CHAPTER III

ENERGY MODELING FOR ECONOMIC ANALYSIS AND DECISION MAKING

3.1 Macro modeling in General:

A model to some extent is an abstraction from reality but it has the basic target of representing the reality of an actual system or a system in process toward a particular intended direction. A good model is both realistic and manageable. It specifies the interrelationships among the various constituents of the economy or a system such as to provide detailed and explicit insights concerning the real system.[1]

Development in Economic theory coupled with advancement in economics and computer technology has resulted into a rapid development of economy wide models during the last five decades. Models have been used to analyze the structure of an economy and also study the behavior of various economic units in producing, exchanging and consuming economic goods and services. Lately, the models have also explored the possibilities of influencing the macro goals set by the public policy.

The economic planning process in India can broadly be broken up into two steps: the building up of the five year plans and the specification of the annual plans. Several planning models were used to arrive at a balanced allocation of resources for attaining the objectives and targets of Growths postulated in each Five-Year Plan. Essentially these models have been of two Categories.

(i) Econometrics models based on Keynesian effective demand.

(ii) Programming and input-output models incorporating essentially the supply side of the economy: The constituent of such model is: (a) growth models for planning purposes (b) multi sectoral comparative static consistency planning models (c) intertemporal consistency planning models (d) comparative static linear programming optimizing planning models and (e) intertemporal linear programming optimizing planning models.

3.1.1 ENERGY MODELING

In order to examine the broad category of issues relating to energy problems a variety of energy models have been developed in India. These models focus on energy as an economic resource and they are directly or indirectly associated with decision making process. Before discussing the energy models developed in India a general review of literature and characterization of the EMS developed their in would be of interest.

3. 1. 2 Classification of Energy Models

EM can be classified into three categories according to the purpose for which they are constructed.

1. **Descriptive:** This type of model attempts to replicate some relevant features of the References energy system (RES)[3] A Reference Energy system is a format for the graphical display of energy balances. Originally designed as toll for technology assessment in the U.S., it has been since been adapted for use in developing countries. It depicts estimated energy demand, energy conversion technologies, fuel mixes and the resource required to satisfy these demands. The pictorial format for the RES is also a network diagram which indicates the total flow of energy sources to final consumption. Conversion efficiency of the technology is employed at various stages of energy production, transmission, distribution and the final end-use destination. It provides detailed information and presents (observable) behavior of the system.

(2) **Predictive:** This type of model is used to forecast future aspects and features of reference system. While doing so, the policy makers incorporate certain contemplated action such

as energy rationing, subsidies and taxes, price control etc. (conditional forecasting) and try to understand the general dynamics and inertia of the system (Unconditional forecasting)

(3) **Normative:** This type of model is used to project how reference system should develop given some over all objectives, like reducing the commercial energy consumption, reduction in the level of Co_2 emission and environmental consequences of increased energy use, efficiency and implementing efficient and energy saving technologies. It can also incorporate the political philosophy of the government in relation to subsidies and taxes and other social objectives determined in the political process. Macro economic information such as stagnation in domestic supply of energy, foreign exchange crunches to import energy products, can also become part of this type of modeling,

Turning toward the historical development of EM, keeping in mind the above classification, a clear-cut demarcation can be drawn between the pre and post oil crisis EMS. The pre oil crisis energy models have two distinct characters. First, energy commodities were treated in isolation. Each energy form had almost its own market, the question of substitution among different energy sources hardly arises, if it does, only in special cases. Second, EM reflected a stable energy pattern within a stable economic environment.[4] Therefore in the 1950s and 1960s, the purpose of constructing EMS was to forecast the energy demand and to support investment decisions related to new capacity build up or expansion of existing capacity.

The post October 1973, oil embargo EMs considered energy playing triple roles in the economy, a production factor, an industrial sector and a final consumption commodity. This topology permits a comprehensive representation of the interactions between the energy and macro economic system[5] (Capros and Samouillidos 1988). The approaches followed by in these models of energy economy interactions, which emerged around the time of the 1973 energy crisis, may be classified following this topology. Large scale macro economic models adapt a structural approach to economic modeling, and thus represent all the three roles of energy[6]. In these models, energy either is introduced in existing framework (Askin, 1978; Pierce and Enzcer, 1974), or is considered specifically in the conception of the model.

The Hudson-Jorgenson (1974) approach is the most typical representative of such models mentioned above. There exists also a variety of small scale approaches to modeling the energy-economic interactions. They are based either on conceptual aggregate models (Gordon, 1975; Hogan and Manne, 1977; Phelps, 1978; Sweeney, 1979; Wright, 1980; Moth and Hall; 1980 and 1981) or on reduced form models (Findlay and Rodriguez, 1977; Bruno and Sach, 1982 and 1985; Tasom, 1983; Hickman, 1987). Most of these small scale approaches emphasize the role of energy as a production factor and assume that it is imported. A new class of energy economy models[7] called the "Linked Energy-Economy modeling" use the advanced facilities offered in the computers. This models are closely related to the theoretical framework of the general economic equilibrium in each component model, that is, expressing the optimizing behavior of an economic agent and the resolution algorithm implements the market clearing mechanism for determining equilibrium price. This allows the consistent Linkage of component models with different forms, usually by means of inter temporal linkage and the empirical convergence technique (Hugen and Weyant, 1982 and 1983). The pioneering work in linking engineering with economy wide model has been developed at Brookhaven National laboratory (BNL) (Lucachinski et al, 1979) and at Stanford University, (Dantzig, et al, 1978)[8].

3.2 REVIEW OF ENERGY POLICY PLANNING AND MODELING IN INDIA

Much before the onslaught of the energy crisis, an integrated energy planning was recognized as an essential element of developmental planning in India as early as in the sixties. As in any other country, all the policy initiative and energy planning during these period was on supply side management of resources. Such thrust, was though well intended, has somewhat misguided belief that enhanced supply would eventually take care of demand at some price. This is the type of policy measures that continued till the energy crisis began to be felt in the early 1970s. It was only then the policy planners turned their attention toward demand side management of energy resources and the Government of India constituted different committees to chalk out certain policy measures to check the growth in the commercial energy demand.

The one significant study[9] on energy is by the National Council of Applied Economic Research (NCAER) where demand forecasts for different types of fuels were calculated for the year 1965-66, 1970-71 and 1975-76. Demand was estimated for different regions and for the broad sectors of the economy.

Second India studies Energy[10] : This dealt with the present use pattern of energy and provided estimates of demand and availability for various types of energy for the year 2000 AD. The study predicted that the energy requirement by the year 2000 would be ten times that of used in 1970-71 in the Indian economy. It predicted the predicament that the economy faces today - oil crisis and the need to find a suitable substitute for oil is inevitable.

Tyner[11] tried to trace the relationship between energy consumption and GDP in India for the period 1953-54 to 1970- 71. His findings were that an increase in the use energy by one Million Tone of Coal Replacement (MTCR) would eventually increase GDP by six crore in 1960 - 61 prices. He also reviewed the operation of the power sector for two decades and observed that the heavy shortfall in the planned power target had crippled both agriculture and industrial output. He argued that heavy emphasis should be placed on the power sector and especially on the coal based thermal power generation. He recommended that India should pursue a strategy to increase oil production by leasing the off - shore to foreign oil companies to minimize the investment liability and reduce the foreign exchange drain on account of increased import of petroleum products.

Pachauri[12] in his study brings together the demand estimates and resource potential, pertaining to various agencies and examines the new technologies and alternatives that India face in the energy sector.

In order to assess the energy supply options in India during the sixties and seventies, the World Bank under took a study headed by Henderson[13] . He reviewed the energy resources of India and the trends in the supply of energy in the decades of sixties and seventies and the policies and prospects for the Fifth Five Year Plan. He noted that the energy intensity has increased from 0.57 to 0.80 from 1960 - 61 to 1970 - 71. He further analyses the changes in terms of composition of output and energy coefficients. Out of the total increase of 81.4 MTCR over the decade, output changes accounted for 55.4 MTCR. Recommendations and policy prescriptions have been made to reduce the energy elasticity coefficients.

As early as mid 1970s, Indian industries consumed more fuel per unit of output than the manufacturing industries in the USA, there by indicating the considerable scope for energy conservation in India. Chitale and Roy in their study, 'Energy Crisis in India[14] further noted that energy input in the manufacturing industries can be reduced by as much as 20 percent. They calculated the energy coefficients for some basic and capital goods industries for the period 1965 - 66 to 1971 - 72. With the high price of oil and its impact on the balance of payments position, the study examined the inter - fuel substitution possibilities. Apart from providing forecast for energy demand, they also made comparative analysis of the forecast.

3.3 Energy Studies by the Government of India

3.3.1 Energy Survey of India Committee (ESIC), 1963 -[15]

The focal point of the ESIC was to study the present and prospective demands and supplies of energy, both total and in respect of constituents of energy on national, regional and sectoral level, using demand side static approach. The study was expected to provide the Government with the basic materials for development planning in the field of energy up to 1981. A special emphasis was given to the energy requirements of the rural areas. It also made several recommendations on investment portfolio in energy sector and mixing of different fuels.

3.3.2 Fuel Policy Committee (FPC) 1970.[16]

The government of India entrusted the committee with the responsibility of outlining a National Fuel Policy for the next fifteen years. It was specifically required to look into the technical and organizational aspect of energy planning with special reference to improving the efficient use of energy resources. The committee was forced to make several recommendation in the light of upheaval that took place in the world oil market in 1973, such as substitution of oil by coal and electricity and on energy conservation in general. Econometrics forecasting technique and end use analysis were made use of while arriving at the sectoral energy demand. However the major thrust of the study was supply side of energy than on sectoral demand analysis and demand management.

3.3.3 Working Group on Energy Policy (WGEP) 1979.[17]

The WGEP constituted in 1977 expected to make detailed projections of demand for both commercial and non-commercial forms of energy up to the turn of century and to make corrective measures to manage the energy demand. It was also a demand side static approach as its predecessors. The reference Level Forecast (RLF) and Optimum Level Forecast (OLF) made by the group highlighted the crucial issued of energy planning relevant to energy conservation and inter-fuel substitution. Its major finding was that the per capita consumption of energy is low, but energy consumption per unit of output is high and increasing. The recommendations of the WGEP provided a broad framework for energy sector planning in the Sixth Five Year Plan.

3.3.4. Modeling Energy Demand for Policy Analysis (Parikh, 1981).[18]

The study on modeling Energy Demand for Policy Analysis was instituted by the planning commission, Government of India under the chairmanship of Jyothi Parikh to fulfill the need for national energy modeling system in order to look at various energy use and options and policies for energy systems management. It was a macro demand side static model. Two models, simulation of Macro Economic Model for Assessing Energy Demand in India (SIMA) and Energy Demand Model (ENDIM) were integrated to assess the impact of various energy policies on energy requirements and to identify energy supply mix of various sources. The major findings of the study was that the energy intensities of small energy consuming industries will increase in future because of the substitution of commercial for non-commercial energy; some reduction in energy intensity is expected from the large energy consuming industries due to improved technology. Imbalanced regional distribution of energy demand and supply and its possible implications have been worked out in the study. Part from projecting the energy demand, it also made recommendation on the investment requirements to meet the projected demand. Special attention was paid to the specific policies for various energy sub sectors.

3.3.5. Advisory Board on Energy (ABE) 1987: Towards a perspective on Energy Demand and Supply in India in 2004-2005.[19]

The two Expert Group though well intended to formulate a energy policy on an integrated system, in practice however, no formal institutional mechanism could be solved on firm footing for examining the various policy issues on an integrated basis. It was in this context that the ABE was set up in 1983 on the eve of the formulation of the seventh plàn. The study estimated the energy requirement in the household sector using a norm of 650 K Cal per a day for cooking and space heating for the year 2004. The Energy Demand Screening Group (EDUC., 1986) in its report, however recommended that the norm fixed for rural areas may be applicable to urban areas and suggested 520 K Cal per day a person in rural areas This was based on the growth in the in per capita useful energy consumption during the period 1960 - 76. On the basis of the this forecast has been made for the year 2002.

3 .3.6. Perspective Planning and Policy for Commercial Energy (Sengupta, 1988, Planning Commission) -[20]

The focal point of the study was to analyze the optimal strategy for supply of energy need of the economy to ensure the achievement of the targets of growth, distribution and efficiency by meeting the final demand for different energy forms at least resource cost. It was a supply side static integrated energy modeling. A system of interconnected individual models on the sub sectors such as : coal, oil, natural gas and electricity have been developed. The findings on the long run demand projections for commercial energy, the availabilities and the economic cost of energy resources are given. Supply side begins with the estimated geological resources and along with their regional distribution. The model has incorporated the conversion of energy resource into the final items of supplies.

3.3.7 Energy Economy Simulation and Evaluation Model (TEESE, Model).[21]

It was a serious attempt by Tata Energy Research Institute (TERI) with support from the Ministry of Non-conventional Energy (MNCE) and the planning commission to develop a comprehensive model of the Indian energy economy system to evaluate quantitatively the impact of policy options within a comprehensive framework. This model has been structured around the approach of the Brookhaven Energy Economy Assessment model (BEEAM)[15]. The model incorporates energy flows at a macro level, integrating Input-Output (I-O) Model and the Linear Programming (LP) Model. It analyses the impact of various price changes, technological changes in terms of efficiency, substitution effects and so on.

3.4 ENERGY MODELS AND MANAGEMENT SCIENCE

At last the dooms day arrived on October 23, 1973, when the long period of uninterrupted came to halt. Long established trends reversed. Discontinuities and interruptions in the energy supply became the norm. Under these circumstances, the outdated energy models became unreliable.

On the empirical front, President Nixon announced on

November 7, 1973, "It soon become evident that the US would remain heavily dependent upon Oil imports throughout the 1980s."[22] This inaccurate declaration was based on the report of the Project Independent Evaluation System (PIES) model. Other models in the United States had projected the price of oil in the range of $13 to $14/barrel in 1975, a decline over the 1975-1980 period to around $ 10 and then a slow increase.[23] In 1866 Professor Jevons forecasted that within 100 years the demand for British coal would be in the order of 2,607 million tones a year. In 1966 U.K coal production was only 298 million tones of coal equivalent.[24] In 1960 Organization for Economic development and Cooperation stated the no persistent shortage of primary energy supply likely by 1975 and there was no need to create new sources of energy. And now, all proved false, the non OPEC countries are diverting valuable scarce resources for the development of alternative energy resources. Even at the theoretical ground energy forecasting becomes unpredictable when the fundamental changes from the very structure becomes unpredictable.

Under these circumstances, what is an imperative in the energy modeling is as Samouilidis and Berhas note. "The principle question was no more what energy demand in some future year would be and how different supply options could contribute to satisfy this demand, but rather a robust, flexible and rational energy policy should be in order to cope with the uncertain future and meet specific economic and social goal.[25] In the final chapter we will see the strategic energy reserve requirement in order to cope with the disruption in the energy supply. Under these circumstances, that a new breed of Energy Models made its explosive appearance in the world of management science.

Management science is defined as the application of the methods and technique of science to problems of management decision making.[26] Its goal is to help managers make better decisions by solving the problems more effectively. In pursuing this goal, a number of techniques have been developed, especially in the field of operations research. These technical models emphasize the managerial role of decision maker...the objective of the analyzed system and possible alternatives available to the management. These models are normative oriented, although their approaches per se are positive.

The emphasis of EM have shifted from the "descriptive" and "predictive" models of energy analysis to the "normative" models of energy planning and management. The following characterizes the difference between EM and conventional management science model.[27]

1. Planning Horizon: Em generally look further into the future than early decision making models.

2. System Boundaries: Usually decision making models within management science describe the behavior of the firm or an industry. EM usually deals with a higher order of aggregation such region or nation.

3. Supporting Science: The industrial models of management science rely heavily on micro economics and the engineering sciences, where as EM draw much from macroeconomics.

4. Model Complexity and Size: Em tend to be more complex and extensive than the conventional decision making models.

5. Model Potential Users: EM usually aims at public decision making , where as conventional management science models address themselves to the decision making within a firm. This makes the EM more complicated than the conventional models.

The mushrooming of the EMs Broaden the scope of and the field of implementation of management science. At the same time, the latter has rich experience to offer to the former. Energy modelers therefore can draw much from the realm of management science.

3.5. EM AS A TOOL FOR PUBLIC DECISION MAKING

The role of EM is to enhance the understanding and communication of the energy issues involving policy making. EM assist the policy maker to review plausible future configurations of the relevant decision variables and parameters. It is therefore impotent to detail the ways EM can become a tool useful to public decision making.

As public policy makers and planners face the problem of economic growth under resource or energy constraints, they seek the best possible information on the consequence of their choice among development alternatives. Conceptually planners are often faced with trade-offs between various levels of economic purity, resource use, and economic activity. The essence of these trade offs is that it is possible to have a pristine environment with at the cost of zero levels of economic activity. On the other hand, it is possible to have a totally dirty environment but have a high economic activity. Further, it is possible to show the relationship between levels of economic activity and resource use. This production or technological relationship simply reflects the use of resources in the production process and shows a proportional relationship between resource user and economic activity.

From a decision maker's stand point, it would be extremely helpful to quantify some of the above relationships. Then, decision makers would be better able to make informed decisions regarding alternative course of action. On the other hand the energy modeler is to identify the above mentioned quantitative relationship by applying energy modeling techniques to the reference system. A complete circle is completed: planners quantify some of the above mentioned relationships and the modeler identifies the above mentioned relationship in given modeling system.

3.5.1 PROBLEMS AND LIMITATIONS OF EM

Though the government of India and the planning bodies of the county have taken several concerted measures to evolve a energy planning policy and modeling, an integrated, comprehensive and coherent energy modeling is yet to see the light of the day. The difficulty lies not in the inadequacy of expertise of committees in themselves, it is a basic structural problem which most of the LDCS so commonly share. The inadequacies can be classified as under:

Samouilidis and Berhans[28] identified five broad categories of problems and limitations of EM.

1. Data complexities: Energy Demand Analysis (EDA) involves (a) assembling and presenting a consistent set of data on consumption of various forms of energy, (b) estimating the level of shortages and/or unfulfilled demand at relevant price ranges, © quantifying the relationship of energy demand with relevant economic variables such as income, population, prices of different energy sources and their substitutes, changes in technology, (d) indigenous energy data, etc. In the context of developing countries, EDA becomes even more complex on the account of following factors.

The role played by the non-commercial fuels in the total energy consumption complicates the compilation of reliable set of data. This is because non-commercial fuels are mostly gathered outside the market place and the transactions are rarely recorded. Primary data are available from field surveys conducted by NSS, NCEAR[29] and other research institutions and individuals. However these surveys are too scattered to give any comprehensive nature of the regional variations in the pattern of consumption of these fuels.[30] In view of these difficulties the FPC (1974) for example, made an order of magnitude estimates of the total energy requirements of the households on the basis of certain normative levels of consumption and subtracted from the total requirements the amount of commercial energy consumed in the household sector to arrive at a rough estimates of non-commercial energy consumed in that sector. When the NCEAR estimated the pattern of Gross and useful energy consumption in the household sector for different income groups in the rural and urban areas in 1985[31] the NCEAR data which is the basis for comparison relates to the year 1977 and the pattern would have undergone remarkable changes.

(ii) It is very hard to really on the estimate of energy demand, to the extent that the consumption of energy is constrained by available supplies, actual consumption does not reflect actual demand.

(iii) Data on commercial energy consumption though available in general, a lot of effort is needed to asses the quality of information. Usually data are available only aggregate terms or by products, and the pattern of uses does not distinguish between transformation uses/losses and final consumption. For example coal output data may distinguish coal by grade but may not give details of collieries' own consumption of coal. Similar problems are there in the oil products, like evaluating data on the use of furnace oil, LSHS (Low Sulfur Heavy Stock) since information may only be available by region or by producing company rather than by end-use. There is no way of estimating the substitution of one oil product for another due to price differential like substitution between kerosene and diesel.

(iv) Even more perplexing problem than the consistent data is the energy indexing, because there are alternative ways of measuring energy and handling energy data indexing. Percebois(1979)[32] discussed different interpretations for measuring energy intensity. Smith (1984) presented common problems extensively involved in energy indexing. For example, to measure electricity from nuclear power plant, the World Bank bases its calculation on the starting point i.e. total (gross) energy content of nuclear fuel, most of which is lost during the process of generation, whereas, the United Nations basis its calculation on the end point, i.e. actual (Net) electricity generated. The former is about three times greater than the latter measurement. It is, therefore important to specify which the energy modeler uses in order to present correct interpretation.

Indexing of energy data are even more complicated than the above mentioned energy measuring problem. In general, the value of energy flows in an energy balance are generally expressed in a common unit, as is the case with EBT and RES . Quantities expressed in different specific units for ,each energy source, such as tones for coal and oil , cubic meters for gas, and kilowatt-hours for electricity, are represented in the balance in terms of common unit. So presented, the balance is easy to interpret and use. However, the conversion of values into a common unit poses serious problems, which can be solved only by using the average conversion factor and, in many cases, adopting a specified convention. The convention at current is Tones of Oil Equivalent (TOE) as the common unit. When oil became the world's most important energy resource, the TOE replaced Tones of Coal Replacement (TCR) as the unit in many countries. Apart from this common unit, there are other units which are some what country specific are also available. The British Thermal Unit (BTU), or multiples of it and the tetra calorie (10^{12}) used in France. The energy unit recognized by the System International (SI) is the joule. Griffin and steel made a detailed analysis of the problem As such , they argue, that there no universal energy index. The index must be chosen carefully to fit the needs of interest and to be sure that it is helping find, not obscuring, the answer to the question in hand The Indian government (1974, 1979) uses the method of Million Tones of

Coal Replacement where one tone of oil products is assumed to be replaced by 6.5 tones of coal because of higher efficiency of using oil in rail transport, cooling etc. In coal equivalent terms (or kilo-calorie terms) a tone of oil would be equal to only 6.5 tones of coal . For detailed conversion factor adopted by EPIC, see appendix 3. In India, the EPIC used the Million Tones of Coal Replacement (MTCR) as a common measure which is also later adopted by the FPC & WGEP on the assumption that "the major practical problems of the Indian energy economy is substitution of different forms of energy, such as oil or electricity for the other forms such as cow-dung or firewood We have therefore used throughout this study units of coal replacement."[33] However after considerable thought was given to the question, Million Tones of oil Equivalent (MTOE) were adopted in this study. This is justified on the grounds that first the growth of oil consumption is much higher than the growth in coal consumption. Contrary to the expectations of the EPIC, coal has been getting replaced by liquid sources of energy. Second, most of the International Institution use (TOE) as a measure for intra-country composition such as Asian Development Bank (ADB), which has experienced the consumption of energy in Developing Countries in terms of (TOE). the Planning Commission and the Official Publications use the same measure.

Third, one of the primary concerns of the present study is with problems of energy imports and primary energy and the reduction of the dependence on import of oil. It would be much easier for the policy makers concerned to visualize the dimensions of some aspects of the problem if it is presented in terms of oil use.

(2) System complexities: It involves the difficulties inherent in the nature of the phenomena in formal ways.

(3) Political complexities: Involving the difficulties inherent in the political nature of the policy making process, e.g, conflicting interests, pressure group, lobbies, etc. which can one way other influence the policy decisions.

(4) Model complexities: involving the difficulties inherent in the complex structure of large scale models usually developed for addressing Policy question.

(5) Communication complexities: involving difficulties inherent in the lack of communication channels linking the various agents in the modeling process, e.g. The different ministries and departments in the ministry power. More the communication problem often encountered between analysts and planners resulting from individual differences, time constraint, and unsatisfactory model documentation.

Reviewing the difficulties in EM, one can shy away from it as exercise in academic futility. Yet the plethora of models addressing the important policy issues is an indication that models and modeling are vital indeed. As points out that "there is often a quite unrealistic attitude regarding mathematical models and their use in policy and decision making. The attitude of policy makers towards models, feeling that models reduce their role and degrees of freedom, and the attitude of the analysts to view their model as the ultimate tool without which it is impossible a rational decision.

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