (ORCOST, CONCOS, FRESCO, MASCO, LORD, etc.) have been developed or adapted to help prepare input and check solutions for technical and economic feasibility.
Output Data	The first 6 modules produce a detailed output, the degree of detail being a user option. Module 6 provides the value of the objective function for all acceptable expansion plans and a detailed description of the best ones (up to 10, at user's option). Module 7 summarizes the input and output of the first 6 modules and provides a detailed schedule of expenditure requirements for the optimal expansion plan.
Observations	Linkages with the social and economic system are not included directly and hence must be reflected in the input data (e.g. load forecast and capital and operating costs) and in the extra-economic constraints imposed on the solution.

Summary supplied by the IAEA Secretariat.

I.I.A.S.A.

The Model		W.D. Nordhaus, International Institute for Applied Systems Analysis, Laxenburg, Austria, 1975[42]. Demand for Energy--An International Perspective.
Subject and Goal		The purpose of the paper is to estimate econometrically the demand for energy in broad sectors of the economy. The paper addresses the three following questions (each one corresponding to a short, medium and long term frame): -What is the time distribution of the response to the recent price increase? -What is the long run price elasticity? -What is the long run income elasticity? In addition, the results will be in a format such that they can be used for the energy demand side of the general model: Allocation of Energy Resources (see Review of Energy Models No. 1, IIASA RR-74-10, p. 63).
System Described		The all-energy system of a country is taken into account. The economy is broken down into 5 sectors: energy, transport, industry, residential-commercial and an aggregation of all of them; 4 kinds of fuels are considered: liquid, gas, solid and electricity. The fundamental relation of this model is derived from the preference relations of the consumers and the technological constraints of the producers.
Area	Time	Econometric estimates for 1955 to 1972, forecast up to 2000 for the US.
	Space	Various countries; at the time being, France, Belgium, FRG, Netherlands, Italy, UK and USA have been investigated.
Modelling Techniques		Econometric techniques; the two main equations of the model expressed the fact that for a given set of prices: -The producer works at a point of his production function which corresponds to the minimum of his production cost; -The consumer maximizes his utility function subject to his budget constraints. In order to study the time lags in the response to evolution of prices, the author introduces a lag structure in his functions. The length of lags is 1 year for income and 4 years for price. The production function is a Cobb-Douglas function in primary factors: labor, capital, energy and time (a proxy for change in technology). All functions are linearized in the logarithm. (Jorgenson created the term "translog" for such a function when second degree terms are also included.) Coefficients are estimated by using ordinary least squares. All forecasts are given in the form of a likelihood interval.
Input Data		For regression analysis, time series of prices and quantities of different forms of energy used in the different sectors of each country are taken over the period 1955-1972.
Output Data		-For each of the 5 adopted economic sectors of all countries, the model gives the price elasticity coefficients for net energy consumption, a forecast to the year 2000 of the different amounts of energy consumption. All forecasts are given inside a likelihood interval. -The author investigates different assumptions on the evaluation of future prices.
Observations		There are two main assumptions in this model: -The form of production and consumption functions is the same for all countries studied; -In the same way it is assumed that elasticities are constant over time.

Summary reviewed by the author of the model.

CLASS E MODELS

CANADA

The Model	F.W. Gorbet, Department of Energy, Mines and Resources, Ottawa, Ontario, 1975[43]. Energy Demand Projection.
Subject and Goal	To model the demand of the energy market so as to facilitate the long projection of Canadian energy requirements.
System Described	The system is formed by 5 energy markets and 10 end-use sectors; 12 fuels are considered. The system recognizes the interdependence of energy consumption and other goods and reserves. It allows examination of a particular energy use in the context of total energy demand linked to demographic and macroeconomic assumptions.
Area — Time	1980-1985-1990.
Area — Space	Canada as a whole.
Modelling Techniques	The link algorithm works as follows: Step 1 For each region convert input BTUs into output energy according to energy use efficiency; Step 2 Regression analysis between aggregate output energy and aggregate activity and price variables over the period 1958-1971; Step 3 Use of CANDIDE's projected values of aggregate variables to develop regional projections of output energy demand (see CANDIDE abstract, p. 84); Step 4 Adjustment of aggregate projections for factors not explicitly treated in Step 2. Step 5 Disaggregate energy output projections in each region to demand projections for each energy source; Step 6 By energy source, convert energy output to energy input projection; Step 7 Derive additional primary energy demands for secondary energy input.
Input Data	Data base: "Detailed Energy Supply and Demand in Canada".
Output Data	The main output data are: -Demand for primary and secondary energy, -Source and use distribution, -Average annual growth rates. Various energy demand projections are obtained subject to 3 basic assumptions: -H1: energy prices continue to increase in real terms until the late 70's, -H2: prices as in H1 but demographic and economic variables continue to grow at estimated rates, -H3: as H2 but rates of growth are historical ones. In H1, 3 micro-simulations have been made: -Increase of 40% in the efficiency of internal combustion, -Increase of 25% in the efficiency of light fuel oil residential furnaces, -Increase in the percentage of housing units of multiple dwellings, from 41% in 1973 to 48% in 1980 and 60% in 1990. In the last 3 cases all results are expressed in terms of percentage reduction from the demand levels.
Observations	The author suggests that research be undertaken to obtain more accurate results.

Summary not reviewed by the author of the model.

CANADA

The Model	M.C. McCracken, Economic Council of Canada, Ottawa, Ontario, 1973. An Overview of CANDIDE I/O Model.
Subject and Goal	Simulation of the impact of a policy on economics; Data unification in the same framework; Forecasts under various assumptions.
System Described	CANDIDE is a large-scale macroeconomic model of the Canadian economy for the medium term. No particular attention is given to the energy sector, but a set of energy variables is included.
Area — Time	Projections to 1980 for major aggregates.
Area — Space	Canada as a whole.
Modelling Techniques	Simulation model of 6 aggregates: -Final demand, -Industry output, -Labor supply and requirements, -Wages and prices, -Government and private revenues, -Money and interest rates, -Financial flows, balance of payments, -National accounts relationships, -U.S. and other foreign linkages. The solution is obtained through Jacobi iteration and the Gauss-Seidel Algorithm.
Input Data	Econometric relations, I/O arrays, identities and lag-time equations covering the entire economy. 377 exogeneous variables including 6 energy variables: electricity, uranium, coal, natural gas, crude petroleum, exports.
Output Data	1553 endogeneous variables including electric power exportation, fuel importation (crude petroleum, natural gas, coal), final demands (gas, petroleum, mining and electricity production).
Observations	Model extentions are in progress.

Summary not reviewed by the authors of the model.

F.R.G.

The Model	S. Rath-Nagel and D. Elsinghorst, Kernforschungsanlage, Jülich, 1975. Alternative Development Patterns of the Energy Economy.
Subject and Goal	Representation of alternative energy demand and supply patterns for the F.R.G. up to the year 2000. Investigation of cause-effect relationships and dynamic behavior in the energy economy is the main objective. Energy demand is described by sector, the interdependencies of the economy and energy supply systems are represented in detail, and the changeable environmental situation due to specific sociological variables is shown.
System Described	The model comprises 8 modules: population and employment, invested capital, production, production demand, investment order, energy demand, energy supply, environment. Sector production (energy, chemical, metallurgical, building materials, other industries and residual sector) is calculated as a function of capital investment, labor force participation and technology. It determines the economic growth, the energy demand of industry and the GNP, from which private and public income and consumption are derived; the main variables for calculating energy use in the non-industrial sectors (4 industrial sectors: chemical, metallurgical, building materials, other industrial; 2 transportation sectors: goods and individuals; 2 household sectors: space heating and other energy consumption; 1 commercial sector). The energy supply sector considers extraction or import of primary energy, conversion and transport of energy for different energy carriers; it has been subdivided into main energy industries: bituminous coal, lignite coal, natural gas and oil production, oil processing, gas supply and electricity supply. The environmental module includes the main emissions from energy use: SO_2, NO_x, C_nH_m, CO, CO_2, P_b, dust.
Area — Time	1950-2000; data from 1950-1974 are used for reference only.
Area — Space	F.R.G. as a whole.
Modelling Techniques	The model uses dynamic simulation techniques based upon coupled differential equations, fitted by data obtained on a weekly basis.
Input Data	Some important input data per unit time are: -Population, -Sector import and export, -Sector coefficients in an I/O matrix, -Structure of final energy use, by energy carrier, -Limitations of domestic energy resources and imported fuels, by energy carrier. The main correlations which are based upon functional relationships are: -Capital vs. average unemployment rate, -Available income of private households vs. GNP, -Public consumption vs. GNP, -Housing area per capita vs. average net income per capita, -Goods transportation vs. industrial production, -Individual transportation per capita vs. average net income per capita, -Specific energy demand of industrial sectors vs. cumulative invested capital of industrial sectors, -Non-energetic consumption of fuels vs. chemical industry production, -Energy consumption of commercial sector vs. production of commercial sector.
Output Data	Some important output data per unit time are: -Capital investment, employment, production (GNP), economic growth rate per sector, -Amount and sector structure of final energy use and primary energy supply per energy carrier, -Amount and cost of imported energy per energy carrier.
Observations	The model is a strategy rather than a forecast model. Alternative energy demand and supply strategies have been simulated: e.g. variation of conditions for economic growth, economic impact of unexpected interruption in oil supply and of delays in nuclear power plant programs, the break-through of new technologies such as large-scale coal gasification, hydrogen and nuclear chemical energy systems. Studies of a fuel substitution and a fuel cost optimization module (LP) are under way, as is further disaggregation of production sectors and the I/O matrix. A module for financing energy investments is planned.

Summary supplied by the authors of the model.

F.R.G.

The Model		A. Voss and F. Niehaus, Kernforschungsanlage, Jülich, 1974. Analysis of the System Man-Energy-Environment.
Subject and Goal		Overall analysis of the system man-energy-environment, including economic, ecological and technological aspects, to show possibilities for long-term development of the world's energy system, particularly with respect to embedding. The model aims at a quantitative description of alternative energy supply strategies by evaluating the positive and negative effects of satisfying energy demand and providing its supply systems. The description of substitution mechanisms among primary energy sources is emphasized, and the impacts of carbon dioxide generation on atmospheric temperature is represented, as is tritium allocation in the global water cycle.
System Described		The interactions between the energy system and the environment are described in 5 sectors: population, energy, non-renewable resources, industry, pollution. The development of interactions between sectors determines that of the overall system and thus that of energy demand. Besides the effects of energy consumption and exploration of new energy resources, the energy sector of the model describes substitution among primary energy sources. Substitution dynamics are described by a differential equation statement, and time-variable causal factors (energy costs, availability, characteristics of use) by a utility function. The global distribution of carbon dioxide and tritium due to energy use patterns is analyzed in the pollution sector, which represents the flow of these pollutants into the atmosphere or hydrosphere.
Area	Time	From 1900 to 2100.
	Space	The world; no regional disaggregation is made except for separation into northern and southern hemispheres for the tritium allocation analysis.
Modelling Techniques		The model uses simulation techniques. The dynamic interactions and feedback loops are described by the system dynamics approach (developed by J.W. Forrester).
Input Data		As the model is a closed cybernetic simulation model, the initial values of the state variables and certain functional relationships must be described. Some of the most important functions are: -Birth and death rates vs. material standard of living, -Primary energy production costs vs. cumulative primary energy consumption, -Energy consumption per capita vs. material standard of living, -Reduction of environmental burdens vs. cost requirements.
Output Data		The development in time of variables such as population, raw material consumption, energy consumption, energy reserves, shares of individual energy carriers in the energy supply, industrial production, environmental burdens, carbon dioxide and tritium allocation due to energy use.
Observations		The model is a strategy rather than a forecast model. It shows a high degree of aggregation and uses global averages. It is a further development of an earlier model of A. Voss, summarized in the Review of Energy Models No. 1, 1974. Studies on the disaggregation in space are under way.

Summary reviewed by the authors of the model.

FRANCE

The Model	D. Finon, University of Grenoble, Grenoble, 1974 (44). Optimization Model of the French Energy Sector.
Subject and Goal	To match energy supply and demand with lowest costs over a long-period (25 years) by final demand simulations on a formalized graph of the French energy sector. The model allows one to study energy sector reactions to any change in economic, social or political environment. It also gives investment requirements and foreign currency needs for import.
System Described	The French energy sector is fully described with a graph where the paths are production means and the knots denote management factors, transportation and consumption. Environmental impacts of energy activity are considered.
Area — Time	1975-2000.
Area — Space	France as a whole.
Modelling Techniques	Linear programming. Within the set of energy production means (paths), the model gives the optimal path which minimizes the discounted costs of investment and management over the period 1975-2000 under constraints such as: -Maximum operating capacities, -Demand, -Political considerations. Graph flows are taken as operating variables, and equipment capacities as equipment variables. The model is divided into 2 sub-systems: -Consumption: the demand is not completely exogenous. Consumer needs are disaggregated between three consumer classes (industry, transportation, household). Nine forms of final energy are considered. A distinction is made between non-substitutable and substitutable uses such as thermal uses. -Production: the model links all production means (coal, gas, fuel and electricity). The graph specifies the connections between operation and management of the production units.
Input Data	Demand forecasts per class of consumer, per energy form and per type of use. -Unit investment and management costs for the supply side (electricity plants, refineries) and the consumption side (household appliances). -Capacity, life time, efficiency and rate of SO_2 emission for each unit, -Extraction costs and import prices of the various fuels, -Mean cost of transportation and distribution, -Operating costs of the various production units.
Output Data	For every year from 1975 up to 2000: -Primary and final energy balances, -The set of production and consumption appliances, -Required investments over time, -Foreign currency required for fuel import, -Total expenditures on a yearly basis, -Amount of SO_2 emission.
Observations	The model allows one to choose among energies both at the final consumption and at the primary level. Energy substitutability does not take into account consumption price elasticities whose usefulness for long-term prospects the author thinks doubtful. Consumer choice is formalized by a discounted cost function which is part of the objective function.

Summary supplied (in French) by the author of the model

IRELAND

The Model	S. Scott and E.W. Henry, Economic and Social Research Institute, Dublin, 1975. Input-Output Analysis of Energy Supply and Demand in Ireland.
Subject and Goal	To analyse the energy transaction flows for one or more past years; to calculate prices per unit for each kind of energy under assumptions of various prices per unit for imported fuels, labour and other non-fuel costs of producing energy; to optimize the energy complex which satisfies given final demands, for example to minimize the cost of imported fuels; to simulate future energy transactions in detail by applying the model to predicted total demands. Allowance may be made for new forms of energy and new technologies of use of energy.
System Described	1) An open static I/O model having a transactions table of about 30 rows of energy products (in physical quantities) and about 35 columns, including at least 5 columns for final uses of energy; 2) A similar model having values of transactions, with 40 to 60 extra rows and columns for all other economic sectors, primary inputs, final demands; 3) A linear programming model using 1) and 2) for various objective functions, and with upper and lower bounds on sector outputs and so on.
Area — Time	Static model, for 1969, 1973, and single future years such as 1980 or 1985.
Area — Space	Ireland.
Modelling Techniques	I/O pricing techniques via Leontief inverse of energy transactions in physical quantities with all other costs treated as primary inputs; quantities and values for specified final demands, via inverse; linear programming techniques are also used.
Input Data	1) The transactions table of physical quantities of energy; 2) The transactions table of values, having 70 or more rows and columns; 3) The (I-A) matrix and constants for LP experiments. Upper and lower bounds and other constraints would be used for some sector outputs, for balance of payments, etc.
Output Data	1,2) Domestic outputs, imports, prices per unit, the latter depending on the prices applied to primary inputs. Direct plus indirect energy requirements per unit of labour: 3) The optimal value of the objective function. Domestic outputs, various kinds of imports, a shadow price for each constraint row, and relevance of upper and lower bounds.
Observations	This model is static. It does not take account of capital costs in choosing the optimal energy pattern The elasticity of demand (with respect to price) for various kinds of fuels is taken as zero. These limitations suggest improvements for future versions of the models.

Summary supplied by the authors of the model.

FRANCE

The Model		D. Finon, University of Grenoble, Grenoble, 1974 (44). Optimization Model of the French Energy Sector.
Subject and Goal		To match energy supply and demand with lowest costs over a long-period (25 years) by final demand simulations on a formalized graph of the French energy sector. The model allows one to study energy sector reactions to any change in economic, social or political environment. It also gives investment requirements and foreign currency needs for import.
System Described		The French energy sector is fully described with a graph where the paths are production means and the knots denote management factors, transportation and consumption. Environmental impacts of energy activity are considered.
Area	Time	1975-2000.
	Space	France as a whole.
Modelling Techniques		Linear programming. Within the set of energy production means (paths), the model gives the optimal path which minimizes the discounted costs of investment and management over the period 1975-2000 under constraints such as: -Maximum operating capacities, -Demand, -Political considerations. Graph flows are taken as operating variables, and equipment capacities as equipment variables. The model is divided into 2 sub-systems: -Consumption: the demand is not completely exogenous. Consumer needs are disaggregated between three consumer classes (industry, transportation, household). Nine forms of final energy are considered. A distinction is made between non-substitutable and substitutable uses such as thermal uses. -Production: the model links all production means (coal, gas, fuel and electricity). The graph specifies the connections between operation and management of the production units.
Input Data		Demand forecasts per class of consumer, per energy form and per type of use. -Unit investment and management costs for the supply side (electricity plants, refineries) and the consumption side (household appliances). -Capacity, life time, efficiency and rate of SO_2 emission for each unit, -Extraction costs and import prices of the various fuels, -Mean cost of transportation and distribution, -Operating costs of the various production units.
Output Data		For every year from 1975 up to 2000: -Primary and final energy balances, -The set of production and consumption appliances, -Required investments over time, -Foreign currency required for fuel import, -Total expenditures on a yearly basis, -Amount of SO_2 emission.
Observations		The model allows one to choose among energies both at the final consumption and at the primary level. Energy substitutability does not take into account consumption price elasticities whose usefulness for long-term prospects the author thinks doubtful. Consumer choice is formalized by a discounted cost function which is part of the objective function.

Summary supplied (in French) by the author of the model.

IRELAND

The Model	S. Scott and E.W. Henry, Economic and Social Research Institute, Dublin, 1975. Input-Output Analysis of Energy Supply and Demand in Ireland.
Subject and Goal	To analyse the energy transaction flows for one or more past years; to calculate prices per unit for each kind of energy under assumptions of various prices per unit for imported fuels, labour and other non-fuel costs of producing energy; to optimize the energy complex which satisfies given final demands, for example to minimize the cost of imported fuels; to simulate future energy transactions in detail by applying the model to predicted total demands. Allowance may be made for new forms of energy and new technologies of use of energy.
System Described	1) An open static I/O model having a transactions table of about 30 rows of energy products (in physical quantities) and about 35 columns, including at least 5 columns for final uses of energy; 2) A similar model having values of transactions, with 40 to 60 extra rows and columns for all other economic sectors, primary inputs, final demands; 3) A linear programming model using 1) and 2) for various objective functions, and with upper and lower bounds on sector outputs and so on.
Area — Time	Static model, for 1969, 1973, and single future years such as 1980 or 1985.
Area — Space	Ireland.
Modelling Techniques	I/O pricing techniques via Leontief inverse of energy transactions in physical quantities with all other costs treated as primary inputs; quantities and values for specified final demands, via inverse; linear programming techniques are also used.
Input Data	1) The transactions table of physical quantities of energy; 2) The transactions table of values, having 70 or more rows and columns; 3) The (I-A) matrix and constants for LP experiments. Upper and lower bounds and other constraints would be used for some sector outputs, for balance of payments, etc.
Output Data	1,2) Domestic outputs, imports, prices per unit, the latter depending on the prices applied to primary inputs. Direct plus indirect energy requirements per unit of labour; 3) The optimal value of the objective function. Domestic outputs, various kinds of imports, a shadow price for each constraint row, and relevance of upper and lower bounds.
Observations	This model is static. It does not take account of capital costs in choosing the optimal energy pattern The elasticity of demand (with respect to price) for various kinds of fuels is taken as zero. These limitations suggest improvements for future versions of the models.

Summary supplied by the authors of the model.

ITALY

The Model		V. Paretti et al., Ente Nazionale Idrocabone, Rome, 1960[45]. Italian Energy Economy.
Subject and Goal		Integration of energy resources into a consistent economic framework.
System Described		The entire Italian energy network is considered, from primary energy (including domestic extraction and import) to the final sectors (public and private consumption, investments, exports).
Area	Time	1953-1957 for energy balance; 1953 and 1956 for the analysis of structural interrelationships; 1965 for forecasting.
	Space	Italy.
Modelling Techniques		The model is based on Leontief input-output analysis.
Input Data		Based on the 1953 Italian I/O matrix. 33 purchasing sectors and about 600 selling sectors are taken into account. The energy supply sector is divided into 4 input items: coal, oil, gas and electricity; and the final sector into 29 items: 17 groups of domestic energy sources and 12 groups of imported sources.
Output Data		Two sets of results have been obtained: -From mathematical analysis of the 1956 I/O table, the "technical coefficients"; -By applying these coefficients, scenarios for the 1965 Italian economic development were obtained. The monetary requirements have been determined for conversion into secondary resources and for consumption. The resource quantities have been derived by using the matrix of 1953 unit prices. Sensitivity analysis was done in order to investigate some technical limits, e.g. in production capabilities of some resources, replacement for some resources, changes in some technical coefficients, and efficiency in energy utilization.

Summary supplied by the authors of the model.

U.S.A.

The Model	R.T. Crow and B. Ratchford, Electric Power Research Institute, Palo Alto, California, 1975[47]. An Econometric Approach to Forecasting the Market Potential of Electric Automobiles.
Subject and Goal	To forecast the market potential for the electrical automobile, in particular its share of the total automobile market, as a first step in assessing the impact of electrical automobiles on electric utility research and development priorities and investment planning.
System Described	Possible substitution of different types of cars for the household sector and is consistent with optimizing behavior as specified by microeconomic principles.
Area — Time	Short term and medium term.
Area — Space	U.S. automobile sector.
Modelling Techniques	Econometric techniques: ordinary least-squares regressions of behavioral equations. The central idea is that consumers react to goods as bundles of characteristics rather than goods in their own right. A utility function is set up and the demand for services is assumed to approximate the distributions of weights of the utility function with respect to characteristics. The consumers are viewed as basing the choice between alternative cars on the relative attractiveness of the cars' attributes. To obtain the market share of electric automobiles, the authors develop solutions for four hypothetical electric cars embodying two different sets of physical attributes plus two assumptions about the identity of the manufacturers.
Input Data	In the demand function the quantity of any car j relative to that of any car arbitrarily chosen as a base is assumed to depend on two types of characteristics: physical attributes (including price), and characteristics specific to the manufacturer of cars j. Data to estimate the model parameters, obtained for 420 observations (352 domestic and 68 foreign) over the period 1960-1973, were: -list price; -front leg room; -rear leg room; -acceleration; -passing speed; -average fuel consumption; -automatic transmission; -ride, -handling, -frequency of repair (qualitative scaling)
Output Data	The 73 potential market and total sales of electric automobiles under each assumption.
Observations	The authors plan research in three areas to understand fully the inovation process: -Investigate the specification of the market share over time, -Investigate cross-section results over time for possible change in parameters, -Extend the characteristics list and observe change in the results.

Summary not reviewed by the authors of the model.

U.S.A.

The Model		E.A. Hudson and D.W. Jorgenson, Data Resources, Lexington, Mass., 1974 Energy Policy and Economic Growth.
Subject and Goal		To investigate the interrelationships between energy utilization and economic activity. Economic growth and energy supply and demand are gathered into a single analytical framework in order to supply a set of projections which could serve as a point of reference for analysis of energy policy.
System Described		All U.S. economic activities are taken into account by using a new approach of dynamization of the input-output matrix. Special emphasis is placed on energy sectors, and sensitivity to different governmental policies is tested. Only foreign and government sectors are exogeneous; all others (mainly business and household) are endogenous.
Area	Time	From 1975 to 2000.
	Space	USA as a whole.
Modelling Techniques		This model is based on an integration of: -A macro-econometric growth model which determines the components of gross national income and product in real terms and also determines their relative prices. The underlying economic theory is essentially the Keynesian multiplier made dynamic by introducing lags in the responses of households and business to changes in income; -An inter-industry transaction for domestic industries (I/O matrix) which consists of a set of balance equations. The novelty is the addition of a model of demand for inputs and supply of outputs to each industrial sector. The input-output coefficients are thus treated as endogenous variables. The producer behavior model determines the I/O coefficient for each sector as a function of the prices of products of all other sectors, the prices of labor and capital services, and the prices of competing imports.
Input Data		The growth model consists of a set of econometric functions fitted on past trend data over the time period 1947-1971. Three main kinds of equation are used: -Behavioral equations related to investment supply, labor demand, production possibility frontier, demand and leisure demand; -Accounting identities related to capital stock and investment, capital service and capital stock, value of output and input, value of consumer goods, value of investment goods, value of capital services, value of labor services, saving, wealth; -Balance equations for consumption, investment, time, labor. The inter-industry model includes 9 sectors: agriculture, mining and construction; manufacturing; transportation and communication; trade and services; coal mining; crude petroleum and natural gas; petroleum refining; electric utilities; gas utilities. The I/O coefficients are dynamized by assuming that they are functions of the output prices of every other sector, the price of capital, labor and competitive import. The price functions are transcendental functions of the logarithm of the input prices. The authors call them "translog prices"; they are in fact Taylor expansions (in logarithmic terms) up to the second order. The coefficients are estimated on past trend data.
Output Data		The main output data are: -total energy demand by sector, -the internal price of all goods, -the bottleneck that could occur in the economy following a fixed energy policy. An extensive analysis of sensitivity to tax decisions has been supplied for the period 1975-2000.
Observations		This model is being developed in the same form in the Federal Republic of Germany for investigation of different energy policies. So far only the gathering of past data is under way. This model seems to be the most elaborated one for linking energy and economic growth. Nevertheless, it is not clear how it can take into account the structural evolution of industry by using the Leontief tables--for example to investigate when a given industry shifts from coal to electric energy.

Summary not reviewed by the authors of the model.

U.S.S.R.

The Model	A.S. Nekrasov et al., Institute "Energosetjproject", Moscow, 1973[48]. Optimal Development of the Energy Industry.
Subject and Goal	Optimization of production and distribution of energy resources with respect to territorial demand.
System Described	The system consists of a set of interconnected economic-mathematical balance models of the development of the fuel-energy industry: general energy industry models on a territorial scale, i.e., country-wide and regional models, specialized models on a branch scale for the energy sectors, and models for individual large energy-consuming enterprises. At each time stage, the central model is the national general energy model (model of the country's fuel-energy balance). It describes, in an aggregated form, the main sectors of the energy industry, ranging from the extraction of natural energy resources, their processing and transformation to consumption. This model is mainly intended to work out the efficient proportions of the development of the individual sectors (sub-systems) of the energy industry and to coordinate them with the potentials and requirements of other economic sectors. It also provides intercorrelated control information for independent optimization of every sector; fuel-energy branch or region. The branch models (of the oil, gas, coal and electric power industries) describe more accurately the development conditions of every branch, examine individual installations, field areas and routes of specialized transportation, and separate the corresponding cost values. The regional models examine individual areas and centers of consumption, divide consumer groups in a region down to individual enterprises, specify the cost values of intraregional transportation, and express in detail the features of a region's fuel-energy industry.
Area — Time	A horizon of 30 years, by steps of 5 years.
Area — Space	Any country or parts of a country.
Modelling Techniques	Linear programming model. The objective function of the general energy model is minimization of the total reduced costs of extraction, processing, distribution, transformation and use of energy resources. The regional and branch models are then correlated by means of correction indices on the basis of optimization. Thus the optimization process is iterative, as there is an exchange of information at every level of the system to find the global optimum.
Input Data	-Plans and forecasts of energy consuming branches and industries, -Output of individual types of production, -Expected deliveries of fuel and electric energy for export, -Specific expenditures and available amounts of energy resources, -Specific reduced value costs.
Output Data	Minimum cost of the energy supply system as a whole and for every stage (extraction, processing, distribution, transformation and use) of energy resources.

Summary not reviewed by the authors of the model.

CLASS F MODELS

E.E.C.

The Model	H. Neu, Ispra Establishment, Italy, 1975[49]. Energy Simulation Model.
Subject and Goal	A simulation model to study the impact of different supply strategies (nuclear, exploitation of home resources) and to develop energy demand and supply scenarios for the year 2000 and beyond. A special goal is the study of the impact of new technologies on the dependence of the E.C. on primary sources imports.
System Described	The system is divided into 4 interconnected subsystems: Demand, Supply, Conversion and Economy. Demand is subdivided into electricity and heat (fuel) for 4 economic sectors (industry, household and commerce, transportation, and energy). The Demand subsystem is connected to the Economy subsystem through the GNP growth rate by functional relationships. From the total electricity demand the required primary energy (fossil, nuclear, hydroelectric) is calculated in the Conversion subsystem and fed into the Supply subsystem, which is structured into production, imports and exports of different primary sources (coal, crude oil, natural gas, primary electricity, primary heat). The costs of imported primary sources influence the GNP growth rate (feedback loop).
Area — Time	1960-2000.
Area — Space	Nine nations of the European Communities; can be applied to any industrialized nation or world region.
Modelling Techniques	The computer language is DYNAMO III. Time series are generated by a loop structure and time varying growth rates. Functional relationships are given in the form of tables (systems dynamics approach). Output data are printed out and plotted by the DYNAMO compiler.
Input Data	For the time period 1960 to 1974: -Statistical data for 1960, -Average growth rates of time series. For the time period after 1974: -Policies for the exploitation of primary sources, -Nuclear installed capacity, -Estimated growth rates of various parameters, -Table functions for the sectorial demand, -Table function for the impact of primary sources import costs on the GNP growth rate (hypothetical), -Oil and gas reserves, -Inflation rate, oil price and other parameters.
Output Data	Plotted curves 1960 to 2000: -GNP at fixed prices, GNP growth rates, -Total inland consumption of primary sources, -Production of primary sources (nuclear, hydro-, natural gas, crude oil, lignite, hard coal), -Imports of primary sources (oil, natural gas, coal), -Sectorial consumption of primary sources, -Sectorial energy consumption per capita, -Sectorial share of primary sources consumption, -Share of different primary sources in total inland consumption. Time series of 70 parameters are printed out.
Observations	An extended model should include other conversion processes besides electricity production. The Economy subsystem should be more detailed, and more sophisticated linkage should be elaborated with the Demand subsystem. The model results suffer from the poor knowledge of functional relationships.

Summary supplied by the author of the model.

Index

Country	No.	Short Title and Author	Class	Page
France	F 202	Availability of Hydraulic and Thermal Supply System, ELECTRICITÉ DE FRANCE	A	17
"	F 203	CRESUS: Survey of Nuclear Fuel Market, COMMISSARIAT A L'ENERGIE ATOMIQUE	B	49
"	F 204	Optimization Model of the French Energy Sector, D. FINON	E	87
G.D.R.	DDR201	Electric Power Generation Optimization, OGREB-INSTITUT FÜR KRAFTWERKE	A	18
"	DDR202	Strategy of Gas Supply Structure, BRENNSTOFFINSTITUT	A	19
"	DDR203	Coal Industry Production and Supply Optimiza-tion, BRAUNKOHLEINDUSTRIE	A	20
"	DDR204	Optimization of Oil Industry, ERDÖLARBEITUNGSINDUSTRIE	A	21
"	DDR205	Short-Term Electric Power Management, OGREB-INSTITUT FÜR KRAFTWERKE	A	22
"	DDR206	Simulation of Rail-Operated Extraction in Lignite Open Mines, INGENIEURBUREAU FÜR RATIONALISIERUNG IN DER BRAUNKOHLEINDUSTRIE	A	23
"	DDR207	Siting of Nuclear Power Stations, STAATLICHES UNTERNEHMEN DER ELEKTROENERGIEVERSORGUNG	A	24
"	DDR208	Central Coordination Model, INSTITUT FÜR ENERGETIK	C	57
"	DDR209	Regional Structure Optimization Model, ENERGIEVERSORGUNGSBETRIEBE	C	58
"	DDR210	Central Production Optimization Model, INSTITUT FÜR ENERGETIK	C	59
"	DDR211	Reproduction Model, INSTITUT FÜR ENERGETIK	C	60
"	DDR212	Substitution Optimization Model, INSTITUT FÜR ENERGETIK	C	61
Greece	GR 201	Short-Term Forecasting Models for Electricity, C. DELIS	A	25
"	GR 202	Public Power Corporation Financing Model, C. DELIS	A	26
"	GR 203	ENAL: Generation Simulation Model, A. SAMARAS & C. STELAKATOS	A	27

Country	No.	Short Title and Author	Class	Page
Greece	GR 204	Model for Planning Energy Development in Greece, C. ARONIS & A. DIAVOLITSIS	C	62
Hungary	H 201	Simulation Model for Petroleum and Gas, K. KELEMEN & A. VÁRI	C	63
"	H 202	Investment Policy in the Energy Economy, F. RABÁR	C	64
Ireland	IRL201	Input-Output Analysis of Energy Supply and Demand in Ireland, S. SCOTT & E.W. HENRY	E	88
Israel	IL 201	Optimal Planning of Electrical Energy Generation Systems, J. VARDI	A	28
Italy	I 201	SICRET: Electrical System Network Planning, P.L. NOFERI et al.	A	29
"	I 202	Electrical System Generation Planning, L. PARIS & M. VALTORTA	A	30
"	I 203	Cobb-Douglas Production Function for Forecasting Energy Consumption, F. BOSELLI	C	65
"	I 204	Italian Energy Economy, V. PARETTI et al.	E	89
Netherlands	N 201	Uranium Resources Assessment with MIMIC, J.W. BRINCK	A	31
"	N 202	Simulation of Oil Extraction, PETER R. ODELL & K.E. ROSING	A	32
Portugal	P 201	Simulation of the Hydro and Thermal Electricity Production System, A. LEITE GARCIA et al.	A	33
"	P 202	EVOFI: Economic-Financial Equilibrium, COMPANHIA PORTUGUESA DE ELECTRICIDADE	A	34
Sweden	S 201	Electricity Production, Pricing and Investment, GÖRAN BERGENDAHL	A	35
U.K.	GB 201	Demand for Fuel, 1948-1975, DEPARTMENT OF APPLIED ECONOMICS, Cambridge University	C	66
U.S.A.	USA201	Economic LP Model of the U.S. Petroleum Refining Industry, F.G. ADAMS	A	36
"	USA202	GASNET - Production, Transmission, and Demand for Natural Gas, ROBERT E. BROOKS	A	37
"	USA203	Simulation of Natural Resource Estimation, DeVERLE P. HARRIS	A	38

APPENDIX A: BIBLIOGRAPHICAL DETAILS OF MODELS

(1) K.J. Roy, "Hydrocarbon Assessment Using Subjective Probability and Monte Carlo Methods", 1975.

(2) R.E. Roadifer, "A Probability Approach to Estimate Volumes of Undiscovered Oil and Gas", 1975.

(3) E.R. Stoian, "A Crude Oil Transshipment Model for North America", 1973; "A Natural Gas Transshipment Model for North America", 1974.

(4) M. Imrich Lencz et al., "Prognoses on the Consumption of Energy, Especially Electrical: Methods and Experience", 1975.

(5) A. Breton and F. Falgarone, "Gestion Optimale des Réservoirs d'une Vallée Hydraulique", presented at the Colloquium on Operations Research, Institut de Recherches d'Informatiques Appliquées, Versailles, 1973.

(6) Electricité de France, Direction des Estudes et Recherches, "Un Modèle de Gestion d'un Ensemble Hydraulique et Thermique avec Abus de Consommation et de Disponibilité des Groupes", Notes HR 9049/3, HR 10156/3 and HR 10420/3, 1974.

(7) Orgreb-Institut für Kraftwerke, "Model for Optimizing Electric Power Generation with Respect to the Cycles per Week", 1973.

(8) Ingenieurbureau für Rationalisierung in der Braunkohleindustrie, "General Simulation Model of Rail-Operated Extraction in Lignite Open Mines Producing One Type of Fuel", 1971.

(9) Staatliches Undernehmen der Elektroenergieversorgung, "Dynamic Economic Model for Calculating the Optimum Siting of Nuclear Power Stations with Respect to the Development of Transmission Network Structure", 1973.

(10) J. Vardi, "Approaches to the Optimal Planning of Electrical Energy Generation Systems: the Israeli Experience", 1973.

(11) L. Paris and M. Valtorta, "Planning the Installation of Large Units in Interconnected Systems: Relevant Parameters and their Relative Influence", CIGRE, Paris, Report 32-12, 1968.

(12) G. Manzoni, L. Marzio, P.L. Noferi and M. Valtorta, "Computing Programs for Generation Planning by Simulation Methods", paper 1.1.10 presented at the 4th Power System Computation Conference, Grenoble, 1972.

(13) P.L. Noferi and L. Paris, "Quantitative Evaluation of Power System Reliability in Planning Studies", IEEE Winter Power Meeting, New York, 1971; and in IEEE Transactions on PAS, No. 2, pp. 611-618, 1972.

(14) P.L. Noferi and L. Salvaderi, "A Set of Programs for the Calculation of the Reliability of a Transmission System", paper presented at the International Union of Producers and Distributors of Electrical Energy, Data Processing Conference, Lisbon, 1972.

(15) Peter R. Odell and K.E. Rosing, "The North Sea Oil Province - An Attempt to Simulate its Development and Exploitation 1969-2029", 1975.

(16) L. Honório and A. Leite Garcia, "Simulation d'un Système de Production Hydro et Thermo-Électrique en Utilisant des Moyens Limités de Calcul Automatique", paper presented at the UNIPEDE Computer Science Colloquium, Madrid, 1974.

(17) Göran Bergendahl, "Investment and Operation of Electricity: I A Multi-Period Cost Minimization Model for Sweden; II Price Discrimination and Nuclear Postponement; III Principles for Pricing Peak and Off-Peak Load, European Institute for Advanced Studies in Management, Brussels, Working Papers 74-4, 1974; 74-15, 1974; and 75-10, 1975, respectively.

(18) DeVerle P. Harris, "Economic Appraisal of Regional Resources Based upon Geostatistical Analysis and Computer Simulation", 1970.

(19) H. Požar and J. Keglević, "A New Method for Determination of the Utilization of Storage Basins of Hydro Power Plants", 1973.

(20) H. Požar, V. Filipović and P. Bodlović, "The Method of Constant and Variable Energy for Analysis of Conditions in the Electro Energetic System Adjusted to Calculation on the Electronic Computer", Energija 21, 1972.

(21) H. Požar and P. Bodlović, "Output Reserve in Thermal Power Plants of a Power System", Elektrizitätswirtschaft 72, 1973.

(22) H. Požar and G. Granić, "Method for Determination of the Influence of Pumped Storage Plants on the Power System of the Electric Power Industry", Elektrizitätswirtschaft 73, 1974.

(23) J.D. Khazzoom, "An Application of the Concepts of Free and Captive Demand to the Estimation and Simulation of Energy Demands in Canada", paper presented at the I.I.A.S.A. Workshop on Energy Demand, Laxenburg, 1975.

(24) K. Kelemen and A. Vári, "Simulation Model of Structural Decisions in the Hungarian National Petroleum and Gas Trust (OKGT)", 1973.

(25) F. Rabár, "Simulation of Investment Policy in the Hungarian Energy Economy", 1969.

(26) F. Boselli, "Discussion sur l'Emploi d'une Version de la Fonction de Production Cobb-Douglas pour la Prévision de la Consommation Finale d'Energie", paper presented at the ECE Symposium on Mathematical Models of Sectors of the Energy Economy, Alma-Ata, 1973.

(27) Department of Applied Economics, University of Cambridge, "The Demand for Fuel, 1948-1975: A Sub-Model for the British Fuel Economy", 1968.

(28) M. Allais, "Algerian Sahara Case Study", Management Science 3, 1957.

(29) Gordon M. Kaufman and Paul G. Bradley, "Two Stochastic Models Useful in Petroleum Exploration", 1971.

(30) Gordon M. Kaufman and E. Barouch, "A Probabilistic Model of Oil and Gas Discovery", 1975.

(31) Kent P. Anderson, "Toward Econometric Estimation of Industrial Energy Demand: An Experimental Application to the Primary Metals Industry", 1971.

(32) L.D. Chapman and T.D. Mount, "Effects of Increasing the Use of Electricity on Environmental Quality in the U.S.: A Model of Power Generation and the Policy Issues Raised by its Application", 1974.

(33) W.K. Foell, "The Wisconsin Energy Model: A Tool for Regional Energy Policy Analysis", Energy Systems and Policy Research Report No. 10, Institute for Environmental Studies, University of Wisconsin, 1974.

(34) J.H. Hollomon, B. Raz and R. Treitel, "Nuclear Power and Oil Imports: A Look at the Energy Balance", Center for Policy Alternatives, M.I.T., Report CPA 75-6, 1975.

(35) B. Ahmed, H. Davitian, B. Glenn, D. Reister and C.E. Whittle, "Long Range U.S. Energy Model", 1974.

(36) P.F. Schweizer, C.G. Love and J. Hunter Gilles, "A Regional Energy Model for Examining New Policy and Technology Changes", 1973.

(37) H. Požar, "Mathematical Model for Determination of Optimal Energetic Structure", paper presented at ECE Symposium on Mathematical Models of Sectors of the Energy Economy, Alma-Ata, 1973.

(38) W.D. Nordhaus, "The Allocation of Energy Resources", Brookings Institution Papers on Economic Activities, 1973-3.

(39) International Atomic Energy Agency, "WASP - The I.A.E.A. Computer Code for Electricity System Expansion Planning", Appendix A to the I.A.E.A. Nuclear Power Planning Study Manual, 1975.

(40) R.T. Jenkins and D.S. Joy, "Wien Automatic System Planning Package", U.S.A.E.C., Oak Ridge, Tenn., Report ORNL-4945, 1974.

(41) International Atomic Energy Agency, "Market Survey for Nuclear Power in Developing Countries", 1973 and 1974.

(42) W.D. Nordhaus, "The Demand for Energy - An International Perspective", paper presented at the I.I.A.S.A. Workshop on Energy Demand, Laxenburg, 1975.

(43) F.W. Gorbet, "Energy Demand Projection for Canada: An Integrated Approach", 1975.

(44) D. Finon, "Optimization Model of the French Energy Sector", Energy Policy 2, 1974.

(45) V. Paretti, V. Cao-Pinna, L. Cugia and C. Righi, "Struttura e Prospettive dell' Economia Energetica Italiana", Edizioni Scientifiche Einaudi, Turin, 1960.

(46) F.G. Adams and James Griffin, "An Economic Linear Programming Model of the U.S. Petroleum Refining Industry", J. American Statistical Assoc., 67, 1972.

(47) R.T. Crow and B. Ratchford, "An Econometric Approach to Forecasting the Market Potential of Electric Automobiles", paper presented at the I.I.A.S.A. Workshop on Energy Demand, Laxenburg, 1975.

(48) A.S. Nekrasov, A.A. Makarow, M.A. Rubin, I.A. Steinevichyus, A.G. Vigdorchik and A.V. Voronin, "Model System for the Optimal Development of the Energy Industry on a Country-Wide, Regional and Sectorial Scale", 1973.

(49) H. Neu, "A Dynamic Model for Simulating Future Energy Demand and Supply in the European Communities: Scenarios for the year 2000 and Beyond", Euratom Report, 1975.

(50) Robert E. Brooks, "Allocation of Natural Gas in Times of Shortage: A Mathematical Programming Model of the Production, Transmission, and Demand for Natural Gas Under Federal Power Commission Regulation", Ph.D. Thesis, M.I.T., 1975.

APPENDIX B: PERSONS AND INSTITUTIONS CONTACTED
(Mailing List)

AUSTRIA

Bundeskammer der gewerblichen
Wirtschaft
Biberstrasse 10
1010 Vienna
Dr. Josef Richter
Dr. Werner Teufelsbauer

Österreichisches Institut für
Wirtschaftsforschung
Arsenal
Postfach 91
1103 Vienna
Dr. H. Kramer
Dr. Karl Musil

Technische Hochschule Wien
Karlsplatz 13
1030 Vienna
Prof. L. Bauer
Dr. Tintner, Institut für Ökonometrie

Prof. Dr. G. Bruckmann
Rechts- und staatswisenschaftliche
Fakultät der Universität Wien
Universitätsstrasse 7
1010 Vienna

Mr. K. Fessl
Österreichische Elektrizitätwirtschaft-AG
Wien

Prof. Han Grümm
Österreichische Studiengesellschaft
für Atomenergie Ges.m.b.H.
Lenaugasse 10
1082 Vienna

Mr. R. Lehner
Steweag
Graz

Dipl. Ing. Pober
ÖEWAG-Verbundgesellschaft
Am Hof 6A
1010 Vienna

Dr. V. Sohenk
Schweizer Botschaft
Prinz-Eugenstr. 7
1030 Vienna

Ministerialrat Dr. W. Franck
Bundesministerium für Wissenschaft
und Forschung
Währingerstr. 28
1090 Vienna

M. l'attaché Scientifique près
l'Ambassade de France
Palais Lobkowitz
Lobkowitz Platz
1010 Vienna

ARGENTINA

Dr. Andre van Dam, Director of
Planning
CPC Latin America
Cerrito 866
Buenos Aires

Dr. Amilcar Herrera
Fundacion Bariloche
Casilla de Correo 138
San Carlos de Bariloche
Prov. de Rio Negro

BELGIUM

Mr. Göram Edsbäcker
European Institute for Advanced
Studies in Management
20, Place Stephanie
1050 Brussels

Mr. M. de Falleur
Bureau de Plan
47-49, Av. des Arts
1040 Brussels

Prof. H. Glesjer
Université Libre de Bruxelles
Terhuspsesteenweg 166
1170 Brussels

Mr. R. Groszmann, Director
Union des Exploitations
Electriques en Belgique
4, Galérie Ravenstain
1000 Brussels

Dr. J.P. Hansen
Cabinet du Ministre des
Affaires Economiques
23, Square de Meêus
1040 Brussels

Mr. M. Jaumotte
Faculté des Sciences Economiques
et Sociales
8, Rampart de la Vièrge
5000 Namur

Mr. P. Markey
Administration de l'Energie
Ministère des Affaires Economiques
49-51, Avenue de Trèves
1040 Brussels

Mr. Manfred Siebker, Managing Director
S.C.I.E.N.C.E.
177, Avenue Louise
1050 Brussels

Prof. J. Waelbroeck
Département d'Economie Appliquée
(DULBEA)
Université Libre de Bruxelles
50, Av. F.D. Roosevelt
1050 Brussels

BULGARIA

Energoproekt
bul. Anton Ivanov N. 56
Sofia
Mr. Kamenov
Mr. Luben Petkov

Eng. Vanio Mitov
c/o The National Center for
Cybernetics and Computer Techniques
8, Slavjanska Street
Sofia

Mr. I.V. Peitchev
Centre Scientifique de Planification
des Modèles Mathématiques et des
Prévisions du Développement Social
et Economique
58, rue Alabine
Sofia

Comité d'Etat de Planification
Institut Scientifique de Planification Economique et de Recherche
7 Noemvri I
Sofia

Institut Economique
Académie des Sciences de Bulgarie
ul. Axakov N. 3
Sofia

Institut Scientifique
Institut du Commerce Extérieur
Sofia

CANADA

Department of Energy, Mines and
Resources
299 Carling Ave.
Ottawa, Ontario K1A OE4
Dr. R.P. Charbonnier, Chief
Energy Research and Development
Dr. F.W. Gorbet
Dr. I.A. Stewart
Mr. C.E. Zwicker, Economic
Studies Division

Economic Council of Canada
P.O. Box 527
Ottawa, Ontario K1P 5V6
Mr. John Dawson, Director
Mr. M.C. McCracken

Ministry of State for Science and
Technology
Ottawa, Ontario
Mr. J.T. Bradley
Dr. A.R. Demirdache, Director of
TF/DA Division

Mr. H. Flynn, Policy Adviser
Technological Forecasting and
Technology Assessment Division
Dr. J.R. Whitehead, Special
Advisor
Office of the Secretary

National Energy Board
473 Albert Street
Ottawa, Ontario K1A OG1
Mr. M.A. Crowe, Chairman
Mr. G.T. McLoughlin
Mr. R.C. Richards, Industrial Models
Division
Mr. E.R. Stoian, Operations Research
Branch
Mr. J.M. Treddenick, Chief
Econometrics Division

Department of Economics
University of British Columbia
2075 Westbrook Place
Vancouver, B.C.
Dr. Paul G. Bradley
Prof. John Helliwell

Mr. Paul L.H. Camirand
Office de Planification et de
Développement du Québec
Université de Sherbrooke
Sherbrooke JIK 2RI

Prof. J.G. Debanne
Faculté des Sciences de la Gestion
Université d'Ottawa
Ottawa, Ontario K1N 6N5

Dr. A.R. Dobell
Planning Branch
Treasury Board Secretariat
160 Elgin Street
Ottawa, Ontario K15 OR5

Mr. R. Hamilton
University of Calgary
Calgary, Alberta

Mr. D.G. Hurst
Atomic Energy Control Board
107 Sparks Street
Ottawa, Ontario K1P 5S9

Prof. A.I. Johnson
Dean of Engineering Science
University of Western Ontario
Richmond Street North
London 72, Ontario

Mr. J.D. Khazzoom
McGill University
Montreal, Quebec

Mr. McCauley
Policy Planning and Evaluation
Directorate
Environment Canada
Ottawa, Ontario K1A OH3

Dr. Peter Meyboom, Director General
Science Procurement
Department of Supply and Service
Ottawa, K1A OS5

Mr. D.S. Montgomery
Fuels Research Centre
c/o 555 Booth Street
Ottawa, Ontario K1A OG1

Mr. Marc Morin, Executive Director
Intergovernmental Committee on Urban
and Regional Research
36 Wellesley Street West
Toronto, Ontario M4Y 1G1

Mr. J. Mullin, Deputy Executive Director
Science Council of Canada
Ottawa, Ontario

Mr. André Raynauld
Economic Council of Canada
P.O. Box 527
Ottawa, K1P 5V6

Dr. K.J. Roy
Geological Survey of Canada
Edmonton, Alberta

Dr. J.T. Ryan
University of Alberta
Edmonton, Alberta

Prof. Leonard Waverman
Dept. of Political Economy
University of Toronto
Toronto, Ontario

Mr. S.O. Winthrop, Director General
Air Pollution Control Directorate
Environment Canada
Ottawa, Ontario K1A OH3

Legislative Library
Legislative Bldg.
P.O. Box 6000
Fredericton N.B. E3B 5H1

CYPRUS

Mr. I. Aristidou
The Planning Bureau
Nicosia

C.S.S.R.

Institute of Fuel and Power
Federal Ministry for Technical Development
Slezska 9
Prague 2
Mr. V. Bruha
Mr. D. Vaverka, Vice Director

Power Research Institute
Partyzanska 7a
Prague 7
Mr. Milos Drahny, Csc.
Mr. Imrich Lencz, Csc.

Mr. Jiri Bouska
Econometric Laboratory
C.S.S.R. Academy of Sciences
Politickych veznu 7
Prague 1

Mr. Bohuslav Cabicar
Energy Economy Section
Energy Research Institute
Nahrou de 19
Prague 10

Mr. E. Goldberger
Most Branch
Research Institute for Fuel and Energy Economics
Most

Mr. V. Kraus
Research Institute of Mining, Economics and Energy
Vladislavova 4
Prague 1

Mr. M. Marval, Head
Energy Development Department
Federal Ministry of Fuel and Energy
Stepanska 28
Prague 1

Mr. Jaroslav Podzimek
Research Institute of Statistics and Accounting
Sokolovska
Prague

Mr. D. Stratil
Computing Research Center
Dubravska cesto
Bratislava

Dr. Tibor Vaško
Committee for IIASA of the C.S.S.R.
Slezska 9, Vinohrady
Prague 2

DENMARK

Mr. Sven Bjørnholm
The Niels Bohr Institute
Blegdamsvej 17
2800 Copenhagen

Mr. Peter Erling Nielsen
Det Økonomiske Rad
Nørre Voldgade 68
1358 Copenhagen

Mr. Bent Thage
Input-Output Dept.
Danmarks Statistik
Sejrøgade 11
2100 Copenhagen

Mr. J.E. Yndgaard
Institute of Economics
University of Aørhus
NDR Ringgade
Universitetsparken
8000 Aørhus

EGYPT

Dr. Samir I. Ghabbour
Dept. of Natural Resources
African Institute
Cairo University
Cairo

F.R.G.

Institut für Elektrische Anlagen
und Energiewirtschaft
Technische Hochschule Aachen
51 Aachen
Mr. R. Bieselt
Prof. Mandel
Mr. Gerd Modemann
Mr. Paul Winzke

Kernforschungsanlage Jülich
517 Jülich 1
Mr. D. Elsinghorst
Mr. W. Meier
Mr. S. Rath-Nagel
Mr. A. Voss

Kernforschungszentrum Karlsruhe
Postfach 3645
75 Karlsruhe 1
Mr. G. Friede
Mr. Dieter Sellinschegg

Dr. Hartmut Bossel
Institut für Systemtechnik und
Innovationsforschung
Fraunhofer-Gesellschaft e.V.
Breslauer Strasse 48
75 Karlsruhe

Prof. W. Dreger
Zentrum Berlin für Zukunftsforschung e.V.
Giesebrechtstrasse 15
1 Berlin 12

Prof. Carl Friedrich
Frhr. von Weizsaecker
Max-Planck-Gesellschaft zur
Erforschung der Lebensbedingungen
der Wissenschaftlichtechnischen Welt
Riemerschmidstrasse 7
813 Starnberg

Mr. M. Liebrucks
Deutsches Institut für Wirtschafts-
forschung
Königin-Luisestrasse 5
1 Berlin 33

Dr. Helmut Maier
Institut für Stadt- und Regionalplanung
Technische Universität Berlin
Strasse des 17. Juni 135
1 Berlin 12

Prof. E. Pestel
Lehrstuhl A für Mechanik
Technische Hochschule
Rodabruchstr.
Hannover 3

Dr. K. Repenning
British Petroleum
Postfach 1030
2 Hamburg

Prof. H. Schäfer
Forschungsstelle für Energiewirtschaft
Am Blütenanger 71
8 Munchen 50

Prof. H.K. Schneider
Energiewirtschaftliches Institut
Universität Köln
Albert-Magnus-Platz
5 Köln 41

Prof. R. Thoss
Institut für Siedlungs- und Wohnung-
wesen der Universität Münster
Am Stadtgraben 9
44 Münster

Dipl. Ing. H. Tröscher
R.W.E.
Kruppstrasse 5
43 Essen

Ministerialrat Heinrich Quante
Energy Analysis and Projections
Bundesministerium für Wirtschaft
Villemomblerstr. 76
53 Bonn

FINLAND

Mr. K.O. Huuskonen, Head
Statistical Office
Neste Oy, Kaivokatu 10A
Helsinki 10

Prof. Antero Jahkola
Imatran Voima Osakeyhtiö
B.P. 138
Helsinki 10

Mr. M.A. Jaakonaho
Study Group for Economic Research
on Energy
Bank of Finland
Hämeenkatu 2 A2
Turku 50

Mr. Erkki Laate
Economic Planning Centre
Erottaja 15 A
Helsinki 13

Mr. Kaarlo Larno, Managing Director
Research Institute of the Finnish
Economy
Kalevankatu 3B
Helsinki 10

Mr. I.H. Lavanius, Chief Inspector
Industrial Department
Energy Policy Branch
Ministry of Trade and Industry
Aleksanterinkatu 10
Helsinki 17

Mr. Tor Nyman
IBM Finland
Helsinki

Mr. Lars-Erik Öller
Economic Department
Ministry of Finance
Fabianinkatu 8
Helsinki 13

Mr. Seppo Salo
University of Technology
Helsinki

FRANCE

Délégation Générale á l'Energie
35, rue Saint-Dominique
75007 Paris
M. Y. Girard, Chargé de Mission
M. Renon

Institut Economique et Juridique de l'Energie
Université de Grenoble - I.R.E.P.
Domaine Universitaire de St-Martin d'Hères
B.P. 47 - Centre de tri
38040 Grenoble Cedex
M. J. Girod
M. J.M. Martin
M. Ramain

Institut National des Sciences et Techniques Nucléaires
91 Gif-sur-Yvette
M. E. Bauer
Prof. Fourgeaud
Prof. Ville

Electricité de France
2, rue Louis Murat
75008 Paris
M. Marcel Boiteux
M. Bernard, Service des Etudes Economiques Générales
M. Breton, Service des Etudes Economiques Générales
M. Gouni, Chef Service des Etudes Economiques Générales
M. Robert Janin, Chef Adjoint Service de la Production Thermique
M. Lacoste, Cabinet du Président Directeur Général
M. Louis Puiseux, Service des Etudes d'Economiques Générales

M. M. Allais
Ecole Nationale Supérieure des Mines
Paris

M. Jacques Attali
Ecole Polytechnique
7, Bd. Flandrin
75016 Paris

Mr. Aujac
B.I.P.E.
122, av. Charles de Gaulle
92 Neuilly

M. Bessière
CEPREMAP
140, rue du Chevaleret
75013 Paris

Mr. D. Blain, Chargé de Mission
Direction de la Prévision
Ministère des Economies et des Finances
9, rue Croix des Petits Champs
75001 Paris

M. Chevet
C.F.P.
5, rue Michel Ange
75016 Paris

M.C. Debackere
Dept. Economie, I.F.P.
1, av. de Bois Préau
92502 Rueil Malmaison

M. Jean Denizet
Directeur des Etudes Economiques et Financières
Banque de Paris et des Pays-Bas
3, rue d'Antin
75002 Paris

M. Destival
Rapporteur Général de la Commissio de l'Energie
18, rue de Martignac
75007 Paris

M. Dourille
C.E.R.E.N.
1, rue Caumartin
75009 Paris

M. F. Finon
Université de Grenoble
38040 Grenoble Cedex

M. Godet
SEMA
Marketing et Modèles de Décision
16 rue Barbés
92128 Montrouge

M. Hamelin, Directeur Général
I.N.S.A.
20, av. Albert Einstein
69621 Villerbanne

M. Hebert
Service de la Statistique
83, Bd. de Montparnasse
75006 Paris

M. Humbert
Institut Géodynamique
Université de Bordeaux III
Avenue des Facultes
33405 Talence

M. Ippolito
Charbonnages de France
B.P. 396 08
9, av. Percier
75360 Paris Cedex

Prof. Levi, Président
CNES
129, rue de l'Université
75007 Paris

Prof. Edmond Malinvaud
Direction de la Prévision
6, avenue de l'Opéra
75001 Paris

M. J. Masseron, Directeur
Centre d'Etudes Supérieures d'Economie Pétrolière
I.F.P.
B.P. 18
92502 Rueil Malmaison

Prof. Nguyen Khac Nhan
Institut Polytechnique
B.P. 15 - Centre de Tri
38040 Grenoble Cedex

M. Pierre, Chef
Departement des Programmes
Commissariat à l'Energie Atomique
29-33, rue de la Fédération
75015 Paris

M. Ploton
E.L.F.-E.R.A.P.
rue Nelaton
75015 Paris

Prof. Roy
Centre Universitaire Dauphine
Place de Lattre de Tassigny
75016 Paris

M. Syrota
Agence pour l'Economie de l'Energie
30, rue de Cambronne
75015 Paris

M. L. Thiriet
Chargé des Etudes Economiques Générales
Departement des Programmes
Commissariat à l'Energie Atomique
29-33, rue de la Fédération
75015 Paris

G.D.R.

Institut für Energetik
Torgauerstr. 114
7024 Leipzig
Mr. P. Hedrich
Dr. Kahn
Mr. K. Lindner
Mrs. U. Reymann

Prof. Hans Mottek
c/o Academy of Sciences of the GDR
Leipziger Strasse
108 Berlin

Prof. J. Rudolph
Hochschule für Ökonomie Berlin
Dunckerstrasse 8
1157 Berlin-Karlshorst

Braunkohleindustrie
Grossräschen

Brennstoffinstitut
Freiberg/Sa.

Energieversorgungsbetriebe
Leipzig

Erdölarbeitungsindustrie
Schwedt

Ogreb-Institut für Kraftwerke
Cottbus

Ogreb-Institut für Kraftwerke
Vetschau

Staatliches Unternehmen der
Elektroenergieversorgung
Berlin

GREECE

Mr. C. Aronis
Centre of Planning and Economic
Research
Hippokratous 22
Athens 144

The Director
Institute of Economic Research
Hippokratous 22
Athens 144

Mr. C. Delis
Chef du Service de Planification
Economique
Entreprise Publique d'Electricité
de Grèce
4, rue Aloupekis
Athens

Mr. A. Samaras
Entreprise Publique d'Electricité
de Grèce
4, rue Aloupekis
Athens

Director of Planning Services
Ministry of Coordination
3 Amerikis Street
Athens

HUNGARY

Econometric Laboratory
Central Statistical Office
Keleti Karoly u. 5-7
Budapest II
Mr. M.L. Halabuk
Ms. Katalin Hulyak

National Board for Power and
Fuel Economy
Marko utca 16
1955 Budapest
Mr. P. Erdosi
Mr. G. Goldvary
Mr. Patyi Karoly

Mr. G. Gekecs
Department Chief
Computer Centre of National
Planning Office
Amgol u. 27
1149 Budapest

Mr. K. Kelemen
Systems Engineering Institute INFILOR
Budapest

Prof. Janos Kornai
Institute of Economics
Hungarian Academy of Sciences
Nado utca 7
Budapest V

Dr. F. Rabár
Laboratory for Information Processing
Budapest

Mr. T. Zettner, Managing Director
Hungarian Electricity Board
Iskola 13
1011 Budapest

ICELAND

Mr. Jakob Björnsson, Director General
National Energy Authority
Laugavegur 116
Reykjavik

INDIA

Prof. T.N. Srinivasan
Indian Statistics Institute
502 Yojana Bhavan
Parliament Street
New Delhi

IRELAND

Economic and Social Research Institute
4, Burlington Road
Dublin
Mr. E.W. Henry
Mr. S. Scott

Department of Finance
Economic Development Branch
72-76 St. Stephen's Green
Dublin 2

ISRAEL

Mr. J. Vardi
Ministry of Development
Tel Aviv

ITALY

ENEL, Ufficio Studi e Ricerche
via G.B. Martini 7
00100 Rome
Mr. F. Boselli
Prof. Learnini
Prof. Valtorta

ENEL
via Valvossori Peroni, 77
20133 Milan
Mr. P.L. Noferi
Mr. L. Paris
Mr. Giorgio Quazza

Mr. Omero Comellini
c/o CNEN-PRV
via Arcoveggia 56
Bologna

Mr. Francesco Del Monte
Facolta di Scienze Politiche
via Zamboni 1
40135 Bologna

Mr. Dario Monti
FIAT
Corso Marconi
10100 Torino

Mr. V. Paretti
Ente Nazionale Idrocarbone
00100 Rome

Prof. Mario Silvestri
Istituto di Fisica Tecnica
Milano

Dott. Sillitti
Istituto Studi Programmazione
Economica
00100 Rome

Biblioteca
ENEL
Compartimento di Milano
via Carducci 1
Milan

JAPAN

The Institute of Energy Economics
28 Mishikubo Sakuragawa-Cho
Minato-Ku
Tokyo
Mr. Yukio Sekiya
Dr. Mitsuo Takei, Manager
Research Division

Prof. Takao Hoshi
College of Engineering
Seikei University
Kichijoji-Kita
Musashino-Ski
Tokyo - 180

Dr. Ruykichi Imai
The Japan Atomic Power Co.
Otemachi Bldg. No 6 1-Chome
Otemachi, Chiyoda-Ku
Tokyo

Prof. H. Katsunuma
27 Shinanomachi
Shinjuku-Ku
Tokyo

Dr. Fusao Mori, Chief Engineer
Central Research Laboratory
Mitsubishi Electro Corp.
2-3 Morunouchi
2-Chome Chiyoda-Ku
Tokyo

Prof. Hirofumi Uzawa
Faculty of Economics
University of Tokyo
Bunkyo-Ku
Tokyo

MALTA

Mr. S. Busuttil
Department of Applied Economics
The Royal University of Malta
Msida

MEXICO

Dr. M.A. Cardenas
Planificacion y Desarrollo
de Sistemas
Florencia No. 39-102
Mexico 6, D.F.

H. Jorge G. Duran, Subjefe de
Planeacion
Cia de Luz y Fuerza del Centro
Melchor Ocampo 171-407
Mexico 17, D.F.

NETHERLANDS

Erasmus University
Rotterdam
Mr. J.A. Hartag
Mr. P.R. Odell

Mr. K. Bez
Cornelis Danckerlsstr. 35
Rotterdam 14

Mr. J. Boon
Lange Kleiweg 5
Rijswijk

Mr. J.B. Brinck
International Resources Consultants B.V.
Alkmaar

Dr. W. van Gool
Analytisch Chemisch Lab.
Croesestraat 77A
Utrecht

Mr. G. Goudswaard
Centraal Bureau voor de Statistiek
428 Prinses Beatrixlaan
Voorburg

Prof. T. Kloek
Econometrisch Institut
Centre for Development Planning
Burg. Oudlaan 50
Rotterdam 3016

Prof. O. Rademaker
University of Technology
Insulindelaan 2
Eindhoven

Dr. R. Rote
Economisch en Sociaal Institut
Vrije Universiteit Amsterdam
de Boelelaan 1105
Amsterdam

Mr. Marcus J. Stoffes
Centraal Planbureau
van Stolweg 14
's-Gravenhage

Prof. Timman
Technische Hogeschool
Julianalaan 134
Delft

Prof. Jan Tinbergen
31 Haviklaan
The Hague

Prof. J.J. Went
Nijverheids Organisatie T.N.O.
Juliana van Stolberglaan 148
Postbus 297
The Hague

Prof. P. de Wolff
Dept. of Economics
Municipal University of Amsterdam
Amsterdam

Institut voor Actuariaat an
  Econometrie der Universiteit
Nieuwe Achtergracht 170
Amsterdam

NORWAY

Planning Division
Ministry of Finance
Akersgt 42
Oslo
    Mr. Per Schreiner
    Mr. Odd Solbraa, Deputy Director

Mr. Odd Aukrust
Central Bureau of Statistics of Norway
Dronningens gate 16
P.B. 8131
Oslo 1

Prof. L. Johansen
University of Oslo
Institute of Economics
Boc 1071
Blindern, Oslo 3

POLAND

Planning Commission
Pl. 3 Krzyzy
Warsaw
    Mr. D. Deja, Chief of Section
      Department of Fuel and Energy
    Mr. S. Hatt, Division for Economic
      Analysis

Mr. Z. Falecki, Director
Scientific Centre for Energy Problems
Central Mining Institute (OEK)
Pl. Gwarkow 1
Katowice

Mr. W. Frankowski, Head
Dept. of Nuclear Power
Institute of Nuclear Research
Swierk k. Otwocka
Warsaw

Mr. M. Hajdasinski
Institute for Projecting and Building
  of Mines
Academy of Mining and Metallurgy
Mickiewicza 30
Krakow

Mr. J. Holubiec, Head of Department
Institute of Applied Cybernetics
Polish Academy of Sciences
Warsaw KRN 55

Prof. Jerzy Kolubiec
The Polish Academy of Sciences
c/o Academia Palazza delle Scienze
2 Vicolo Doria
00187 Rome

Prof. Roman Kulikowski
Polish Academy of Sciences
Palace of Culture and Science
Warsaw 00 901

Mr. R. Nowakowski
Head of Laboratory
Instytut Energetyki
Mysia 2
Warsaw 00 496

Prof. Dr. Krzusztof Porwit
Instytut Planowania
Plac Trzech Krzyzy 5
Warsaw 15

PORTUGAL

Companhia Portuguesa de Electricidade
Av. Infante Santo 15
Lisbon I
Mr. R.J. Minotti da Cruz Filipe
Mr. A. Leite Garcia

Mr. J.M. Santos Mota
Presidencia do Conselho
Junta Nacional de Investigacao
Cientifica e Tecnologica
Lisbon

RUMANIA

Dr. M.H. Botez, Director
International Center for Methodology
for Future and Development Studies
University of Bucharest
Bucharest 8

Mr. Jankovitch
Le Comité d'Etat du Plan
Calea Victoriei 152
Bucharest

Mr. M. Petcu
Institut de Recherches d'Energétique
Industrielles et de Projets
d'Outillages Energétiques
Bucharest

Mr. M.I. Sacuiu, Secrétaire
Scientifique
Centre de Statistique Mathematique de
l'Académie des Sciences
Calea Grivitei 21
Bucharest 12

SOUTH AFRICA

Mr. P.W. Stark, Secretary for Planning
Paulhof
Minnaarstraat
Privaate bag X213
Pretoria 0001, Republic of South Africa

SPAIN

Mr. R. Vazquez Candame, Secrétaire
Institut du Développement Economique
Antigua Universidad de Alcala de Henares
Madrid

Mr. Espi
Comisaria del Plan del Desarrollo
Economico y Social
Castellana 3
Madrid

SWEDEN

Government Committee for Energy Forecasting
Munkbron 11, ltr, EPU
11128 Stockholm
Mr. Mats Höjeberg, The National Swedish Industrial Board
Mr. E.S. Ben Salem, Chief

Mr. K.H. Aberg
The National Institute of Economic Research
Nybrokaien 13
Stockholm

Mr. Göran Bergendahl
University of Gothenburg
Vasaparken
41125 Gothenburg

Mr. B.O. Karlsson
Secretariat for Economic Planning
The Swedish Ministry of Finance
Riddarhustorget 7-9, Fack
10310 Stockholm 2

Mr. Per Lindblom
IFIAS
The Nobel House
Sturegaten 14
10246 Stockholm

M. Hans Lönnroth
Cabinet Office
Delegation on Energy Policy Fack
10310 Stockholm

SWITZERLAND

Battelle Research Institute
7, route de Drize
1227 Geneva
Prof. E. Fontela
Mr. Claude Masseti

Université de Fribourg
1, route du Jura
1700 Fribourg
Prof. Billeter, Institut pour l'Automation et la Recherche Operationnelle
Institut des Sciences Economiques et Sociales

Prof. Blanc
Institut de Mathématiques Appliqueés de l'Ecole Polytechnique Fédérale
33, avenue de Cours
1000 Lausanne

Prof. R. Bombach
Institut für angewandte Wirtschafts-forschung
4000 Bale

Prof. B. Fritsch
Institut für Wirtschaftsforschung an der ETH
Universitätsstr. 14
8006 Zürich

Prof. Schelbert
University of Zürich
Rämistr. 71
8000 Zürich

Prof. L. Solari
Centre d'Econometrie
Faculté des Sciences Economiques et Sociales
6, rue de Saussure
Geneva

THAILAND

Dr. Marzouk, Deputy Director
ECAFE
Research and Planning Division
Sala Santitham
Bangkok

TURKEY

Mr. M.O. Tarkan
Turkish Electricity Authority
TEK, Planlama ve Koordinasyon D.
Necatibey Cad. 36
Ankara

U.K.

Department of Energy
Thames House, Millbank
London SW1P 4QJ
Mr. A.D. Johnson
Mr. P.J. Jonas

Department of Trade and Industry
Thames House, Millbank
London SW1P 4QJ
Mr. F.W. Hutber

University of Cambridge
Cambridge CB2 3RQ
Dr. R. Eden,
Cavendish Laboratory
Department of Applied Economics

University of Sussex
Falmer
Brighton, Sussex BN1 9RF
Prof. Freeman, Science Policy
Research Unit
Dr. Geoffrey Heal

Mr. L.G. Brookes
U.K. Atomic Energy Authority
11 Charles II Street
London SW1 4PQ

Mr. D. Burnet
Northern Ireland Joint
Electricity Authority
12, Manse Road
Castlereagh, Belfast BT6 9RT

Mr. M.W. Clegg
British Petroleum
Britannic House
Moor Lane
London EC2Y 9BU

Prof. R.J. Deam
Energy Group
Queen Mary College
Mile End Road
London E1 4NS

Mr. C.E. Iliffe
Reactor Group
U.K. Atomic Energy Authority
Risley, Warrington, Lancs.

Mr. F.P. Jenkin
Central Electricity Generating
Board
Sudbury House
15 Newgate Street
London EC1

Dr. Jones
Programmes Analysis Unit
Chilton, Didcot, Berks. OX11 ORF

Prof. G. Kouris
Department of Economics
University of Surrey
Guildford, Surrey GU2 5XH

Prof. P.D. McPherson
Department of Systems Science
City University
St. Johns Road
London

Mr. Peter Roberts
System Analysis Research Unit
Department of the Environment
2 Marsham Street
London SW1P 3EB

Dr. M. Slesser
Energy Analysis Unit
C.I.I. Building
100 Montrose Street
Glasgow G4 OLZ

Mr. R.C. Tomlinson
Operation Research Society
Nevill House
Waterloo Street
Birmingham B2 5TX

U.S.A.

Electric Power Research Institute
3412 Hillview Avenue
Palo Alto, Calif. 94304
- Mr. Frank Alessio
- Dr. R.T. Crow
- Dr. Sam H. Schurr
- Dr. Chauncey Starr

Harvard University
Cambridge, Mass. 02138
- Prof. Robert Dorfman, Dept. of Economics
- Prof. Hendrik Houthakker, Dept. of Economics
- Prof. Dale Jorgenson, Dept. of Economics
- Prof. Wassily Leontief, Littauer Center
- Prof. A.S. Manne, Littauer Center

Institute for Energy Analysis
P.O. Box 117
Oak Ridge, Tenn. 37830
- Mr. McPherson
- Mr. David Reister
- Dr. Ernest G. Silver
- Mr. Charles E. Whittle

M.I.T.
Cambridge, Mass. 02139
- Prof. Morris Adelman, Dept. of Economics
- Dr. M.L. Baughman, Energy Analysis and Planning Group
- Mr. Robert E. Brooks
- Prof. Franklin Fisher, Dept. of Economics
- Dr. J.H. Hollomon
- Prof. Gordon Kaufman, Sloan School of Management
- Prof. P.W. MacAvoy, Sloan School of Management
- Prof. Robert Solow, Dept. of Economics
- M. R. Treitel, Center for Policy Alternatives
- Prof. David White, Energy Laboratory

Rand Corporation
1700 Main Street
Santa Monica, Calif. 90406
- Mr. Kent P. Anderson
- Mr. William E. Mooz

Stanford University
Stanford, Calif. 94305
- Prof. Thomas J. Connolly, Dept. of Mechanical Engineering
- Prof. George B. Dantzig, Dept. of Operations Research
- Prof. Dr. Bert G. Hickman, Dept. of Economics

Thayer School of Engineering
Dartmouth College
Hanover, N.H. 03755
- Prof. D. Meadows
- Dr. R.J. Rahn

University of Pennsylvania
3718 Locust Street
Philadelphia, Penn. 19104
- Mr. F.G. Adams, Dept. of Economics
- Prof. Lawrence R. Klein, Dept. of Economics

Yale University
New Haven, Conn. 06520
Dr. W.D. Nordhaus, Dept of Economics
Dr. Martin Shubik, Cowels Foundation for Research in Economics

Mr. Robert Ayres
International Research and Technology Corp.
1225 Connecticut Ave. W.
Washington, D.C. 20036

Mr. H.L. Brown
Drexel University
Philadelphia, Penn. 19104

Mr. E.S. Cazalet
Stanford Research Institute
Menlo Park, Calif. 94025

Dr. L.D. Chapman
Cornell University
Ithaca, N.Y.

Prof. Hollis Chenery
IBRD
1818 H Street N.W.
Washington, D.C. 20433

Dr. Earl Cook
Texas A & M University
College Station, Texas 77843

Mr. E.A. Copp
American Petroleum Institute
1801 K Street N.W.
Washington, D.C. 20550

Mr. P.P. Craig
Office of Energy Policy
National Science Foundation
1800 G Street N.W.
Washington, D.C. 20550

Dr. J. Darmstadter
Resources for the Future, Inc.
1755 Massachusetts Ave. N.W.
Washington, D.C. 20036

Dr. J.G. Ecker
Rensselaer Polytechnic Institute
Troy, N.Y. 12181

Mr. E. Erickson
Dept. of Economics
North Carolina State University
Raleigh, North Carolina 27607

Dr. W. Foell
University of Wisconsin
Madison, Wisconsin

Mr. Laurel Friedman
Charles River Associates, Inc.
16 Garden Street
Cambridge, Mass. 02138

Dr. Ralph Gomory
IBM - Thomas J. Watson Research Center
P.O. Box 218
Yorktown Heights, N.Y.

Mr. DeVerle P. Harris
Pennsylvania State University
University Park, Penn.

Dr. K. Hoffman
Dept. of Applied Science Engineering and Systems Division
Brookhaven National Laboratory
Upton, Long Island, N.Y. 11973

Dr. Charles W. Howe
Department of Economics
University of Colorado
Boulder, Colorado 80302

Dr. Robert A. Herendeen
Oak Ridge National Laboratory
Oak Ridge, Tenn. 37830

Mr. M. King Hubbert,
U.S. Senate
Washington, D.C.

Mr. E.A. Hudson
Data Resources
Lexington, Mass. 02173

Mr. Gerald W. Johnson
System and Energy Group
TWR Inc.
1 Space Park
Redondo Beach, Calif. 90278

Dr. Thomas Long
Dept. of Chemistry
Kent Laboratory
University of Chicago
5727 S. Ellis Ave.
Chicago, Ill. 60637

Prof. M. Mesarovic
Case Western Reserve University
Cleveland, Ohio

Mr. John H. Rixse
Office of Engineering
U.S. Agency for Int. Dev.
Dept. of State
Washington, D.C.

Mr. Stephen Rosenthal
University of California
Berkeley, Calif.

Mr. P.F. Schweizer
Westinghouse Electric Co.
Pittsburg, Penn.

Mr. Jeremy Shapiro
National Bureau of Economics
575 Teech Square
Cambridge, Mass. 02139

Prof. Herbert A. Simon
Dept. of Psychology
Carnegie-Mellon University
Pittsburgh, Penn. 15213

Prof. Vernon L. Smith
California Institute of Technology
Pasadena, Calif. 91109

Mr. R.M. Spann
Dept. of Economics
Virginia Polytechnic Institute
Blacksburg, Virginia

Mr. P.K. Verleger, Jr.
Senior Economist
Data Resources Inc.
29 Hartwell Ave.
Lexington, Mass. 02173

Mr. James A. Walker
Executive Office of the President
New Executive Office Bldg.
Washington, D.C. 20503

Cowles Foundation Library
30 Hillhouse Avenue
New Haven, Conn. 06520

Decision Sciences Corp.
Jenkintown, Penn.

U.S.S.R.

Academy of Sciences
State Committee for USSR
Council of Ministers for Science and Technology
11 Gorky Street
Moscow
- Dr. Ivanov
- Dr. Kichatov
- Dr. Nikolai Kourochkin
- Dr. Kuzovkin
- Dr. Minaev
- Acad. M. Styrikovich

Mr. S.A. Avramenko
The Computing Centre
State Planning Commission of the Ukrainian SSR
Kiev, Ukrainian SSR

Mrs. I.N. Bessonova
G.M. Krzhizhanovsky State Research
Institute of Energetics
Academy of Sciences of the USSR
Leniuskij pr. 14
Moscow

Prof. V. Gluskov
Institute for Cybernetics
Academy of Sciences of the Ukrainian SSR
Kiev, Ukrainian SSR

Dr. Yuri F. Kichatov
Institute of Control Problems
Profsojuznayo 81
Moscow V 485

Dr. V. Medvedev
Scientific Research Institute of
Economic and Economic-Mathematical
Planning Methods
Gosplan, BSSR
1 Slavinskogo
Minsk 23

Dr. A.I. Mekibel
Central Economic Mathematical
Institute
Dept. of Economics
2nd Yaroslavskaya ul 3
Moscow

Prof. N. Moiseev
Academy of Sciences
40 Vavilov Street
Moscow B-333

Dr. A.S. Nekrasov
Institute Energosetiproject
Moscow

Dr. Raman, Chairman
State Planning Committee of the Latvian
SSR
11 Gorky Street
Moscow

Prof. S. Yampolsky
Institute of Economics
Academy of Sciences of the
Ukrainian SSR
Kiev, Ukrainian SSR

YUGOSLAVIA

Economic Institute
Kennedyer trg 7
Zagreb
Dr. R. Lang
Dr. Drago Vojnic, Director

Prof. S. Obradovic
Svetog Nanma 14
Belgrade

Prof. Hrvoje Pozar
Elektrotechnicki Fakultat Zagreb
Trg Marsala Tita 14
Zagreb

Prof. V. Rupnik
Research Centre of the Faculty
of Economics of the University
Trg Revducije 11
Ljubljana

Mr. Simonovic
Director in Zeps
Internacionale brigade No. 1
Belgrade

Mr. Todorovic
Institute for Industrial Economics
Trg Marsala Tita 16/11
Belgrade

Mr. B. Udovicic
Institut de l'Electricité
Zagreb

INTERNATIONAL ORGANIZATIONS

Commission of the European
Communities
Direction of Energy
200, rue de la Loi
1040 Brussels
Mr. L. Corradini
Mr. R. De Bauw
Mr. Van Scheepen

Division of Nuclear Power
I.A.E.A.
Kärntner Ring 11
1010 Vienna
Mr. Rurik Krymm
Mr. Polliart
Mr. T.J. Roberts

O.E.C.D.
2, rue André Pascal
75775 Paris Cedex 16
Monsieur Laading, Chef, Division de l'Energie Direction de l'Industrie et de l'Energie
Prof. K. Oshima, Director for Science Technology and Industry
M. Potier, Central Analysis and Evaluation Unit Environment Division

O.P.E.C.
Dr. Karl Lueger-Ring 10
1010 Vienna
Mr. Cherif Faidi,
Mr. Mahjoob A. Hassanain
Mr. Dicky Darsono Soemiatno

Mr. Ryokichi Hirono
Research and Planning Division
U.N. Economic Commission for Asia and
the Far East
Sala Santitham
Bangkok 2

U.N. Economic Commission for Europe
Palais des Nations
1211 Geneva 10
Mr. Brendow
M. F.R. Brusick
Mr. H.G. Dirickx
Mr. C. Lopez-Polo
Dr. R. Rubin, Direction Genérale de la Recherche de la Science et de l'Education

UNIDO
P.O. Box 837
1011 Vienna
Dr. Y. Cho, Industrial Programming Section of the Industrial Policies and Programming Division
Mr. Becker-Boost

Mr. Helmut Neu, Head
Direct Conversion Division
EURATOM-CCR
Ispra, Varese

APPENDIX C: ERRATA FOR REVIEW OF ENERGY MODELS NO. 1 (JULY 1974)

Page No.	Comment
8 FG 2	The authors are: J. Bürstenbinder, W. Dreger, H. Illing, F. Opalla and P. Rosolski.
84 Ref. (53)	Authors as above; Interim Reports 1972, 1973, 1974.
9 UK4 34 82 Ref. (33)	The correct spelling of the author's name is Iliffe.
33	As the model author, replace O. Tarkan by Dennis Anderson, International Bank for Reconstruction and Development. Ref. (32) on page 82 should thus read: Dennis Anderson, "Models for Determining Least-Cost Investments in Electricity Supply," Bell Journal of Economics and Management Science, 3, 1972.
34 Input Data	- Point 3, The annual mean availability of stations: delete values, as these are liable to change - Point 5, replace "The maximum value...of time" by "The annual mean demand-duration curve as a function of time".
94	In the second column: - delete the third address (Centrum voor...) - the fourth address should read: Econometric Institute Erasmus University Burg. Oudlaan 50 3016 Rotterdam