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A CONCEPTUAL MODEL FOR INDIA

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ENERGY-ECONOMIC PLANNING IN THE DEVELOPING COUNTRIES

A CONCEPTUAL MODEL FOR INDIA*

Shishir K. Mukherjee+

ABSTRACT

Developing countries have been adversely affected by the four-fold increase in oil prices of late 1973. As Energy sectors and other economic sectors are competing for the limited investible resources, increasing energy import and development costs might constrain the economic growth rate in the developing countries in the foreseeable future. Integrated planning for energy and non-energy sectors should be given high priority in these countries to analyse energy policy and development plans within a framework of economic planning. The methodologies used for energy sector planning are not usually applicable to the developing countries due to various reasons.

The present paper describes an approach for integrated Energy-Economic Planning for the developing countries and illustrates this approach in the Indian context. An Energy-Economic Planning Model is considered for India, linking a macro-economic Input-Output Model with Energy Supply Models representing production/conversion and transportation activities and Energy Demand Forecasting Models through an Energy Impact Model. The objective is to determine optimal energy sector development plans for meeting energy demands from productive activities and final consumption, based on alternative future growth scenarios. The Impact of the energy sector on the economy would also be analysed in the Energy-Economic Modelling framework.

1. INTRODUCTION

Energy use has always been linked to economic growth and prosperity of a country. But the energy crisis of late 1973 caused by steep increase in the price of oil has made it necessary that energy sector

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planning and its relationship to economic growth is given increased attention, specifically in the developing countries which had been adversely affected by the oil price rise. The traditional approach to energy planning consisted of (a) Energy Demand Forecasting, (b) Energy Supply Analysis and (c) Energy Supply-Demand Balancing, carried out in that sequence by the individual energy-supplying sectors in isolation from each other. This approach could not satisfactorily handle the effects of inter-fuel substitution and relative price changes on the consumption of individual energy forms. The demand for energy and consequently the investment and foreign exchange needs for the energy sectors are influenced by the rate of growth of the non-energy economic sectors. But these in turn will influence and might constrain the rate of growth of the economy. In the traditional approach, this dual relationship between energy and economic sectors was rarely considered while planning for the energy sectors, but in the post-OPEC era, the prospects of economic growth of any country, and specifically the developing countries, are very intimately linked with the developments in the energy sectors, and an integrated framework for energy-economic planning is needed.

During an earlier study, while investigating suitable methodologies for energy demand forecasting and energy planning applicable in the developing countries, Mukherjee (13) examined some of the methodologies that were used for energy planning in the developed countries such as USA, Canada, UK and France and also in India and Bangladesh.

It was felt that most of the sophisticated econometric and other modelling approaches used in the developed countries (specifically those based on price endogenous supply-demand balancing models) are not suitable for the developing countries. This is not because energy demand in the developing countries is considered price-inelastic, as increase in the price of oil products in early 1974 did have significant effects on their demands, but due to the imperfect market mechanism prevalent in the developing countries. Many developing countries have now nationalized their energy sectors where the public sector organizations in those sectors not only enjoy monopoly rights but their prices are also fixed by the government. It is also felt that following the steep oil price rise in 1973-1974, which acted as a large impulse on the different energy sectors, the supply-demand system would take several years to slowly move towards a new equilibrium situation, but further price changes have taken place before this process is completed. Thus, the energy-economic system might be continually trying to reach a new equilibrium due to the impulsive changes in prices imposed by external factors, but never really reaching the states described by the solution of price-endogenous supply-demand equilibrium models. It is also felt that in the developing countries structural methods related to the economy would be more successful for energy demand forecasting and planning models for the supply sectors would yield greater benefits if least-cost methods for investment planning are followed.

Energy planning in the developing countries is further complicated due to the lack of reliable data on energy consumption, energy prices and other socio-economic variables which determine energy consumption.

Due to this the studies carried out in the developing countries generally show a lack of systematic analytical framework. Energy demand forecasting is usually carried out by simple extrapolation of past trends whereas supply planning is carried on individual project basis and in isolation from other energy sectors. Further complications arise due to the prevalence of non-commercial energy sources, which constitute almost half of the total energy consumed in countries like India and is the only available source of energy for non-lighting uses in a large percentage of villages. As data on the consumption and supply of non-commercial energy sources such as firewood, animal and vegetable wastes, are almost non-existent except those collected by some rural and urban household surveys, planning for energy in the rural sector is very difficult.

The energy-economic model for India is an attempt to fulfill this need for suitable methodology of energy planning in the developing countries and the purpose of the integrated modelling framework would be to study the inter-relation between macro-economic models for the total economy and energy sectors including the impact of specific energy supply scenarios on the economy, and optimal development of the energy sectors consistent with national economic goals. It is expected that the methodology developed for India would be also suitable for many other developing countries in Asia, Africa and Latin America. Section 2 of this paper presents a review of energy-economic planning models used in other countries and Section 3 is devoted to the past experience in energy planning in India. Section 4 describes a national energy economic planning model for India under development, while the concluding Section 5 discusses the importance of such energy-economic planning framework, the iterative solution methodology, the limitations of the model and future research areas.

2 REVIEW OF ENERGY-ECONOMIC MODELS

The importance of modelling the inter-relationships between the energy sector and the rest of the economy has become increasingly evident in many developed and developing countries, particularly since the oil crisis of 1973. In the non-OPEC developing countries this has become essential as the energy sector provides inputs to all the other sectors of the economy and are now claiming a larger share of the total investible resources including foreign exchange reserves. The high price of energy sector development and high cost of energy goods, specifically petroleum and its products, is thus constraining the growth of the rest of the economy. The energy sectors also require goods and materials which could be energy-intensive (e.g. aluminium, steel, cement, and thus not only claim a major share of the industrial production but require additional energy in their production. The traditional approach used for planning sectors, which involved forecasting energy demand based on desired economic growth rates, and planning for the supply of the required amount of energy, is no longer adequate. It is possible that desired economic growth rates may lead to such large investments for the energy sectors, and the non-energy sectors, as well as foreign exchange requirements for importing energy goods, that the economy might not be able to sustain this and a downward revision of the growth rate might be called for. Thus planning for the energy sectors should be undertaken within a consistent economic planning framework, so that the two-way inter-relationship between the energy sector and the rest of the economy is adequately represented.

In the U.S.A., a leading effort to link the energy sector to a macro-economic model of the economy is the Hudson-Jorgenson model (8), which was first reported as a part of the Ford Foundation Energy Policy Project. The model showed that a substantial reduction in energy use could be achieved in USA without major economic cost and this result had been controversial. The Hudson-Jorgenson model consists of a macro-economic growth model and econometric model of inter-industry transactions for nine sectors, five of which are energy sectors, related to coal, petroleum and natural gas and electricity and the rest of the economy is aggregated into four sectors: agriculture, construction and non-fuel mining; manufacturing; transportation; and communication trade and services. The inter-industry model of the US economy is integrated with econometric models of consumer demand and production through a novel device of input-output coefficients which are functions of the prices of products, labour, capital services and competing imports. The econometric model of inter-industry transactions includes a model of demand for inputs and supply of outputs for each of the nine industrial sectors, which must balance each other. The input-output coefficients are treated as endogenous variables rather than fixed coefficients. The prices of all nine products and the matrix of input-output coefficients are determined simultaneously from the model for producer behaviour. The macro-economic model consists of endogenous business and household sectors and exogenous foreign and government sectors. The demand and supply conditions for consumption, investment, capital and labour are integrated and the model is made dynamic by linking investment to the growth of capital stock. The model determines gross national product in real terms and relative prices of labour and capital services required by the inter-industry model.

The Hudson-Jorgenson model being a leading effort to link energy sector to a macro-economic model, its advantages and limitations have been discussed widely (9). The major criticism is the basic assumption in the model of market induced demand-supply equilibrium. Energy prices, as is evident now following the formation of OPEC, are no longer determined by only market forces, and the energy supply-demand situation is rarely in equilibrium, specifically in the developing countries where quite often physical controls are used to curb demand, and prices are fixed by the government, who also own the energy supply agencies in many countries such as in India. The dynamics of the adjustment process due to changed prices and availability of energy is perhaps more important now than the precise equilibrium solution as we may never reach there. The enormous data requirements of the Hudson-Jorgenson model could also create a problem in implementing this type of models in the developing countries only a few of which have developed inter-industry models.

DRI Energy Policy Model (3) has been developed to link the energy demand and macro-economic models together. A general equilibrium model for the U.S. economy including energy and non-energy sectors are considered where prices are determined by a market clearing process. The energy demand model is a partial equilibrium model in which inter-fuel substitution is allowed for given energy demand, and prices are determined in a manner that allows for energy market clearance. Thus, essentially, DRI Energy Policy Model attempts to construct a general equilibrium modelling framework which also incorporates the energy sectors in adequate details for policy planning purposes. As discussed before, the usefulness of such a model would be quite limited in a developing country due to the imperfection of the market mechanism and sudden impulsive price jumps for oil. Econometric macro-economic models are also not very well established in the developing countries.

The Gulf-SRI Model (20) is also based on the assumption of energy supply and demand balancing through the market mechanism. Normally, this concept means that a single price balances supply and demand quantities based on single supply and demand curves. This concept of a market clearing price is generalized in this model to the simultaneous balancing of thousands of supplies and demands over time and connected by a complex network. The solution provides a large number of market clearing prices, each specifying the economics of a fuel at a particular location and time, along with the quantities produced, flow through the transportation network and capacities for energy conversion processes. The main advantages of the Gulf-SRI model is that it is regional in nature, and is based on detailed engineering specification of various energy paths with their efficiencies in a complex network through which energy is extracted, processed and transported to the ultimate user. But it has some of the same limitations of the other models based on the assumption of market equilibrium between demand and supply of energy.

Various modelling techniques have been developed at the Brookhaven National Laboratory (7) including the Reference Energy System, Brookhaven Energy System Optimization Models (BESOM) and an energy input-output model. These techniques are used jointly for strategic planning in the energy sector and these techniques or sub-models are used in an iterative manner. The reference energy system is a network presentation of all technical processes from extraction, refinement, conversion, transport, distribution and consumption in various end uses.

The optimization models are used to analyse interfuel substitution and optimal investments in the energy sector. The single period optimization model is linked to the total economy through an energy input-output model. The final demand (GNP) vector and the technical coefficients of the input-output model could be changed to reflect economic changes, alternative life styles and technological changes in the energy industries. The energy input-output model measures the output of the energy sectors in BTU's of different fuels and the output of these sectors are distributed to eight dummy energy production sectors including motive power, various heating and cooling applications and electricity. Energy requirements from the non-energy sectors are redefined in terms of these energy product categories which permit substitution among fuel supplies.

The solution of the combined energy sector optimization and input-output models is obtained in an iterative manner. Initially a projected final demand vector for input-output model is obtained from the assumed GNP for the planning year and the input-output model is solved to determine basic energy demands or total outputs of the eight energy product sectors. The basic energy demands are disaggregated to obtain appropriate demand equation constraints for the energy optimization model. The energy model is then solved to determine energy supply-demand configurations and set of energy flows. From the energy model output some of the input-output coefficients are computed and these are inserted in the input-output model. The same iterative process is continued and convergence of Basic Energy Demands is tested after each iteration. This approach appears amenable to those developing countries where detailed input-output tables are available, but does call for large data requirements including physical data on energy consumption in the various industries.

The Pilot Energy Model (1) is a dynamic linear programming model based on an input-output table of US economy and a detailed representation of the energy sectors. In the model, a 23-sector input-output matrix represents various industrial processes. The national bill of goods for consumption and investment in capital and government services is met by the net output from the industry and net imports. The capacity expansion in the energy and non-energy sectors are determined within the model. The exogeneously given workforce meets the manpower needs for sustaining industrial production, energy processing and capacity expansion.

The detailed energy sector of the model contains technical description of the exploration, extraction, conversion and transmission processes connected with the nuclear industry, oil and gas, coal and electric power generation. The processing levels are limited by the available capacities and new capacity could be constructed. Proven reserves may be augmented by further exploration activity. Any difference between domestic production and consumption of energy is made up by imports/exports. The linkages that interconnect the energy sector and the rest of the economy are the energy demands of the economy, the demands for bill-of-goods needed for energy processing and capacity expansion, and total manpp er available. Different objective functions, linear and nonlinear, representing an appropriate utility function could be employed with the model. The main purpose of building the model was to analyze the physical potential of the economy under (i) alternative objectives, (ii) changing availability of various forms of energy, and (iii) changing desirability and economic feasibility of energy conversion technologies and other situations. Again pilot energy model developed using appropriate technological information would be applicable to larger developing countries having well developed industrial structure and which have developed detailed input-output models for the economy. (17)

A new development in the Pilot Energy Modelling Project is the Welfare Equilibrium Model (WEM) which is "a medium scale (35 years, 1975 - 2010) linear programming model for generating internally consistent projections of U.S. energy supply, energy demand and economic growth within an economic framework of consumer welfare maximization and competitive market equilibrium. The first energy-economic model developed on the PILOT project was the physical flow model (1, 2) discussed above. The initial strategy was" to obtain a physical flow (primal) solution using linear programming and to obtain the prices and money flows using a financial flow model operating on the optimal basis". The latter was supposed to account for market inperfections and institutional distortions and minimize the role of the shadow prices. Due to thefixed coefficients of the historical (1967) input-output table used in the economic system, solution of the PILOT model under various policy assumptions always exhibits a strong coupling between the availability of energy and the economic growth. The energy demand adjustments therefore had to the exogenously specified.

WEM was developed as one of the approaches to describe a more flexible relationship between the availability of energy and economic growth. The WEM approach is embedded in the setting of a multi-sector, neoclassical growth with explicit factor substitution possibilities, and general (dynamic) equilibrium and examines the equilibrium properties of the shadow prices of factors of production, goods and services, and raw energy resources and their numerical values. The shadow prices in WEM corresponds to a perfectly competitive market equilibrium but certain national goals and institutional constraints could also be incorporated in the model.

WEM is driven by a objective function maximizing a household welfare function of consumption and leisure, based on historical data, and it also incorporates long run marginal cost curves for energy resources so that its shadow price reflects its exhaustible nature. It is possible to consider process analysis of energy demand in the WEM framework through parametric studies and linkage with process analysis models of energy demand. Thus, WEM is a tool for integrated long term planning of the U.S. energy system, and for comparing options designed to provide a transition from the economy that is heavily dependent on oil and gas to an economy that is dependent on a balanced fuel mix and cost-effective energy conservation. One of the remarkable feature of WEM is its unique objective function which incorporates a trade-off between additional consumption and leisure.

There have been many other approaches towards energy-economic planning applied to US, Canada, France, UK and various other developed countries which are not described in this paper. The purpose was to focus on the various methodologies used including econometric modelling, input-output analysis and mathematical programming or a combination of these techniques, and the underlying assumptions such as market clearing price induced equilibrium or optimization planning approach. It is becoming clear that the planning approach involving optimization type supply models within a macro-economic consistency framework might be applicable to developing countries with an industrial base and suitable energy data.

3. INDIAN EXPERIENCE WITH ENERGY PLANNING

The first systematic study for energy planning in India, involving a study of energy resources, demand, investment and pricing was carried out about 15 years ago, by the Energy Survey of India Committee (4) appointed by the Government on January 3, 1963. The study carried out by the committee covered present and prspective demands and supplies of energy, both total and also in respect of various forms at national, regional and sectoral levels. In the absence of detailed studies and research on the energy sectors, the committee did not apply any specific modelling framework either for demand forecasting or for investment analysis, but simple assumptions were used for projecting future demand for energy. Energy demand forecasts were made by an analysis of the levels and trends of energy consumption in the recent past but these were related to the rate of growth assumed for the major economic sectors.

The total demand for energy, commercial and non-commercial, were projected on the basis that it would grow in future about proportionately to national income as in the past. These aggregated forecasts were supplemented by sectoral projections of energy demand in the transport, industry, agriculture and the domestic sector by different energy forms. Energy-use coefficients were carefully estimated based on past trends in each industry or transport activity and these were projected into the future with judicious adjustments made for technological and economic factors. The domestic sector presented special problems, mainly due to the overwhelming dependence on non-commercial sources of energy by the domestic sector, specifically in rural areas. The survey undertaken of the energy consumption pattern for rural households and familities in the three larger cities of India provided useful information on the energy consumption pattern in the domestic sector. The Energy Survey Committee had laid a good foundation for future energy policy studies in India.

The more recent energy policy study in India was undertaken by the Fuel Policy Committee (FPC) appointed by the Government on October, 12, 1970 and this committee submitted an Interim Report (5) during May 1972 and the final report (6) in 1974 after some of the energy forecasts and recommendations prepared in 1973 were revised following the increase in the international price of crude oil. The Fuel Policy Committee in which the author served as a Consultant followed an approach quite similar to that used by the Energy Survey of India Committee, but they used more systematic methodology for demand estimation and optimization of the investments being planned for the energy sectors. It was the first study where energy sectors were looked at in an integrated manner. A Linear Programming optimization model was used to represent production (or import), processing and transportation (to the major demand centres) of oil and oil products, coal and fertilizer for investment and operating decisions involving location, capacity and technology choices. A dynamic model of the power sector was used to determine the role of nuclear energy, thermal and hydro generation in India's power sector. The demands of primary fuels (oil and coal) for power generation were derived from the solution of this model. Optimization models were also developed for investment planning in power generating and transmission facilities on regional basis (11).

The energy demand forecasts for coal, oil and electricity in the Fuel Policy Committee Study were arrived at by regression analysis using parameters such as national income and index of industrial production. These estimates were also verified by end-use analysis of the large energy-using sectors. The effect of price on the demand of energy goods were not considered. Though, in the case of oil products such as motor gasolene, prices were raised following the oil price hike and such selective pricing for different oil products did produce differential effects on their consumption as can be seen in Fig. 1. Also electricity consumption in residential and commercial sectors did show some amount of price elasticity (12). The demand for energy for the industrial sector was based on the physical targets of production planned for different sectors of the economy and the norms of energy consumption developed for these sectors, based onpast industrial survey data. But for the GNP growth rates and physical targets for various sectors, though the interim report (5) considered several scenarios, in the final report (6) only a single scenario was considered. The physical targets provided by the Planning Commission and the Ministriesbased on material balancing exercises carried out by using an Input-Output Table. The three different cases shown in the Fuel Policy Committee report (6) were related only to the price of oil and the success of substitution of oil products and not on any variations in the physical production targets. As the Indian economy grew at a much lower rate during the final years of Fourth Plan and during the Fifth Plan, FPC projections were generally on the higher side.

The Case II estimates in FPC report for 1978-79, 1983-84 and 1990-91, representing an intermediate scenario regarding oil price rise and success of substitution efforts, were respectively 140.8, 210.8 and 352.5 million tonnes for coal (excluding power generation), 32.30, 42.58 and 66.74 million tonnes for oil products and 124.00, 205.00 and 392.0 billion kilowatt-hours (kwhrs) for electricity. These forecasts were definitely on the higher side, based on much higher rates of economic growth than actually experienced during the remaining years of fourth and fifth five year plan periods. Current targets for the production of coal during 1977-78 and 1982-83 as contained in the latest plan document (18) are 103.20 and 149.0 million tonnes and that of electricity 100.0 and 167.0 billion kwhrs.

The energy demand supply forecasts provided by the Fuel Policy Committee extended only until 1990-91. Parikh (15) has extended the results of this report until 2000-01, as a part of the Second India Studies sponsored by the Ford Foundation (India). Parikh used the same data base used in the FPC report, but considered two distinct scenarios, one associated with low population, high growth and contained urbanization, and the other with high population, low growth and high urbanization, to provide forecasts for two out of the three cases considered in the FPC report based/different assumptions about /on the future price of oil and success of the oil substitution effort. Parikh also computed the resources requirements in the economy for meeting the fuel needs in future and analysed the effects on demand of energy related policies in other sectors like transportation and urban land-use.

Parikh (15) used the same GNP growth rates as used by the Fuel Policy Committee i.e., 5.5% for the period 1970-71 to 1978-79 and 6% for the following period upto 1990-91, assumptions highly optimistic in light of past records of realistic growth of Indian economy. He used an even higher GNP growth rate of 7% for the period 1990-91 to 2000-01. The latest official draft plan document (18) assumed a GNP growth rate of only 4.70% for the period 1978-83. Thus, the energy demand forecasts obtained by Parikh (15) are possibly very much on the higher side. The total investment requirements for meeting these forecasts are also much higher when considered against the investment needs of other sectors. Even if these financial outlays are available, the organizational and managerial problems involved with raising the production of coal, electricity and oil products several times the current production might prove to be insurmountable.

Parikh and Srinivasan (16) have developed and applied a Programming Model for determining the food and energy choices for India under various assumptions related to macro-economic parameters for India and energy-related policies in various productive sectors of the economy including transportation. The model is supplied with exogenous demand projections for determining an optimal set of energy production, conversion and transportation activities. The energy demands for domestic, transport and agricultural sectors have been estimated within the modelling framework, but demands for the other industrial sectors were projected from other studies, though they are not explicitly mentioned.

A detailed scheme for integrated energy sector planning is shown in Fig. 1 of their report, but Parikh and Srinivasan (16) have not yet implemented it completely, specifically the static multi-sectoral input-output model. The study includes detailed supply models for oil products, electricity and fertiliser production and choices in food and agriculture. Under the same assumptions regarding population growth rate, degree of urbanization and economic growth rates, various cases were solved by changing assumptions regarding the international price of oil, and coal, availability of firewood, and domestic crude, and the capital cost of nuclear power plants. The projections for primary and secondary energy in Parikh (15) and Parikh & Srinivasan (16) are comparable, though the latter discusses five cases and both are possibly overestimates, specifically for coal, The study, however, has been a nice attempt at integrated energy planning, eventhough industrial sector was not included, and the two-way linkage between the economy and the energy sectors are missing. Parikh and Srinivasan (16) uses a multiperiod dynamic model for the electricity generating sector to minimise the discounted costs of capacity additions and energy generation.

In a recent study carried out at IIASA, Jyoti Parikh (14) discussed the SIMA model for India, where energy demand and supply analysis have been carried out within a two-sector (agriculture and non-agriculture as well as urban and non-urban) macro-econometric modelling framework. The major limitation of this unique study is the aggregated nature in which industrial sectors have been treated and that the model would not be useful in dealing with alternative choices of investments in the energy sector. There have been numerous attempts in analysing the energy policy options for India, the technological alternatives, the role and scope of energy conservation and the importance of the rural energy scene, the notable contributions being those by Reddy and Prasad (19) and Makhijani (10).

In this context of past experience of Energy Planning in India, the Indian National Committee for World Energy Conference, an independent body with participation by government have appointed the author as the Convenor of a Panel for Developing an Energy Model for India. A national energy planning study is commencing and an interdisciplinary team would be engaged in developing an integrated energy modelling framework for India and various regional submodels for energy and demand forecasting, supply and investment analysis. In the next section the approach taken for developing this energy-economic model is discussed.

4. A NATIONAL ENERGY MODEL FOR INDIA : THE METHODOLOGICAL APPROACH

The Energy Model for India would basically consist of four sets of models which would be interlinked with each other and these models could be solved in an iterative manner to obtain a solution to the energy demand-supply situation under certain given assumptions. A broad framework of the four models, a maco-economic model, demand fore-casting model, energy supply model/economic impact model is shown in the /and enclosed figure 2. It was decided that too much time would not be spent to develop a macro-economic model if the existing long term perspective model based on an input-output table of the Indian economy being used by the perspective Planning Division of the Planning Commission for the Sixth Plan is made available for the study. The basic function of the macro-economic model is to generate alternative economic scenarios and socio-economic forecasts for the future until the year 2000. The available input-output model and long term perspective model used by the Planning Commission until the year 2000 would be used and alternative economic scenarios would be generated if this becomes necessary.

It was decided that considerable effort should be directed to develop a set of demand forecasting models for the residential and commercial, transport, industrial and agricultural sectors. The demand forecasting models would analyse the effect on demand of various socio-economic vari-ables such as per capita income, the price of alternative energy forms, index of industrial production, degree of urbanization and rural electri-fication and physical targets of production in various sectors of the economy. The demand forecasting models should also be capable of analysing the effects of substitution among different fuels and various governmental policies related to urban transport, rural industrialisation, housing and energy conservation as well as environmental pollution control. A framework would also be prepared for analysing the role of technological changes as well as now technologies. Such a framework would be useful in also identifying areas where studies should be carried out for technological improvement of energy conversion and utilisation equipments and processes.

The supply models would be formulated for the coal, petroleum and electric power sectors for energy production, transportation and consumption by various regions of the country. The electric power sector model would be based on regional basis to analyse investment needs for different electricity regions as well as proper mix of hydro, thermal and nuclear plants, their time phasing and the role of super thermal plants. A highly aggregated national model of the power sector might be attempted later based on the regional electricity models to study the working of the proposed national grid and the superthermal plants.

In the petroleum sector, models should be developed for (i) oil exploration, development and production and (ii) refining and distribution sectors. While petroleum exploration, development and production model should be set on a regional basis for the Assam, Gujarat and Bombay High Off-shore basins, it is visualized that the production and distribution model would be developed on a national basis.

The objective of the oil and power sector models would beto supply the regional demands obtained from the forecasting models at minimum social cost. The Petroleum Refining and Distribution sector model would represent various alternative activities in petroleum refineries among which the model finds a least cost solution. The model would be based on a simplified description of a refinery, a schematic diagram of the activities in the refinery is shown in Fig.3, taken from Parikh and Srinivasan (16).

Similarly, a model of the coal mine development, production and transportation would be attempted on a national basis with the objective of minimizing the total social cost of meeting the demand for coal from the various sector. In the area of non-conventional energy sources, forecasts would be made regarding their availability and scope of utilisation in various sectors of the economy based on studies carried out by various institutions and the results will be integrated with other sectoral models.

The economic impact model would use as inputs the various energy supply scenarios and energy facilities required. Based on the construction requirements of the energy facilities and their operation, the economic impact model would provide the detailed requirements for investment and working capital, manpower by categories and critical materials such as steel, cement, aluminium, copper, construction equipment etc.

The purpose of the integrated modelling framework would be to study the inter-relationship between the four sets of models being contemplated. It is expected that alternative economic scenarios, various assumptions regarding policies in transportation, agriculture and urban sectors, and different assumptions on international price of oil will lead to different sets of forecasts for energy demand. The supply models based on these demand forecasts will provide data for investment needs and facilities for the energy sectors. The economic impact model would provide detailed listing for capital as well as manpower and materials requirements for the energy supply scenarios. The consistency of such investments and other requirements for the energy sectors within the overall macro-economic framework could be seen from the macro-economic model. To study the impact of various supply model solutions on the rest of the economy, technology-based economic impact models are needed which would translate the investment requirements in the energy sectors for, say, setting up a refinery, power plant, transmission line or coal mine, into requirements of capital, foreign exchange and materials such as steel, aluminium, copper, cement, construction equipment and various categories of skilled labour and managerial personnel.

Though the objective of the study is to develop an National Energy Model for India, it is also expected that the study will also suggest suitable methodology for energy demand forecasting and energy-economic planning in the developing countries having similar problems and experiences as India.

Investigations are now being carried out into three aspects of energy planning methodology - (a) Energy Demand Forecasting, (b) Optimal Investment Planning and Supply Models for Energy Sectors and (c) Integrated Framework for energy economic planning. Some of the results already available from these research studies will be applied in the National Energy Model. A methodology for optimal investment planning in electrical power generation and transmission system based on further modification of a Network Modelling approach reported earlier (11) is under experimentation now and this model could be applied for planning regional power systems in the five major power regions in the country. Network Model presentation of a hypotehetical power system is shown in Figure No.3. The Network model would be also applied for studies related to the National Power Grid, the location of super thermal and nuclear plants and construction of high voltage transmission lines (400 kv and higher) for bulk inter-regional power transfer.

To develop a suitable methodology for energy demand forecasting, two specific approaches or techniques are being investigated. a) Econometric modelling, and b) Input-output Analysis and specific industry studies. Econometric modelling approach has been found suitable for forecasting electricity demand in residential and commercial sectors and in explaning interstate differences in the per capita consumption of electricity due to variations of per capita income, price of electricity , degree of urbanisation and rural electrification (12) This method is now being extended to the industrial and agricultural sectors also.

The alternative approach for demand forecasting is based on using an input-output Table of the Indian Economy (expressed in monetary terms) to develop an Energy Input-Output table in physical terms. An Energy input-output table, in which the energy sectors are separated from the other sectors of the economy, expresses the energy inputs in physical terms required for the production of an additional unit of output in any other sector of the economy by taking into consideration the flow of energy through the Intermediate goods. In this study of energy demand forecasting based on an Input-output analysis and obtaining energy intensity of various sectors of the economy, the 66 sector input-output Table used for the Fifth Five Year Plan (18) was used in an aggregated form for 24 sectors, due to the difficulty in obtaining the upto-date input-output Table for Indian economy recently developed by the Planning Commission and the Central Statistical office for preparing the latest Five Year Plan 1978-83 (18). Physical energy-use data available from the Annual Survey of Industries (ASI) Reports were used to develop energy coefficients for each sector in terms of tonnes of coal, oil products, and kilowatt-hour (kwh) of electricity used per rupee of output. As most of the sectors are not really homogeneous, physical energy-use coefficients in tonne per tonne or BTU per tonne become quite meaningless except for a few homogeneous sectors. Due to the difficulty in obtaining output prices for various commodities and prices for energy sold to different sectors, demand forecasting using this methodology is difficult and has some pitfalls. But it is expected that if past data on consumption of energy and industrial output in physical terms are available, energy input-output analysis would be highly useful for forecasting industrial demand as direct price elasticity is negligible. For forecasting demand for energy sold to the final demand including the domestic sector, econometric analysis would probably be a better method to take into account income and price statistics.

Input-Output Analysis of energy demand based on a national input-output table provides energy demand for oil products, coal and electricity only on a national basis. But for using these forecasts as inputs for the energy supply models these would have to be regionalised as investment decisions and locations of energy facilities as well as investment needs for transportation facilities cannot be taken unless energy demands are allocated by regions. To resolve this problem two alternative approaches have been proposed in addition to the simple approach of allocating total energy demand between the regions based on past trends of regional demand and growth potential of different regions. The first approach is based on the use of regional input-output tables in the construction of regional energy input-output matrix and developing regional energy demand forecasts. Input-output tables for various States in India are available now based on State level studies for inter-industry flows and these could be utilized. The second approach would be based on a methodology of allocation of industrial output among the various regions (or states) in India based on the base year proportional contribution/of each state in the national output and forecasts of future /('Share') proportional contributions based on the analysis of growth trends of each industry in the region and computation of shift factors. The resulting regional outputs by various industry sectors could then be used for forecasting regional demands for coal, electricity and oil products. The second approach appears more promising and would be examined in detail to develop a satisfactory methodology for regional energy demand forecasting.

One of the problems associated with using energy input-output tables for demand forecasting is the difficulty in handling inter-fuel substitution due to relative price changes in a satisfactory manner. This can be done in a judgemental basis if consumption data is available for a sequence of years when the relative prices of energy were changing, by preparing a set of energy input-output tables corresponding to the different sets of fuel prices. This could be also analysed through the application of the Reference Energy System Technique (7) developed at Brookhaven National Laboratory (BNL), USA or by using an approach similar to the Hudson-Jorgenson Model (8). Iterative approaches involving macro-economic and input-output models and technological models for supply analysis as discussed by Hoffman and Jorgenson (7) is also highly useful and the current work on developing an Energy Model for India is also conceptually based on a similar iterative approach.

At this time, the nature of the integrated framework for energy-economic planning suitable for the developing countries is not quite clear. Various approaches have been attempted in the developed countries specially in USA. The Hudson-Jorgenson Model (8) uses an input-output table in which the coefficients are functions of various economic parameters including prices determined by the solution of econometric models. Similar integration of input-output models and econometric models have also been tried at the Brookhaven National Laboratory (7). The pilot energy model developed at the Stanford University consists of a large dynamic Linear Programming Model which also includes an input-output table of the economy and detailed representation of different energy production, conversion and transportation sectors. It appears that an approach similar to the pilot energy model could be more appropriate for developing countries where input-output tables have been prepared, reliable energy sector data are available and the emphasis is on planning investments in the energy sectors. Thus, the current energy modelling study for India will be concentrated on a similar approach specially if the input-output analysis approach for demand forecasting becomes successful. The other approaches for energy-economic planning will involve development of suitable aeconometric models for the national economy, which by itself may become a major research effort.

5 CONCLUDING REMARKS

Due to the intimate linking of the energy sectors with the rest of the economy, it has now become obvious that energy planning should only be carried out in an integrated framework for energy-economic planning which is suitable for analysing the effects of economic growth on energy consumption and also the effect of the energy sector on therest of the economy. In the past, the absence of such a framework has led to wrong and frequent over-estimation of energy demand and subsequent under-achievements in energy production programmes leading to energy shortages. In the absence of any long term perspectives, the actions of the governmental agencies associated with decision making in the energy sector had been ad-hoc and myopic leading to frequent shortages and excesses. It is erroneous to think that dueto chronic energy shortages, demand forecasting is no longer important and what is needed is only to plan for supply of increasing amounts of energy. A long-term look at demand is all the more necessary in a scarcity situation so that appropriate policies could be formulated for containing demand and planning for supply.

Due to the high investments in the energy sector and high stakes involved with the success or failure of our energy supply policy, the development and application of a National Energy Model is essential and the study being undertaken by the Panel on Developing an Energy Model for India should receive high priority and cooperation of the energy sector agencies including the State Electricity Boards and public sector companies, the Planning Commission and the Central Ministries. Such a model should be ultimately integrated into the national planning framework adopted by the Planning Commission.

Fig. 1. FAST CONSUMPTION OF SELECTED PRODUCTS

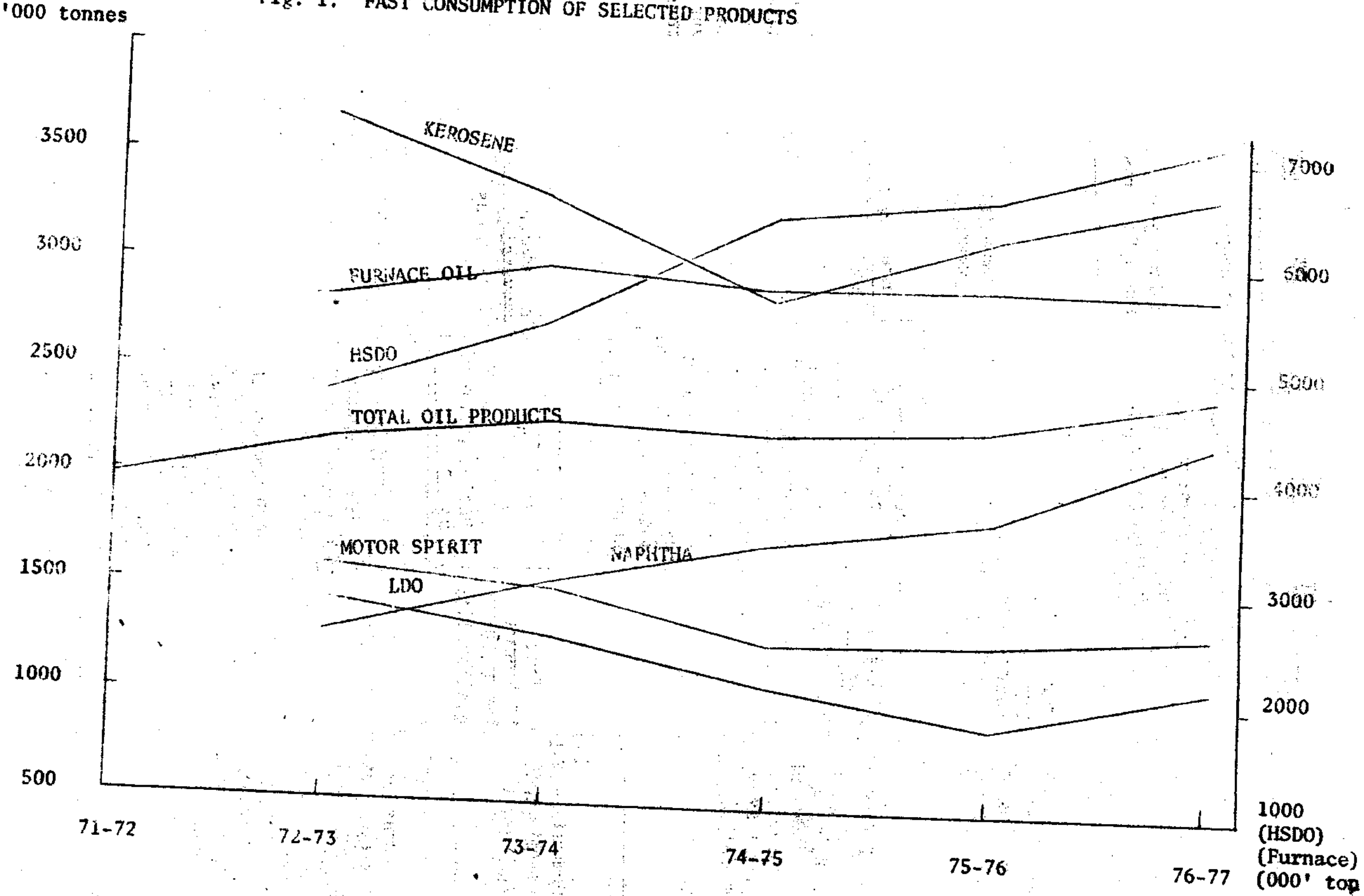
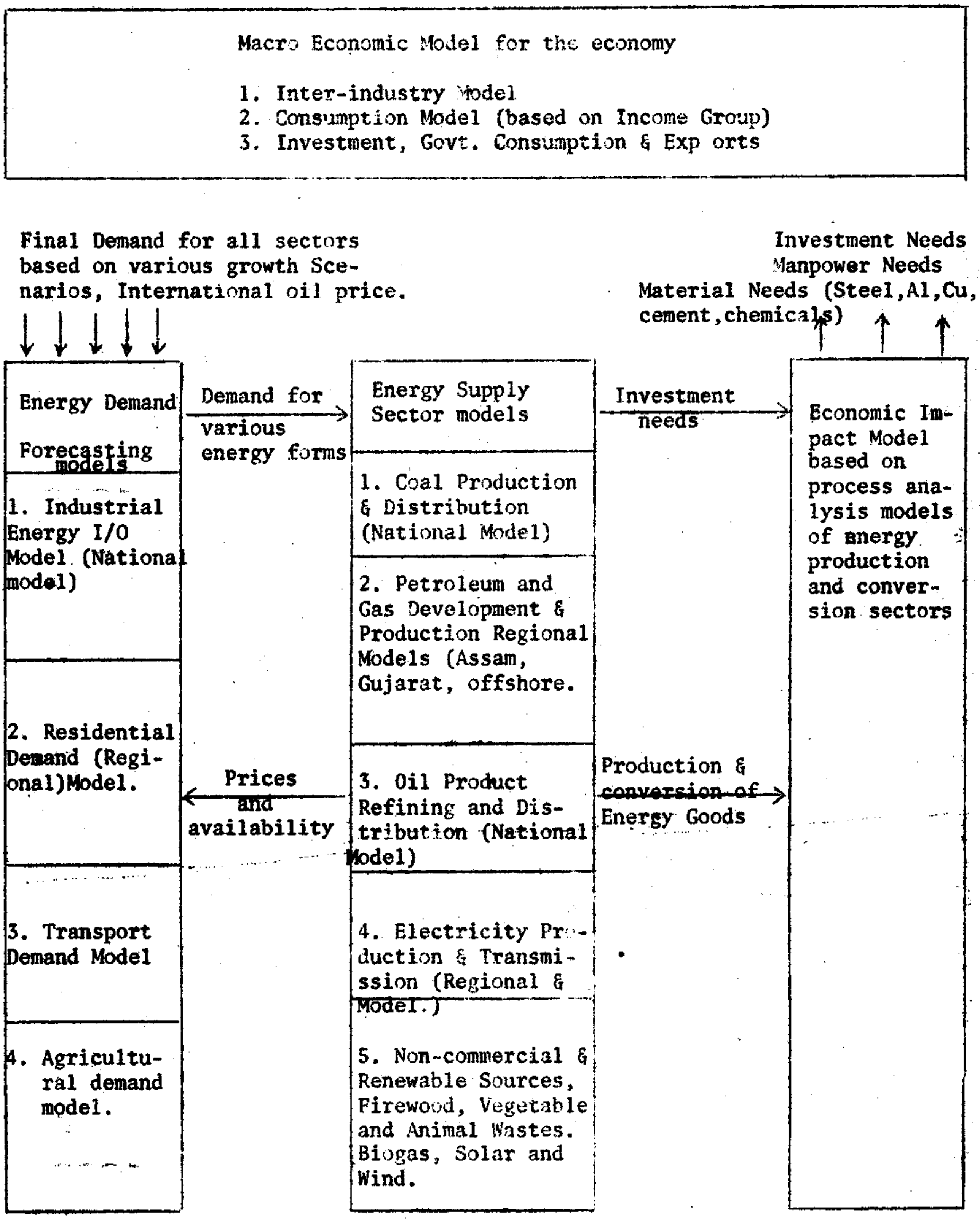
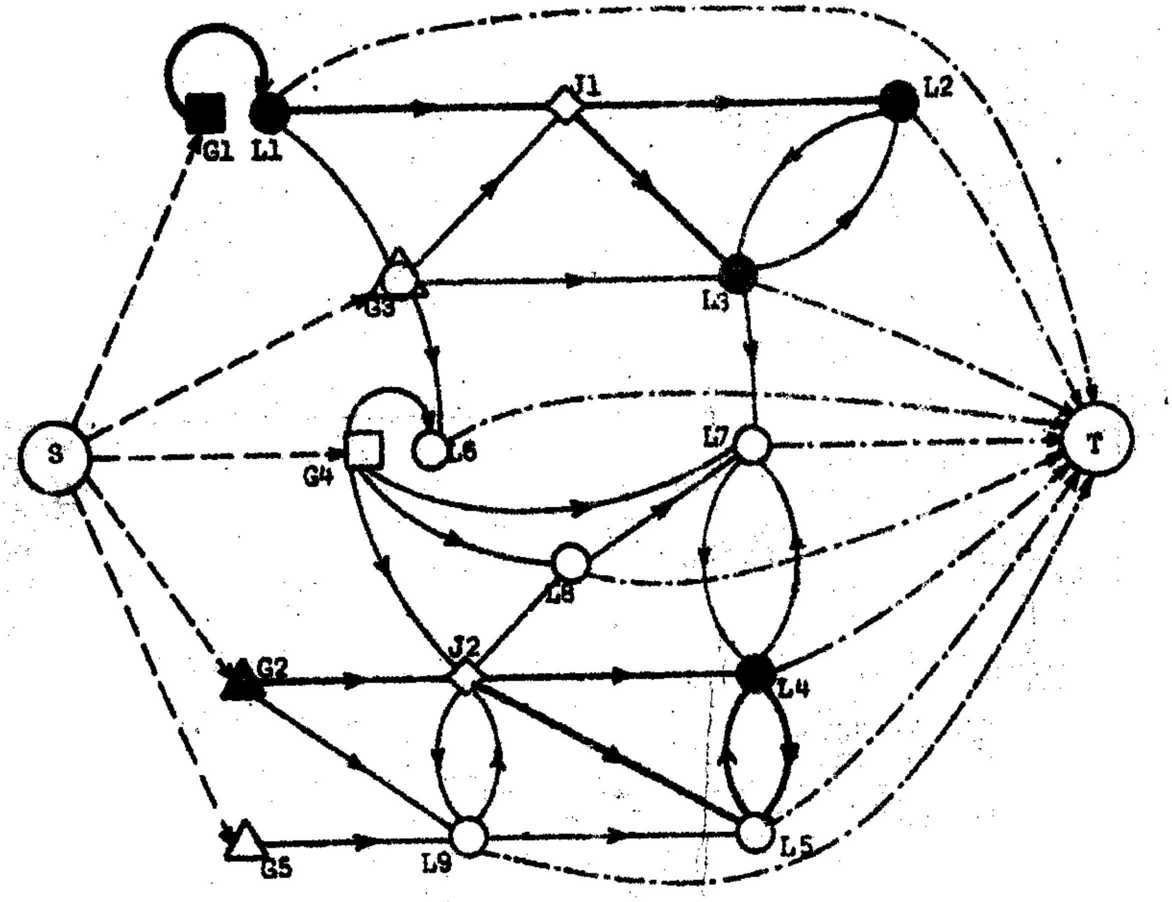


FIGURE 2

INTEGRATED FRAMEWORK FOR ENERGY-ECONOMIC PLANNING



NETWORK MODEL PRESENTATION OF A HYPOTHETICAL POWER SYSTEM.



Hydro Plants
- Existing (G2)
- Proposed (G5)

Thermal Plants
- Existing (G1)
- Proposed (G4)

Nuclear Plants
- Existing
- Proposed (G3)

Load Centre
- Existing (L1-L4)
- Proposed (L5-L9)

Junction Joints (J1-J2)

Transmission Lines
- Existing
- Proposed

Generation Arcs

Consumption Arcs

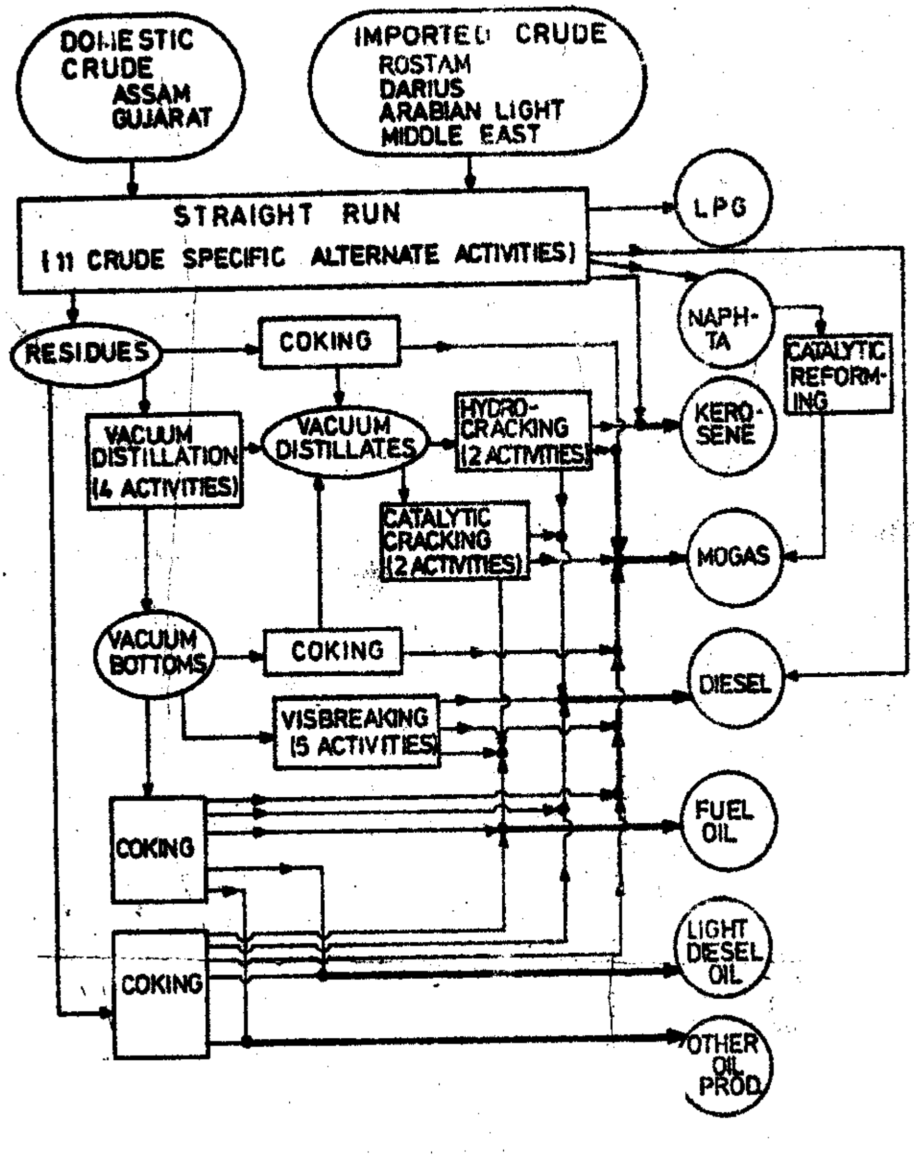


Figure 1. Choices in refining and secondary processing.

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