MODELING APPROACH TO LONG-TERM ENERGY DEMAND AND ENERGY POLICY IMPLICATIONS FOR INDIA

Jyoti K. Parikh

May 1981
PP-81-8

INTERNATIONAL INSTITUTE FOR APPLIED SYSTEMS ANALYSIS
A-2361 Laxenburg, Austria

PREFACE

The energy sector claims nearly 27% of the public sector plan allocations in India. Other developing countries also spend similar proportions of their investments for the energy sector. Efficient management of the energy system and optimal planning for its development could result in substantial savings of plan resources. Therefore, the need for setting up a national energy modeling system was felt for quite some time within the Planning Commission of Government of India. The present study was initiated in the Planning Commission to fulfill the need for a national energy modeling system. The study was carried out during 1979 to 1980. Such a modeling system can permit a detailed look at various energy uses and options and help to identify policies for energy systems management. Considering the long gestation periods necessary for initiating and completing energy projects, a long-term perspective upto the year 2000 was considered necessary. However, while doing so, this work identifies a number of areas where certain policies, decisions and action plans are required within the sixth plan period (1980-85) itself, if some of the long-term goals are to be reached by the year 2000.

The overall concept of energy modeling system developed here derives much from the energy modeling system for different world regions proposed by IIASA energy program led by Prof. Wolf Häfele, report of which is recently published in two volumes titled "Energy in a Finite World" and with which the author was associated for two and a half years. However, individual models were developed specifically for India to address the questions that concern policies at national level - and in particular for India. These are

- SIMA model for generating macro-economic scenarios,
- ENDIM model for simulating sectoral energy demand corresponding to macro-economic scenario generated by the SIMA model and which considers alternative policies for demand management in industries, transport, household and agriculture sectors,

- INVEST model which identifies the conditions under which energy requirements for economic growth of India could be met.

The projections given here are to be interpreted as 'if' and 'then' statements are by no means absolute numbers. Yet, the efforts put into making various assumptions internally consistent, analyzing data at considerable disaggregated levels, understanding relationships of energy system with socio-economic developments and constructing and analyzing a number of scenarios, make this exercise useful for understanding energy system and therefore, assessing implications of various energy policies.

It is hoped that this work, with suitable modifications, also provides necessary framework for examining energy policies for other developing countries.

ACKNOWLEDGMENTS

I am grateful to Dr. V.G. Rajadhyaksha, Shri T. Sankar and Shri T.R. Satishchandran who have made efforts to initiate this work within the Planning Commission, New Delhi, where I carried out this work as Senior Consultant in the Energy Division. This work could not have been initiated, completed and printed without the keen interest and whole hearted support of Shri T.R. Satishchandran, Adviser (Energy) for this work. He has contributed a great deal through valuable discussions during the course of this work.

I have benefited from participation in the Meetings of the Working Group on Energy Policy (WEP) set up by the Ministry of Energy and to that extent, there has been interaction between this work and that of the WEP.

Shri A. Chaitanya has gone beyond the call of his duty to assist me in carrying out this work. Thanks are also due to Shri V. Mohan, A. Sehgal, J. Magoo, Satish Kumar, M. Ubale and other members of the Computer Centre for their help in numerical and computational work.

Dr. Y.K. Alagh presently at Sardar Patel Institute, Ahmedabad and Dr. Venugopal of NCAER, New Delhi, have critically read the manuscript and offered a number of constructive suggestons.

I would like to thank in addition, Nitin Desai, Jayanta Ray, J.S. Mishra, H.R. Rao, Hanumantha Rao, Mahesh Kapoor, M. Satyapal and Rangaswamy of the Planning Commission who have contributed to this work through discussions. I have also had discussions with a number of persons within and outside of the Government and the limited space restricts me from naming them individually.

I am grateful to J. Kindler and W. Häfele, Program Leaders at IIASA, for their encouragement and support for bringing this out as a Professional Paper of IIASA, prior to its publication as a book by the Planning Commission, New Delhi.

Several drafts of this book had been prepared by Shri B.D. Kumar, Personal Assistant at the Planning Commission, New Delhi. Ms. Vicky Hsiung at IIASA put in her sincere and diligent efforts to prepare the two final drafts in a short time in spite of the workload.

Despite my association with a number of staff members in the Planning Commission, the views expressed here are not necessarily of the Planning Commission.

TABLE OF CONTENTS

MODELING APPROACH TO LONG-TERM ENERGY DEMAND AND ENERGY POLICY IMPLICATIONS FOR INDIA

Jyoti K. Parikh

1. OBJECTIVE AND APPROACH

1.1 Objective of the Modeling System

The energy sector calls for 28.5% of the plan allocations in the revised Sixth Five Year Plan. The Planning Commission sets the targets for the energy sector of the Plan, by using the input-output model of the Perspective Planning Division and modifying the results in consultation with the Energy Division. However, the input-output model approach (coupled with material balance) treats all the sectors of the economy of India equally and no special emphasis is given to look into the energy sector in sufficient detail, in particular, from policy point of view. Because of the importance of the energy sector, it was felt that a separate model reflecting the interconnections of various energy policies, end-use activities and energy demand in some detail could strengthen the efforts of planning for the energy sector. On the other hand, a working group on energy policy was also set up by the Planning Commission involving essentially the representatives of the various ministries and organizations concerned with supplying and transporting energy.

The rationale for initiating the present work on energy modeling system within the Planning Commission was two-fold:

- To augment the input-output model approach.
- To augment the efforts of the Working Group on Energy Policy (WEP).

Each rationale is explained below.

1.1.1. Supplementing Input-Output Model Approach

(a) In the input-output model, the advantages of looking at the energy-use for various activities directly in the physical units get lost. This is because an input-output matrix in physical units is not available.

(b) The changes in energy consumption due to substitutions and model shifts, e.g., wood to kerosene or road to railways, etc., cannot be easily estimated in the input-output model.

(c) Disaggregated information is required in estimating requirements of oil products, such as gasoline, kerosene, diesel, etc., which is not available in the present input-output matrix.

(d) Impacts of various energy policies, e.g., rural electrification, railway electrification, pricing policies, etc., could be better understood from an end-use model.

(e) Some long-term changes, such as increased urbanization, technical changes, etc., could be better incorporated in a sectoral simulation model.

1.1.2. Supplementing Efforts of WEP

A Working Group on Energy Policy (WEP) had been set-up in 1977 which has submitted its final report which includes some perspectives on the energy sector upto 2000. As the time available to this group was rather short, it used simple methods such as trend method or GDP elasticity method for obtaining reference level projections to determine policy guidelines. The modeling system discussed here is an effort to give an independent look and also to provide a framework within which the recommendations of the WEP of various energy policies can be examined in detail. This model augments the efforts of the WEP as follows:

(a) Some of the assumptions of the WEP are either made more explicit or replaced by behavioral equations.

(b) As the model is computerized, it facilitates a more critical examination of changes in many of the variables which are assumed to have only one value in the WEP approach. For example, effects of varying urban population, efficiency norms, etc., this permits one to identify the robust as well as the sensitive elements of the energy systems which requires examination of many scenarios.

(c) Energy use is correlated with specific policy variables so that impacts of various policies could be examined.

(d) Effects of socio-economic variables other than just GDP are also explored.

(e) The WEP does not examine whether investment required for the energy sector, which is growing annually at 6% to 10% would be available in an economy growing at annually 3% to 6%. This issue of consistency can be examined in the present modeling system.

(f) The WEP gives projections for the target years F1982*, F1987, F1992 and F2000. After the new Government took over in 1980, the decision has been taken to consider the sixth five year plan period from F1982 to F1984. This means that the figures for 1984-85, 1989-90 and 1994-95 have to be worked out; which means shifting the targets by two years in a consistent manner. Again, as the model is computerized, this was not difficult.

1.2 Approach of the Energy Modeling System

The system envisaged has three parts:

(a) A model to project macro-economic aggregates;

(b) Multi-period, multi-sectoral models for assessment of energy demand split-up into many categories of end-uses, some of which are projected using econometric methods; and

*F stands for financial year, e.g. April 1982 to March 1983. Alternatively, also described as 1982-83.

(c) Calculations of the investment required for the energy sector and cross-checking the consistency with the results of the macro-economic model.

Schematic representation of interactions of the three models suggested above is given in Figure 1.1.

As energy resources are finite and their inter-sectoral and inter-temporal allocations need careful considerations, in addition to short- and medium-term forecasting, long-term perspectives on energy are also necessary.

In a long-term model, it is essential that the number of exogenous parameters is not excessive and these should either be policy variables, such as energy prices, or should be those which can be reasonably predicted for future, such as population. Macro-economic aggregates would be also required for scenario specifications. Projections for the future are always beset with uncertainty, and by necessity are conditional statements, predicated on certain assumptions. The methods used for projectons should aim at being explicit about these assumptions and also keeping them minimal and consistent. The approach is combination of the relationships derived from multiple regressions, end-use method and simulation of scenarios. When the regression method is used, its objective is not just to explain the past, but rather to predict the future. It is, therefore, essential that the variables which are likely to change in the future are considered as independent variables, so as to capture the expected changes.

1.3. Energy Production to Consumption: Some Definitions of Terms

It is necessary to define the terms used to describe energy at various stages, as it flows from production point to consumption point (Häfele, 1981). Figure 1.2 illustrates these terms and energy transformations. Primary energy is a gift of nature and here, each energy resource is considered according to its calorie equivalent terms. This energy goes through central conversion facilities such as refineries, power plants, etc., outcome of which are secondary energy forms which may be different from the original primary energy forms, e.g., electricity

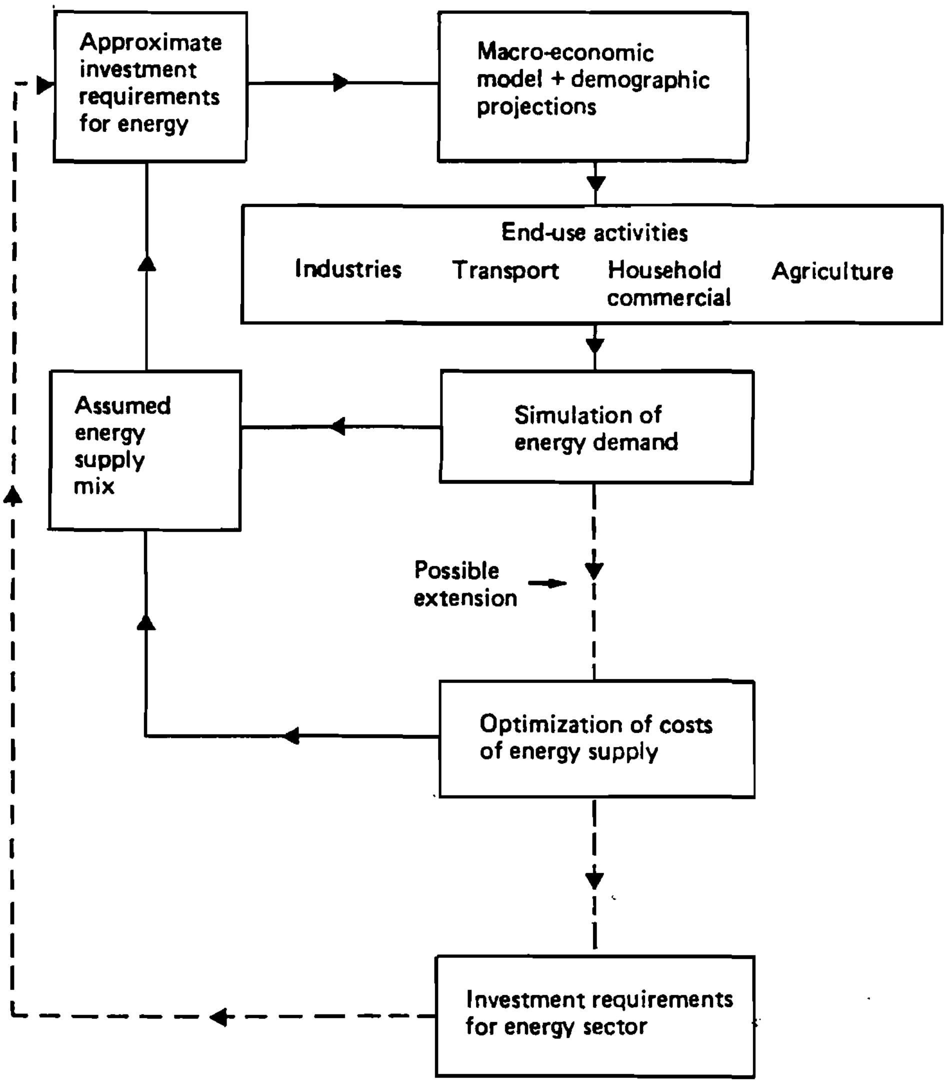
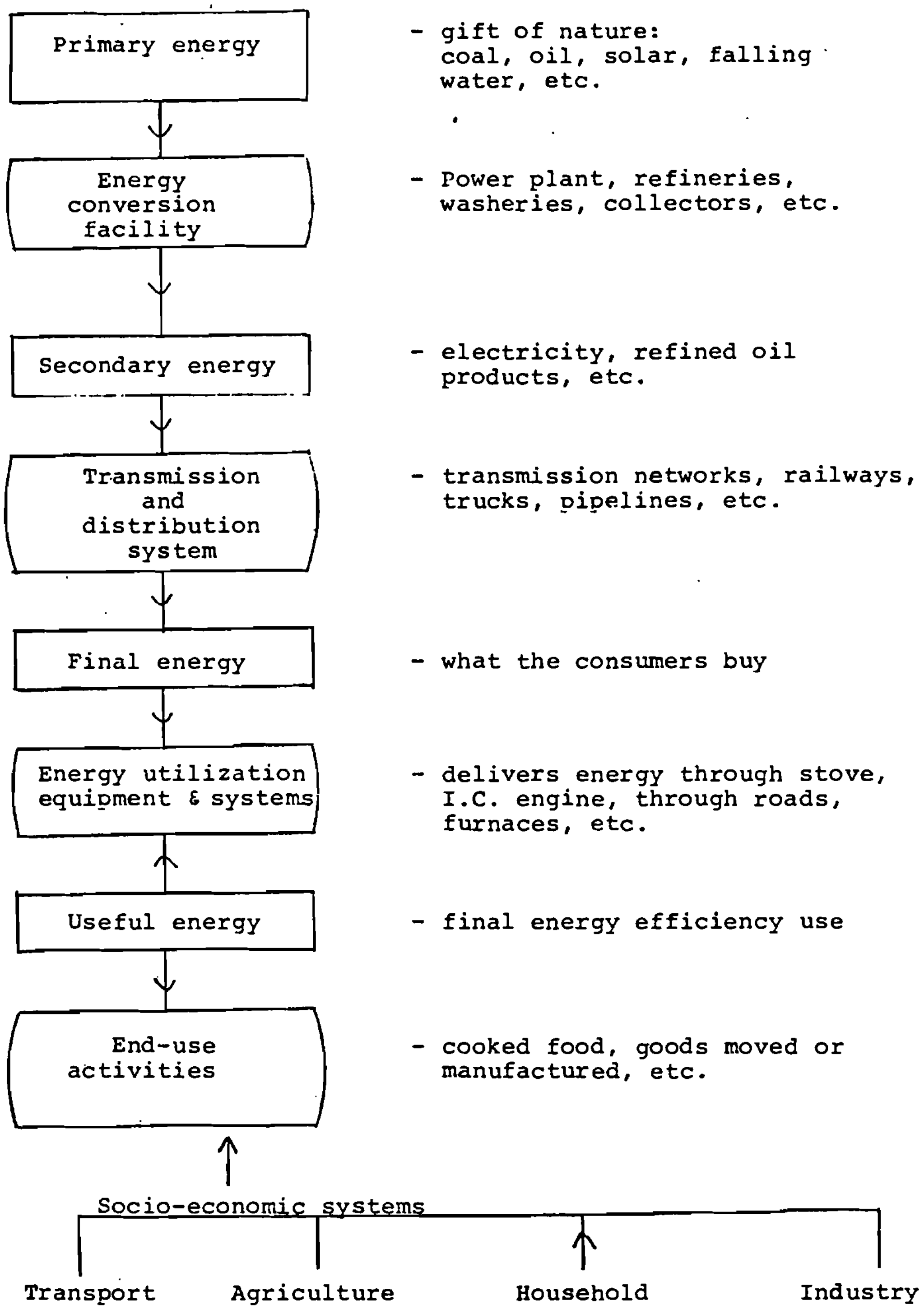


Figure 1.1. Energy Modeling Systems



Source: J. Parikh (1980). "Energy Systems and Development". Oxford University Press.

Figure 1.2 Flow of Energy from Production to Consumption Points and its Transformations from coal. Final energy is what consumers buy, i.e., secondary energy, exclusive of distribution losses. Useful energy is that which is finally delivered to the system through energy utilization equipment. In general, all equipment that use oil or electricity or even coal (except in power plants and some furnaces) are efficient, but the use of non-commercial energy (wood, waste, dung, etc.) which is found in developing countries, is not so efficient. Useful energy can be calculated by considering which form of primary energy is used and for what purpose. In terms of primary energy, the contribution of non-commercial energy to total primary energy would be high and that of oil small. But, when considered in terms of useful energy, the contribution of non-commercial energy would decrease, while that of oil would increase. In this work, everything is discussed in terms of final energy because in the demand system, only that energy is perceived and paid for which is delivered. The losses in the supply system, choices of technology, i.e. whether to produce electricity by coal, hydro or nuclear are to be considered separately in the energy supply model.

It can be seen in Figure 1.2 that the analysis of the energy demand system starts from the final energy (or as delivered energy) onwards and identifies how the energy is used, for what purpose and what policies may alter the pattern of energy usage. Similar analysis has to be also done for energy supply system where all steps taking place between primary energy to final energy should be examined so as to increase efficiency. An integrated approach concerning energy demand and supply system can help to identify steps which connect the appropriate primary energy forms with the required useful energy so as to increase the efficiency of the entire energy system.

1.4. Scope of this Work

The modeling scheme described above is followed by a description of the macro-economic model and the energy demand model (ENDIM) in Chapter 2, the sectoral details of which are given in Chapters 3 to 6. The energy demand for two generated scenarios are summarized in Chapter 7. Although two scenarios are selected for the final presentation, a number of policy alternatives have been tried out for each sector and are reported in the respective chapters.

Investment requirements are calculated in Chapter 8 and the implications of the regional distribution of energy demand are discussed in Chapter 9. Finally, a summary is given in Chapter 10. The units chosen to describe the energy systems are explained in Annexure I.

Special emphasis has been laid on constructing several alternative scenarios of energy demand to demonstrate the use of the models. In addition, a background of the energy scene of the country is also provided to underline the context in which the models are built.

2. DESCRIPTION OF THE MODELING SYSTEM

In general, the formulation of any model goes through the following steps:

- o Analysis of the past and present data.
- o Decisions concerning how best to structure the problem .
- o Identification of those factors
  - (a) which are undoubtedly going to change in future such as energy prices, energy efficiencies, technical changes, etc.,
  - (b) which are controllable through policy; and
  - (c) which will vary gradually due to socio-economic changes (e.g., urbanization).
- o Formulation of the mathematical model of the above-mentioned identified factors.
- o Verification of the mathematical model to see if it reproduces the past.
- o Judgment concerning numerical inputs, (i.e. scenario variables) based on the data analysis.
- o Running the model for various scenarios, examination of results and interpretations in terms of policy.

The modeling system described here has a similar structure to IIASA energy modeling system described by Häfele (1981) and Basile (1980). However, the demand model of IIASA described by Lapillonne (1978) was inadequate for understanding national energy policy questions and had to be drastically restructured.

2.1. The Macro-economic Model (SIMA)

The projections of the macro-economic variables (viz. GDP, consumption, export, etc.,) are obtained from the Simulation of Macro-economic model for assessing energy demand for India (SIMA model) developed by Jyoti and Kirit Parikh.* Demographic projections are also exogenous to the model. As the SIMA model is already published, it is only briefly described below. Alternatively, any other model could be used to provide the macro-economic parameters for the demand model.

The full interaction of the two sector economic model could be seen in Figure 2.1.

2.1.1. Generation of Gross Domestic Product

The gross domestic product is a function of output of agricultural and non-agricultural sectors.

The specified growth rate determines the output of agricultural sector. The output of non-agriculture is determined by the capacity created through capital stock accumulation and the extent to which capacity can be utilized.

2.1.2. The Spending of GDP

The GDP generated is utilized in private and government (public) consumption, and investments. Government consumption is a function of taxes collected, which in turn depends upon the output of agriculture and non-agriculture sectors (since income from the two sectors are taxed differently). Private consumption on the other hand is determined by the per capita GDP after tax as well as by the composition of GDP. Private consumption would be higher, if the share of agricultural GDP is higher in the total GDP.

---

*Simulation of Macroeconomic Scenarios to Assess the Energy Demand for India (SIMA), IIASA publication, RR-79-15, December, 1979 by Jyoti K. Parikh and Kirit S. Parikh.

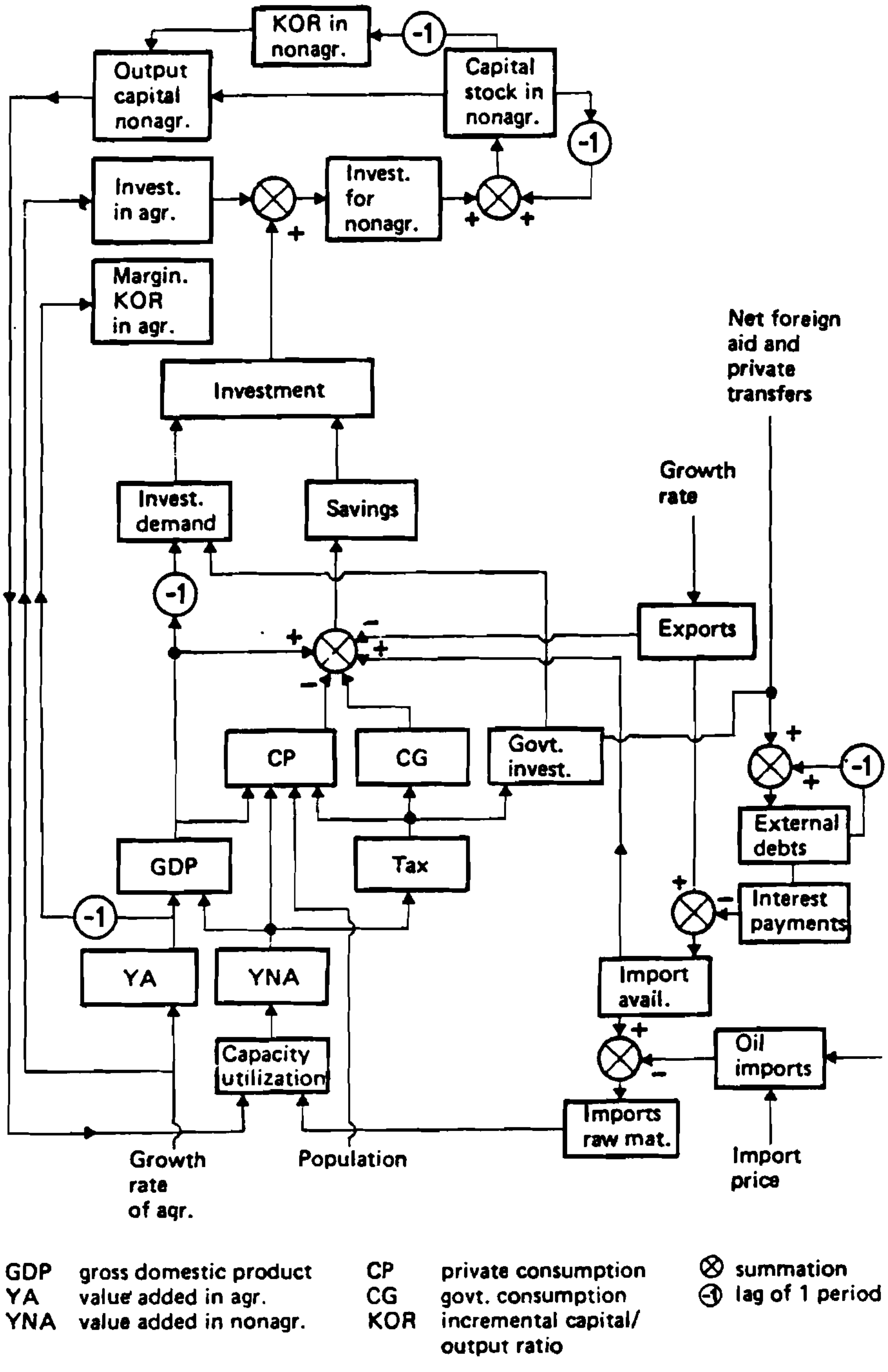


Figure 2.1 The Model Structure - The Macro-economic Sector

2.1.3. Capital Formation

The level of investment is determined by the demand for investment and the availability of investment. Government investments which are determined by the amount of taxes collected and the amount of aid received, stimulate private demand for fixed investment. The level of previous year's GDP also affect private demand for fixed investment. Investment availability is determined by the GDP identity. The actual investments comprise inventory formation, replacement requirements, net fixed investment in agricultural non-agriculture sectors. The last of this, is added to the existing capital stock of non-agriculture.

In view of the limited land, the agricultural production required for the growing population would require increased capital inputs. The capital output ratio in agriculture, therefore, is taken to increase monotonically with the level of agricultural output. On the other hand, the capital/output ratio in the non-agriculture sector which is high at present is expected to decline with the diversification of the capital stock and increased efficiency of capital use. The asymptotic limits of the capital/output ratios for both the sectors are exogenously specified. The schematic behavior of the capital/output ratios are indicated schematically in Figure 2.2.

2.1.4. Foreign Trade

Imports are determined by the availability of foreign exchange from net export earnings and other transfers from abroad. The import of oil at exogenously specified import prices, is first set aside and the imports of other raw materials, spare parts and equipment are then determined.

2.1.5. Selection of Macro-economic Scenarios from SIMA Model

The SIMA model generates several scenarios of macro-economic growth, one of which provides an input to the demand model (ENDIM) discussed here. A growth scenario of long-term GDP growth of 4.62% was chosen so as to provide contrast to the WEP scenario

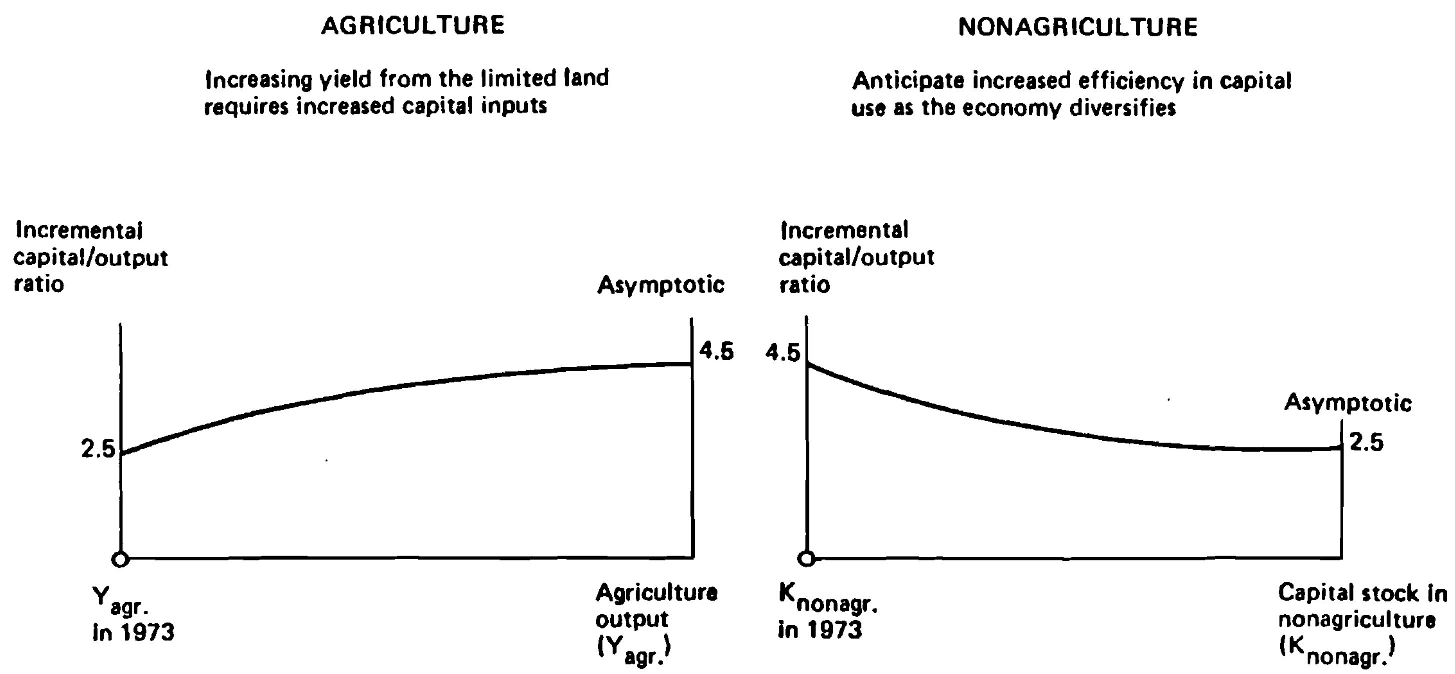


Figure 2.2 Schematic Behavior of exogenously specified incremental Capital/Output Ratios in the Two Sectors of the Model.

which considers 5.8% growth between 1982-2000 (one of the scenarios generated in the SIMA model also gives 5.62% growth, when capital output ratio is reduced compared to the past). The highlights of one of the SIMA and WEP scenarios are given in Table 2.1.

2.2. Energy Demand Model: ENDIM

The major purpose of the demand model is to provide a framework to examine the relationships of the energy sector with the development of socio-economic system and the effects of energy policy measures on it. Moreover, the model gives indication of the levels of energy demand for every five years, consistent with macro-economic assumptions. The demand model is essentially simulation model where the dependent variables are the end-use activities in the following four sectors:

(i) Industry;
(ii) Transport;
(iii) Agriculture; and
(iv) Household and Commercial.

In the model, for some of the activities, econometric estimates are made based on multiple regressions where the end-use activity levels are independent variables. For other activities, the energy projections are based on energy consumption norms derived from past data modified in the light of changes which may be reasonably expected in the future.

The end-use activity model is constructed with a view to examine the following issues:

(i) Energy is required as an intermediate product to carry out certain end-use activities and is not demanded for itself. These activities, for example, may be to travel, obtain cooked food, attain certain temperatures, produce certain materials, etc. Means of achieving these end-use requirements are not unique and alternative ways of achieving them could be introduced which could lead to different energy consumption <u>without</u> sacrificing the end-use requirements. These alternatives need to be examined keeping technological changes in view.

Table 2.1 Macro-economic and demographic inputs in the ENDIM Model for Low* and High** Scenarios

	1977-78	1984-85	1989-90	1994-95	2000-01	Growth rates for 1984-2000
Gross domestic products 10^9 in Rs. of 1970-71						
Low	412	534	657	817	1065	4.42
High		577	761	1019	1445	5.90
Industrial GDP						
Low	73.7	101	131	180	245	5.70
High		110	152	224	332	7.21
Private consumption						
Low	311	365	445	546	704	4.19
High		394	511	677	950	5.65
Population						
Total	622	722	785	847	921	1.53
urban						
Low	131	165	189	214	247	2.55
High		175	208	245	295	3.32

* Projections based on one of the scenarios of SIMA model developed at IIASA.

** Used by WEP (Given by PPD) based on the stipulated growth rates of 4.7%, 5.5% and 6% respectively for the periods F1977-82, F1983-88, F1988-2000.

(ii) As the major problem for India's energy supply is the provision of oil, the possibilities of oil substitution in various sectors need to be examined.

(iii) Not just the absolute economic growth but also the changes in its origin and distribution affect the energy consumption. This needs to be examined.

(iv) Sensitivity of different users to the energy policy measures needs to be gauged and effects of technological and other changes need to be considered.

(v) Estimation of disaggregated oil products are required in order to examine if the required mix of light, middle and heavy distillates are in accordance with the refinery balance.

2.2.1. Structure of the ENDIM Model

Briefly, the energy demand model works as follows. The following macro-economic and demographic variables are considered as given:

GDP - Gross-domestic Product in Rs. 10^9 (1970-71 prices).

CP - Private consumption in Rs. 10^9 (1970-71 prices).

YIND/GDP - Fraction of the industrial GDP in total GDP.

N - Population in 10^6.

NU - Urban population in 10^6.

In addition, certain policy and scenario variables have also to be prescribed.

YLEC - Value added by the large energy consuming industries in Rs. 10^9.

FREL - Number of villages electrified in 1000 villages.

PTLPR - Crude price index (1970-71 = 100).

AREA - Net area sown in million hectare.

AE, AD, AC, BE, BD, BC = Fractions of passenger km and ton-km moved by electric, diesel and steam locomotives respectively.

Energy consumption norms for various activities and industries. Equations for the model are given in Annexure II.

Based on these variables, the following sectoral end-use activities and consequent energy demands under various policy scenarios are projected. As indicated before, the aim of the model is not merely to make projections, but to examine the effects of alternative policies. In the following, the sectoral approaches are indicated along with the policies examined.

2.2.2. Industries Sector

Energy intensities for (energy consumption per V.A. Rs. 10^9) large energy consuming (LEC) industries and non-LEC industries are worked out from the past data. How they may change over the future is postulated from the study of processes and technologies see, e.g. Parikh and Chaitanya (1980). The industrial GDP disaggregates in these two types of industries. This then gives projected energy requirements. Alternative combinations of LEC vs. non-LEC and changes in energy intensities are considered to understand the effects of policy for LEC-non-LEC mix and policy for energy-conservation and efficiencies. In the second approach, 19 individual industries for which long-term projections are available are considered. The energy requirements for these industries are worked out from the data of the production technology. The energy consumption by the remaining industries or other industries is obtained on a percentage basis.

2.2.3. Transport Sector

The following end-use activities and their modal splits are projected:

- o Ton-kilometers
  - Road
  - Railways
- o Passenger kilometers by public mode
  - Regional
    - Road
    - Railways
  - Urban
    - Road
    - Suburban

- o Passenger transport by private mode
- o Other services such as post, police, defense, etc.
- o Air and water transport.

Energy consumption norms for each activity are worked out and the possible changes are assessed and incorporated. The following oil conservation policies are considered:

(i) Low urbanization;
(ii) Increased efficiency in transport vehicle utilization;
(iii) Increased transport by rail; and
(iv) Railway electrification.

2.2.4. Agriculture Sector

In the agriculture sector, direct energy-use for pumping and mechanization is considered. Energy embodied in the fertilizers, and pesticides is already considered in the industries sector. Energy for pumping is projected and its split into diesel and electricity are calculated. The following are considered:

- o effects of area expansion vs. intensification, of agriculture;
- o effects of increased rural electrification, and
- o higher crude prices.

2.2.5. Household Sector

In the household sector, it is essential to examine:

- o effects of various income levels and its distribution amongst 8 different expenditure classes;
- o rural-urban differences of household consumption;
- o non-commercial energy consumption and the possibilities of renewable energy resources as substitutes for kerosene.

Therefore, three methods are considered to get insights into these issues:

1. End-use method: energy required for cooking and for lighting and comfort is calculated separately.
2. Direct-use method: here, electricity, kerosene and non-commercial energy are directly correlated with socio-economic variables (NU, CP, etc.).
3. Income distribution method: using urban and rural household consumption data for 8 different expenditure classes, energy demand is calculated from class specific consumption patterns.

The end-use activity model investigates implications of alternative policies in a much greater detail by considering the end-use activities (such as ton-kilometers - TKM, etc.), as dependent variables. In order to ensure an exhaustive treatment of all the end-uses, it would be necessary to validate the model for one year (e.g. 1976; it should be checked if 1976 energy consumption could be predicted by the model using 1976 data).

2.3. Hierarchy of Scenario Specifications

Three scenarios based on GDP and urbanization have been generated. A set of other scenario assumptions assumed with particular GDP and urbanization combination are indicated in Figure 2.3. In principle, a large number of scenarios could be generated but in order to restrict them to a few number, a hierarchy is assumed to eliminate certain possibilities. For example, high railway electric traction is assumed with high urbanization. Thus, a set of plausible scenarios are split into three different categories and energy requirements for each of these scenarios have been calculated. They are referred as follows:

1. High : High GDP, high urb.
2. Low : Low GDP, low urb.
3. High(L) : High GDP, low urb.

Low GDP (low YIND, low GP)	High GDP (High YIND, High CP)	
Low urb.		
Low REL		
Low LEC	High Urb.	Low Urb
Low net area sown	High LEC	Low LEC
Low electric traction	Low net area sown	High net area sown
Low share of rail for long distance (PKML)	High electric traction	Low electric traction
	High rail share	Low rail (PKML) share
Low share of suburban rail for urban transport	High suburban share	Low suburban share
Low	High	High (L)

YIND Industrial GDP
GP Private consumption
REL Rural Electrification
LEC Large energy consuming industries.

Figure 2.3 Hierarchy of Scenario Specifications

The first two indicate two limits - high and low - and give a range in which energy consumption may lie. The last scenario has been specifically constructed to give a comparison of model results with the WEP projections which has not made explicit assumptions about urbanization, but their results seem to indicate as though low urbanization with high GDP has been assumed.

2.4. Model Invest to calculate the Investment Requirements

Whether the investment for the projected energy requirements can be obtained from the economy has to be checked in order to know if the energy demand obtained from the end-use energy can be realistically met. For doing so, a model is developed to calculate the investment for the energy sector while considering also the gestation period of the investment. The essential steps are as follows:

(i) Total available investment in the economy for low and high GDP is calculated from the macro-economic model. Out of the total available investment, the fraction which is available for public sector is calculated on a scenario basis.

(ii) Assuming a mix of thermal, nuclear, and hydro-capacity utilization, and their performance standards, what is the secondary energy that needs to be generated in order to meet the final energy demand and what energy capacity needs to be created is calculated.

(iii) The streams of investment are calculated considering the gestation period for each of the energy activities, for example, 5 year gestation period for the thermal power plants, etc.

(iv) The fraction of total investment required in the energy sector is calculated and compared with the past.

2.5. The Computation Procedure for the Modeling System

The sequence of computations in the proposed modeling scheme is already shown in Figure 1.1. It is described in words below:

1. Macro-economic-demographic model provides the inputs required for simulating energy demand.
2. Using these inputs, the demand model calculates energy demands for industries,transport, agriculture, and household sectors. (These demands then can be fed as inputs to the energy supply model where the optimal mix of energy supply can be derived.)
3. Whether the investment required by the energy sector could be provided by the economy is consistent with the macro-economic assumptions has to be cross-checked. If the future percentage shares of investment and imports required for the energy sector in the total economy are significantly different from the present percentages, then second iteration would be carried out with reduced demand of energy brought about by increase in price and other conservation measures. This will be done only for a few sectors and for energy forms, where energy prices could have impact. However, in order to calculate investment, some assumptions concerning energy supply would have to be made, e.g. mix of hydro, thermal and nuclear, capital costs and gestation period of the power plant, etc.
4. Extension of the modeling system - energy supply model: It is necessary to construct a supply model which evaluates consequences of various energy supply strategies. An understanding of these consequences such as required investment, resources of fossil fuels to be located and/or developed, etc., could help in identifying supply strategies. In addition, for obtaining the same level of outputs, choice of an appropriate mix of technology would be determined (e.g. a given electricity requirement could be met from hydro, thermal or nuclear power plants). Such a

model, if constructed, eliminate some of the assumptions made in step 3 by actually deriving the numbers and should, in principle, be introduced prior to step 3.

2.6. Regional Distribution of Energy Demand

It should be realized that in the above model, the spatial dimension of India is not considered. What are the energy requirements of various regions or the States of India? What considerations should be made in allocating the national energy requirements of various regions or States? Some of these issues are discussed as a follow-up of the modeling work. However, this is not based on any model but judicious mix of various considerations that go into distribution of energy demand. This aspect is very important in order to work out the implications of energy transport, mine development, oil drilling and oil receiving points for imported oil, gas utilization, etc. In the following sections, details of each of the sectors of the ENDIM model are given.

3. INDUSTRY SECTOR (MANUFACTURING)

Industry sector is the largest consumer of commercial energy. It consumed nearly 64% of electricity, 60% of coal and 65% of fuel oil in 1978-79. Industry sector is a difficult one to model because of the diverse industrial activities requiring different levels of energy consumption per unit output (norms), and because of qualitative and quantitative changes taking place in various sub-sectors of the industry sector. It is also difficult to project production levels for various sub-sectors for a long-term. For a short-term, the input-output model coupled with the material balance used in the Planning Commission approach would be the most appropriate method where the required production levels for the individual industries in the economy are fixed by the input-output model. The energy consumption could be derived based on the energy required for producing unit physical output considering the requirements of the existing and planned (or under construction) technology of producing the output.

For a long-term model, some simplifications would be required as production levels for many industries cannot be fixed a priori. The time horizon for the input-output model, could be extended from 5 years upto 15 years at the most.

On the other hand, the WEP scenario considers overall energy intensities (or energy consumption per Rs. of value added) for the entire industries sector. It is assumed that from 1987/88 onwards, electricity intensity would stabilize and coal and oil intensities would decrease.

Because of the importance of the industries sector, a detailed analysis of energy intensities and energy efficiencies is made over the last two decades as well cross-national comparisons of energy consumption in the industries and reported elsewhere (Parikh and Chaitanya, 1980; Parikh, 1981).

3.1. The Approach used in the ENDIM Model

Two alternative methods are used for the industry sector in the present model. In the macro-method, the industries are divided only into two types of classes. In the end-use method, the disaggregation is in terms of the 19 industries in eight broad categories. They are discussed below.

3.1.1. Macro-method

As the projections for many of the industries for a long-term of 20 years are not available, the distinction is made for only two types of industries, viz:

(i) Large energy consuming industries (LEC) (registered sector);

(ii) The rest of the industries, viz. non-energy intensive industries (registered sector) and the unregistered sector - non-LEC industries.

The past developments of these industries are given in Table 3.1.

Table 3.1. The Percentage Shares of Types of Industries in the Total Value Added by Industries

Year	% of Total Value added in industries			LEC as a % of the registered sector
	Registered		Unregistered	
	LEC	non-LEC		
1951-52	34.98	19.91	45.11	63.73
1961-62	32.97	25.33	41.70	56.55
1971-72	33.78	28.27	37.95	54.45
1975-76	34.73	26.89	38.38	56.36

Total of registered and unregistered industries may not be exactly 100 due to rounded figures.

Source: Central Statistical Organisation, Basic Statistics relating to the Indian Economy (1965,1977)

3.1.2. End-use Method

For a short-term of 5 to 15 years, energy required is calculated from the material balance approach taking targets given by the input-output model for the large energy consuming industries. The following categories of large energy consuming industries are considered separately for the short-term forecasts for energy consumption in the industries:

(i) Textiles and Fibres;
(ii) Pulp, Paper and Newsprint;
(iii) Iron and Steel and Basic Alloys;
(iv) Non-ferrous Basic Metals;
(v) Petroleum Products and Fertilizers;
(vi) Cement;
(vii) Agricultural processing; and
(viii) Other remaining industries.

The first six categories of industries consumed more than 65% of energy used in the industrial sector in 1971 but produced only 35% of the total value added by the industries sector. In fact, these industries accounted for 60% and 88% of coal and fuel oil consumption respectively, used in the industries sector. Two other categories of industries are also added. The output levels for these industries, obtained from the input-output model, are taken from the Sixth Five-Year Plan 1980-85. The individual industries considered could be seen in Figure 3.1.

3.2. Expected Changes in the Energy Consumption in the Industries

Both of the above methods require that the coefficients of energy consumption per value added (defined as energy-intensities) or per physical output for each of the sub-sectors of industries are analyzed from the recent data of several years.

The energy intensities are likely to change due to the following:

(a) Due to introduction of better technology and process management, consumption norms are expected to decrease for some of the industries. As shown below, if consumption norm decreases, the energy intensity decreases if value added/output does not decrease:

$$\text{Energy intensity} = \frac{\text{Energy}}{\text{Value added}} = \frac{\text{Energy/output}}{\text{(value added/output)}}$$

$$= \frac{\text{Consumption norm}}{\text{value added/output}}$$

(b) Due to increase in wages, the value added per output would increase. Therefore, even if the consumption norm does not decrease, energy intensities could decrease in <u>some</u> sectors.

(c) Due to increase in the scale of production.

(d) Due to increase in energy prices, e.g. it is found that fuel oil consumption per unit output has declined recently after the price rise of oil.

While the above-mentioned reasons lead one to expect reduction in consumption norms and energy intensities, the following reasons may increase both of them:

(e) Due to increased share of the quality of the products, such as fine paper, fine textiles and purer chemicals.

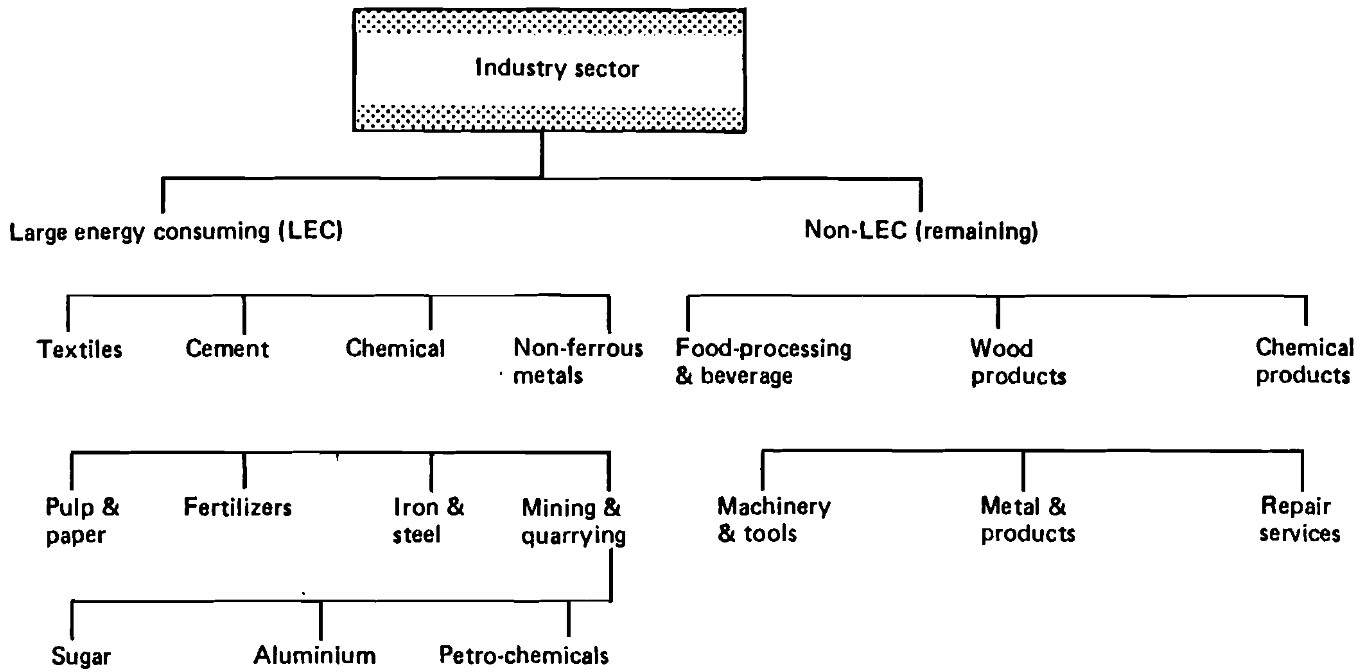


Figure 3.1. Submodel for Industry Sector:(End-use Method)

(f) Due to less imports of high quality products, machinery, parts, etc.

(g) Due to substitution of human labor and also fuel oil by electricity.

The latter three reasons especially increase electricity consumption per value added and/or, per ton of product. Based on these considerations, base-level energy intensities for electricity and oil in the LEC industries are assumed to reduce gradually but modestly over time because of the possibilities of energy conservation by better management or by technological changes. The judgment for the latter is done by surveying literature on existing and new technological processes on saving energy and the possibilities of adopting them in India.

It appears that the past trend of increasing energy intensities observed in the LEC industries (Parikh and Chaitanya, 1980) will still continue in the non-LEC industries due to:

- o Lack of R & D efforts in the industries for energy conservation.
- o Lack of incentives as the energy consumed by individual unit may not be significant so as to encourage measures for energy conservation. Collectively, however, these industries consume 37% of the electricity and their share is expected to increase in future.

It is difficult to predict how value added per output would change in future on an aggregate basis and more detailed investigations are necessary. The analysis at disaggregated levels for the industries given in Figure 3.1 are also carried out.

Table 3.2 gives the present and assumed energy intensities for the macro-method.

3.2.1. Comparison of Energy Consumption with other Countries

International comparison of energy intensities in industries is given in Table 3.3. It can be seen that the industries in India consume very high amount of electricity and thermal energy per dollar of value added. However, it is necessary to make

Table 3.2. Energy Consumption Norms used for the Industry Sector of the Model

	1976-77	1984-85	1989-90	1994-95	2000-01
Electricity (10^9kWh per Rs.10^9)*					
LEC Industries	1.39	1.521	1.439	1.355	1.200
Non-LEC Industries	0.390	0.486	0.557	0.607	0.600
Fuel Oil (10^6mt.per Rs.10^9)					
LEC Industries	0.1126	0.113	0.108	0.085	0.060
Non-LEC Industries	0.0037	0.0037	0.0037	0.0037	0.0037
Coal, Coke, Charcoal(10^6mt.per Rs.10^9)					
LEC Industris	1.648	1.666	1.666	1.666	1.666
Non-LEC Industries	0.421	0.442	0.463	0.508	0.600

*Includes contributions from non-utilities. Value added is given in the prices of 1970-71.

Table 3.3. International comparison of energy intensities in industries

	Western Europe[1]	Eastern Europe[1]	India
Electricity/V.A. (kWh/$)	1.26	2.05	5.52
Thermal Energy/V.A. (kWh/$)	4.48	11.82	43.2
Thermal (useful/final energy, %)	65.4	74.5	30[+]
	After corrections for purchasing power		
Electricity (kWh/"$")*	1.411	1.414	1.520
Thermal** energy (kWh/"$")	5.02	8.156	11.985

*"$" is corrected $ for purchasing power of a dollar worth of national currency within the country. The representative countries taken are W. Germany and Hungary from World Bank (198[illegible]).

**Thermal energy is converted into kcal and then to electricity using 0.123 tce = 1000 kWh (i.e. the comparison is in the heat units and not in mtcr units, conventionally used in India, e.g. Fuel Policy Committee).

[+]Approximate figure is guesstimated.

[1]A. Khan and A. Hölzl (1981). Forthcoming IIASA Research Report titled "Evolution of Future Energy Demand Till 2030 in Different World Regions - An Assessment made for the Two IIASA Scenarios.

corrections for purchasing power of the national currency worth a dollar within the country. It has been shown by Kravis et al (1977) that for a comparable mix of commodities, the purchasing power of a rupee within India is 3.3 times larger than that indicated by the official exchange rate for the traded commodities. This factor, if used, would partly correct for the wage component of the value added (for example, value added generated from a taxi driven for 1 kilometre would be small in India compared to the developed countries and, therefore, energy per value added would be correspondingly high for that activity). However, even after corrections for purchasing power, electricity consumption per dollar of value added in India is still high compared to the developed countries. It is especially high in the case of thermal energy use. This may be because of inefficient use of energy due to old technology, bad maintenance and poor quality of coal (the proportion of ash in coal can be as high as 35% in India. Moreover, industries based on natural gas or oil - which can be more efficiently used than coal - are much less in India compared to Western and Eastern Europe. Natural gas and oil are more efficient fuels compared to coal.

The above discussion is summarized in Table 3.4.

3.3. Discussion of Results of the Macro-method

Tables 3.5 and 3.6 give the energy demand for the industries sector for the low and high GDP scenarios. The industrial GDP grows at an annual growth rate of 5.7% in the former and 7.2% in the latter case for the period 1984-2000 (see Table 2.1). The gap between the two projected energy requirements for the two scenarios widen with time giving the difference of as much as 76 bkWh of electricity and 98 mt. of coal in 2000. The projections given in Table 3.6 are somewhat close to the WEP projections of electricity. However, the projections of coal of the ENDIM model are much higher (319 mt.) than that of WEP (265 mt.). This is because the charcoal consumed in the non-LEC industries is also included here and it is assumed that even if measures for coal conservation are taken, in future, the coal intensities would not decrease because of lack of fuel oil and decline in the quality of coal.

Table 3.4. Why do the energy consumption norms and energy intensities increase in India compared to the past and compared to the other countries?

Increase compared to the past in India+	Energy/Output (Consumption Norms) (A) a) Improvements in quality of products b) Substitution of human and animal energy c) Substitution of non-commercial energy	Energy/Value Added* (D) a) Wage increase is slow b) Controled prices for some of the outputs c) Increase in consumption norms
Increase relative to other developed countries	(B) a) Technology of production not improving fast enough b) Scale of production c) Capacity utilization not good due to interruptions in production, for a variety of reasons d) Problems of measurement and comparison of energy use between countries e) Increased use of coal instead of gas or oil and decreasing quality of coal	(E) a) Wage - increase in other developed countries is higher b) Corrections for purchasing power of a rupee is necessary
Increase relative to other developing countries	(C) a) Increased use of coal b) Sometimes better quality product	(F) a) Comparatively large production base of energy-intensive industries such as iron and steel, chemicals, fertilizers and metals

*Energy/Value Added = $\frac{\text{Energy/Output}}{\text{Output/Value Added}}$. Therefore, the numerator is the same as in the (A), (B) and (C) blocks given on the left-hand side.

+This is not true of all products.

Table 3.5. Energy Demand for the Industry Sector - Low Demand (Low GDP, Low YIND, Low LEC)

	1978-79	1984-85	1989-90	1994-95	2000-01
Electricity (10^9 kWh)					
LEC industries		49.3	58.7	70.6	82.3
Non-LEC industries		33.5	50.5	77.5	105.9
Total	53.9	82.8	109.2	148.2	188.2
Fuel Oil (10^6 mt.)					
LEC industries		3.7	4.4	4.4	4.1
Non-LEC industries		0.3	0.3	0.5	0.7
Total	4.5	4.0	4.7	4.9	4.8
Coal, Coke, Charcoal (10^6 mt.)					
LEC industries		54.1	67.9	86.8	114.3
Non-LEC industries		30.5	42.0	64.9	105.9
Total	50.5	84.6	109.9	151.7	220.2

Scenario Assumptions:

L GDP = Low GDP = compound annual growth for 1984-2000 - 4.4%.

L LEC = Low LEC = LEC value added growth 4.8% per annum, non-LEC 6.0%, LEC/YIND = 27.7%.

Table 3.6. Energy Demand for the Industry Sector - High Demand High YIND, High GDP, High LEC, Scenario.

	1978-79	1984-85	1989-90	1992-95	2000-01
Electricity (10^9kWh)					
LEC Industries		54.8	77.7	102.2	133.3
Non-LEC Industries		35.87	54.7	90.4	132.8
Total	53.9	90.6	132.4	192.6	266.1
Fuel Oil (10^6mt)					
LEC Industries		4.1	5.8	6.4	6.7
Non-LEC Industries		0.3	0.4	0.6	0.8
Total	4.5	4.4	6.2	7.0	7.5
Coal, Coke, Charcoal (10^6mt)					
LEC Industries		60.0	90.0	125.6	185.0
Non-LEC Industries		32.6	45.5	75.6	132.8
Total	50.5	92.6	135.5	201.2	317.8

Scenario Assumptions:

H LEC = High LEC value added growth 7.3% per annum, non-LEC 7.1%. LEC/YIND = 33.4%.

3.4 Policy Implications for Industries

3.4.1. Choice of Technology

What happens if in a low GDP case high LEC industrial mix policy is pursued (and vice versa, i.e. high GDP with low LEC)? Then one can analyze the impacts of the industrial policy to encourage high LEC or low LEC. As the difference between the two strategies get accentuated only with time, the results for only the year 2000 are compared when these differences are large and noticeable. These are given in Table 3.7. It can be seen that the difference between scenario (1) and (2) is of 10 bkWh, 0.9 mt. of fuel oil and 18 mt. of coal. This is approximately the same for low and high GDP scenarios (3) and (4). This can, therefore, be considered as the effect of reducing the share of LEC in the industries sector from 33.4% to 27.7%. This difference is small, because due to substantial R & D efforts put in the LEC industries, not necessarily within India but elsewhere as well, the energy-efficiency in the LEC industries can be increased by already well-known methods. The measures required for energy conservation are not so well identified in the non-LEC industries as in the LEC industries.

3.4.2. Changes in Energy-Intensities

How crucial are the policy concerning energy intensities and the assumptions of envisaged changes, values of which are given in Table 3.2? They are, of course, crucial. In fact, several scenarios were carried out to gauge their significance. In the absence of any policy and R & D efforts, electricity intensities in the non-LEC industries are expected to increase much more than those assumed in Table 3.2. If, in case the electricity intensity of the non-LEC is increased by 12.5% and of the non-LEC by 25% by 2000, then nearly 37 and 50 billion units more would be required for the low and high GDP scenarios, respectively.

Similarly, coal intensities in the LEC industries are assumed to stabilize due to strong conservative measures; but if they were to increase because of lack of fuel oil and low

Table 3.7. Energy Demand for the Industry Sector - Comparison of Scenarios in 2000

	L GDP L LEC	L GDP H LEC	H GDP L LEC	H GDP H LEC
Electricity (10^9 kwh)				
LEC industries	82.3	102.9	111.7	133.3
Non-LEC industries	105.9	95.6	143.6	132.8
Total:	188.2	198.5	255.3	266.1
Fuel Oil (19^6 mt.)				
LEC industries	4.1	5.1	5.6	6.7
Non-LEC industries	0.7	0.6	0.9	0.8
Total:	4.8	5.7	6.5	7.5
Coal, Coke, Charcoal (10^6 mt.)				
LEC industries	114.3	142.9	155.0	185.0
Non-LEC industries	105.3	95.6	143.6	132.8
Total:	220.2	238.5	298.6	317.8

Scenario Assumptions:

L GDP = Low GDP = Rs. 1361×10^9 - compound growth for 1984-2000 - 4.4%, YIND growth 6%.
H GDP = High GDP = Rs. 1622×10^9 - compound growth for 1984-2000 - 5.8%, YIND growth 7.1%.
L LEC = Low LEC value added growth 6%, per annum, non-LEC 7.6%, LEC/YIND = 27.7%
H LEC = High LEC value added growth 7% per annum, non-LEC 7.1%, LEC/YIND = 33.4%

This scenario approximately corresponds to the WEP scenario.

Table 3.8. Energy/value Added in the Industries Sector for Selected Years - Past and Future

Energy Form and Units	1960-61	1965-66	1970-71	1975-76	1984-85	2000	
						Low	High
Energy Consumed by Industries:							
Coal (10^6t)	20.90	30.10	31.07	51.01	84.58	220.2	317.8
Oil (10^6t)	3.61	4.04	5.45	3.77	3.91	4.78	7.49
Electricity (10^9kWh)	11.60	22.62	34.55	43.35	82.90	188.2	266.05
V.A. in Industries (10^9Rs. in Rs. 1970-71)	31.3	44.6	53.2	62.8	101.40	245	332
Energy Intensities:							
Coal/V.A. (10^6t/10^9Rs.)	0.667	0.675	0.584	0.812	0.834	0.899	0.957
Oil/V.A. (10^6t/10^9Rs.)	0.115	0.0908	0.102	0.0601	0.039	0.019	0.022
Electricity/V.A. (10^9kWh/10^9Rs.)	0.370	0.508	0.645	0.690	0.817	0.768	0.801

Rs. in prices of 1970-71.

quality of coal by 41.0%, then 138 and 16 mt. of more coal would be required for low and high GDP scenarios, respectively.

In order to cross-check the assumptions of Table 3.2, the emerging overall intensities of the future are compared with the past in Table 3.8. It can be seen that the intensities in electricity increases by 2000 up to 0.8 bkWh per billion Rs. This is high compared to the present but its growth rates are much lower than they have been in the past. The overall oil intensities go down considerably whereas coal and electricity intensities go up. The comparison of the overall intensities with the past, given in Table 3.8, therefore, provide a check. As mentioned earlier, more work on a disaggregated level of intensities and an assessment of possible changes on value added per output is in progress. Thus, one of the important lessons of the model is that more important than pursuing non-LEC path is the policy to curb the growth of increase in the intensities of the non-LEC industries. This would mean that they would require larger R & D support - something that only LEC get at present.

3.5 Discussion of Results of the End-use Method

In order to have further insights and cross-checks for the simplified macro-method given above, it is necessary to derive the energy requirements for the individual industries. Unfortunately, the targets of production for individual industries in physical terms are available upto the year 1994-95 only in the revised Sixth Plan.

Unfortunately, detailed fuel oil consumption norms for various industries are not available and are highly susceptible to the pricing policies and availability of oil. Therefore, oil requirements are not cross-checked by using the end-use method. The same holds for coal, for which disaggregation is available in terms of hardly 5 to 7 industries. Moreover, the WEP Report already has made these attempts and, therefore, this exercise is not repeated here. Thus, only the electricity requirements are cross-checked using the end-use methods for which physical output projections are taken from the 6th Five-Year Plan 1980-85.

Table 3.9 indicates the commodity projections and also gives the corresponding electricity requirements. Electricity consumption norms in the LEC industries have not been changed up to 1995 because of:

- o expected substitution of oil by electricity;
- o expected improvements in the quality of products; and
- o increase in the shares of the high quality products in the total output.

All of these would normally call for higher electricity consumption norms. However, if some efforts are put in to conserve electricity, the savings could balance the expected increase. Thus, it may be possible to keep the overall consumption norms from rising. This assumption is not inconsistent with the assumptions made in the macro-method upto 1994-95 reported in Table 3.2 which refers to average intensities including other LEC industries.

The requirements for "other industries" are made on a percentage basis. It has been found that nearly 48% of the electricity consumption is in the production of major commodities described above and the remaining 52% is in the "other industries".

It can be seen that the electricity demand derived by the detailed end-use method (if continuing share of the other industries for the High (L) demand scenario is assumed) agrees reasonably well with the projections made by the macro-method given in Table 3.5. If, however, the shares of other industries were to go up, end-use method will agree with 'high' scenario of the macro-method.

3.6. New Energy Sources for the Industries

The preceding analysis assumes no new energy sources for the industries sector. As India's gas resources are limited, they would be best utilized as feedstock in the fertilizer industries, which is a non-energy use of an energy resource. The anticipated increased use of charcoal (or wood) is already incorporated in the coal demand for non-LEC industries.

Table 3.9. Electricity Demand from the End-Use Method using Long-Term Plan Targets from the revised Sixth Plan and its Comparison with the Macro-Method and WEP Scenario

Item	Unit	1984-85 (projection)		1994-95 (projection)	
		Production Target	Electricity consumed in Mkwh	Production Target	Electricity consumed in Mkwh
Sugarcane	10^6t	200	868	300	1302
Jute & Mesta	10^6 bales (180 kg)	9.1	737	12.5	1012
Oil Seeds (major)	10^6t	11	508	16.5	762
Coal	10^6t	165	2475	325	4875
Crude Oil	10^6t	21.6	432	20.6	412
Iron Ore	10^6t	55	825	75	1125
Petroleum Products*	10^6t	35.3	1094	61.4	1903
Cement	10^6t	33	3960	65	6670
Mild Steel*	10^6t	11.4	8550	22	16500
Cloth*	10^6 mtrs	13030	7052	20000	10824
Paper and Paper Board	10^3t	1500	2100	3000	4200
Newsprint*	10^3t	180	378	370	777
Synthetic Fibres	10^3t	204	1026	490	2959
Nitrogenous Fertilizers (N)	10^3t	4200	5922	9700	13678
Phosphatic Fertilizers (P_2O_5)	10^3t	1400	1610	3600	4140
Aluminium*	10^6t	300	6000	700	14000
Copper Refined	10^6t	45	9	75	15
Zinc	10^3t	85	357	160	672
Lead	10^3t	25	13	50	25
Subtotal:			43916		85851
Other Industries			47954		93745
Comparison of three methods:					
(A) TOTAL OF END-USE METHOD			91870		17959
(B) MACRO METHOD					
High			90600		192600
(C) WEP SCENARIO					
Optimal forecast			95758		186606

Type (A) is from the end-use method using plan targets and percentage shares of "other" industries;
Type (B) is from the model assuming energy intensities for the LEC and non-LEC sectors; and
Type (C) gives the projections made by the WEP.

*figures for 1994-95 are not given in the draft plan (1980-85) and are approximate.

I am grateful to Shri J. Magoo for providing consumption norms for various industries.

In addition to natural gas resources, new finds of which are recently being discovered, often solar energy and non-commercial and human energy applications may be relevant, too. In order to assess possible impacts of solar energy, the energy required in the industries needs to be split into the following components:

(a) Hot water for washing (less than 100°C)
(b) Hot water for boiling, sterilizing (above 100°C)
(c) Hot air for drying (less than 100°C)
(d) Low pressure steam
(e) Hot air for drying or baking (ovens above 100°C)
(f) High pressure steam
(g) Other heat requirements.

Hot water and hot air systems required for (a) to (d) and even solar ovens could be made commercially available with payback periods less than 5 years, if suitable tax incentives could be provided. Constraints of the available area in the industries for solar collectors and concentrators in comparison to energy requirements in an industry have to be, however, considered.

In addition, solar boilers and solar furnaces can make important contributions in the small-scale industries.

4. TRANSPORT SECTOR

Transport sector accounted for nearly 33% of oil product consumption*, 13% of coal consumption and 3.3% of electricity consumption in 1976. Efforts have been made to estimate the demand for transport in terms of the end-use activities by the Working Group on Energy Policy (WEP) and by the National Transport Planning Committee (NTPC).

The WEP has projected demand for transport in two ways:

(i) by using the historical trend method;
(ii) by using the GDP elasticity method in which it is assumed that the rate of energy consumed and GDP generated will remain constant (0.5). The constant was derived using one year data.

---

*33% of oil products by weight. If considered in mtcr terms where different oil products have different weights - diesel being 4.5 times than fuel oil, etc. - then it is 55% of oil products.

It is found that the constant GDP elasticity method always gives higher projections than the trend method. Strictly speaking, this method is not quite correct because whether the GDP elasticity is constant is not verified. (In fact, the regression results show very poor correlation between transport activities with the GDP, except in the case of the net ton-km which correlates with the industrial GDP.) Using two methods for projections, the one which gave higher results was taken by the WEP.

The NTPC carried out its own projections based on econometric methods. Here, however, transport by each mode is projected separately, for example, by road or by railways, etc., as though they are independent of each other. Their projections, in general, are somewhat lower than the WEP projections. Derived in this way, they obtain higher share of railways in the total transport than that shown in the WEP scenario. In contrast to these methods, the objective of the present method is to identify policy measures to minimize oil consumption in the transport sector which is the largest consumer of oil products.

4.1. Brief Description of the Approach

The approach to the transport sector projections is outlined in Figure 4.1. The land transport is discussed first, followed by the water and air transport. The estimation of air and water transport has been done on growth rate basis where the growth rates for different time periods are selected based on the analysis of the past and expected developments in future. In case of the land transport activities, rather than projecting transport by individual modes, total transport is projected for each activity, viz., regional passenger transport, urban passenger transport and goods transport. The modal splits for each activity are derived separately. A wide variety of factors were analyzed and it is found that most of the transport requirements particularly those for passenger transport are highly correlated with urban population or share of urban population in total population. Very little correlation has been found with the gross domestic product and related variables, except in the case of total ton-kms which are sensitive to industrial GDP.

Each of the land transport activities are discussed in the following sections.

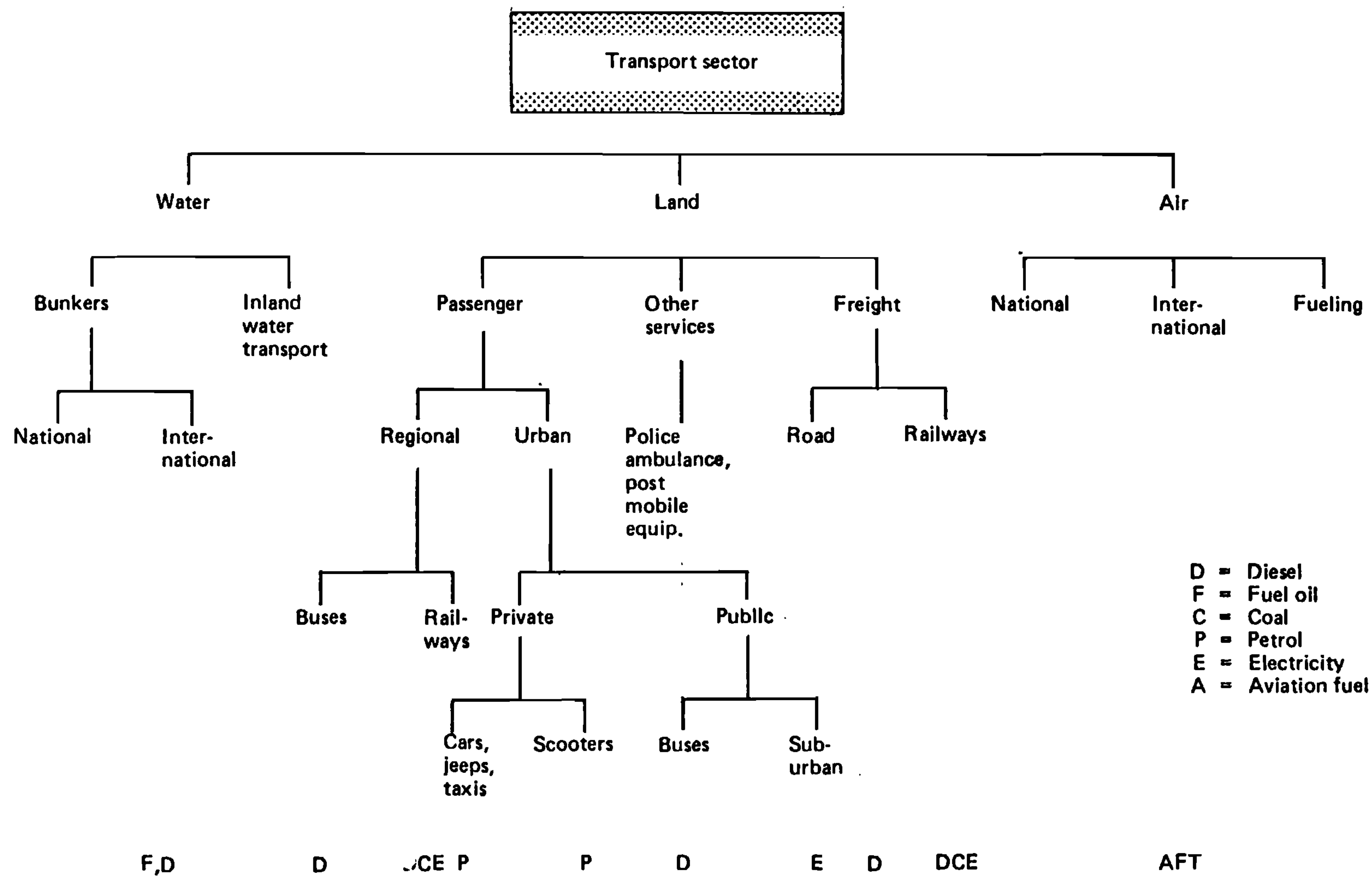


Figure 4.1. Structure of Sub-Model for Transport Sector

4.2. Estimation of Ton-Kilometers

The requirements of goods transport depends on the location of supply and demand centres of commodities and the level of output of industries. The bulk commodities* constitute nearly 80% of the total ton-kilometerage by railways. Unfortunately, detailed information is not available for the road transport carried out by trucks. In fact, most of the data on goods transport has to be inferred from the available trucks, their capacity and, to some extent, diesel consumed by them. The share of road transport in the total goods transport has increased from 16% in 1960-61 to 33% in 1976-77. It is likely that increasing shares of the bulk commodities and even other commodities may be transported by railways in future. In the model, total ton-kilometers increase with the increase in industrial GDP and urban population.

4.2.1 Average Lead in the Railways

In the past, the average lead (average distance to which goods are hauled) has increased from 465 kms. in 1950 to 713 in 1977. However, since 1971, the average lead grew slowly as can be seen in Figure 4.2. Between the years 1960-61 and 1977-78, tonnage hauled by railways has grown at 2.0% whereas the average lead grew only at 1.4%. This means that the total growth rate of ton kilometers is 3.4%. If, however, the average lead does not grow much in future then the ton-kilometers will grow at the same rate as the originating tons. The present average lead of 713 kms is already quite large considering the size of the country. The fact that the average lead is gradually saturating points to the fact that, in future, the growth rate of ton-kilometers may not be as high as it has been in the past where the tonnage as well as the average distance had increased. In addition, the following reasons may also result in reduction in average lead in future:

(i) In recent years, the decisions concerning locations of future production points of the major bulk commodities are done after examing the possibilities of reducing transport of inputs and finished products as far as possible.

---

*These are: coal, ores, foodgrains, cement, mineral oil, iron and steel, and fertilizers.

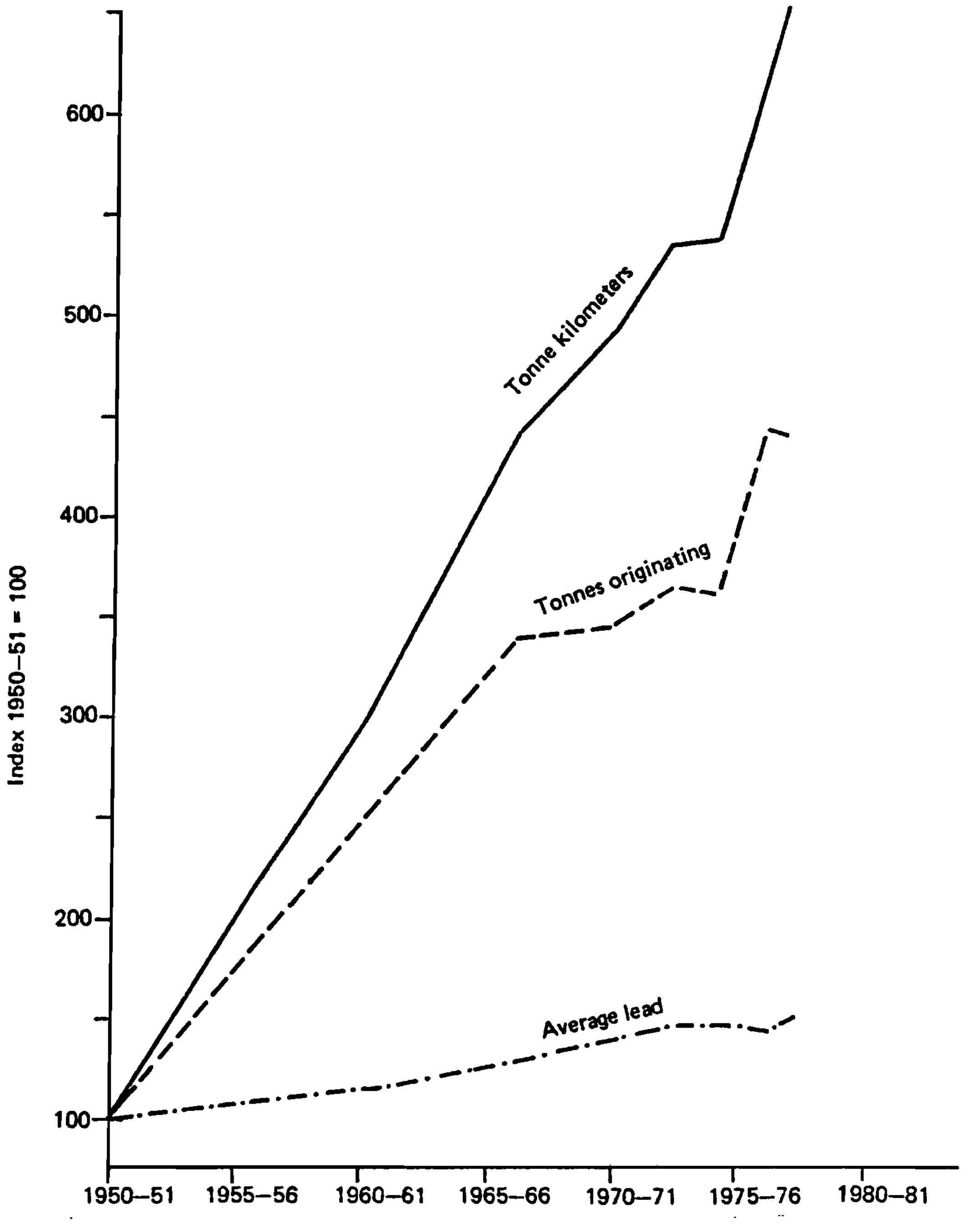


Figure 4.2. Development of Goods Transport (Railway)

(ii) Various States which did not have production facilities for the bulk commodities are gradually acquiring them; e.g. fertilizer plants, cement factories, refineries, etc.

(iii) In some cases, pipelines are being set up for carrying oil and natural gas to be used for fertilizer production, refineries, etc. To reduce coal transport, super thermal power plants are being set up at the pit heads of the coal mines.

Based on those arguments, one expects much less growth in ton-kilometers in future compared to the past.

4.3 Estimation of Passenger Kilometers

In the past, passenger kilometers (pkm) grew at a much faster rate (5% to 7%) than the ton kilometers (3% to 5%). Here again, the railway data is more reliable compared to those of the buses. The data for road transport is only available for the public buses. Therefore, the data concerning the private buses is obtained by assuming the same performance standards as the public buses. The developments in the past are indicated in Figure 4.3. The passenger transport is divided into urban and regional transport. The urban transport is divided further into mass transport (public) and personalized transport (private).* Adding the available data of the cities, it can be estimated that the pkm in the urban areas is 12% of the total passenger kilometers by public transport. The diesel consumption was also the same proportion. However, the data for all the cities in urban areas are not included, whereas the data for regional transport is more comprehensive, than the urban transport (see e.g. Table 4.6). Making estimates for the cities not included in the available data, it is expected that the percentage of urban passenger kilometers would be the same as in the total passenger kilometers as the urban population in total population, i.e. 21%.

---

*From this point onwards, 'public' means mass transport and 'private' means personalized transport.

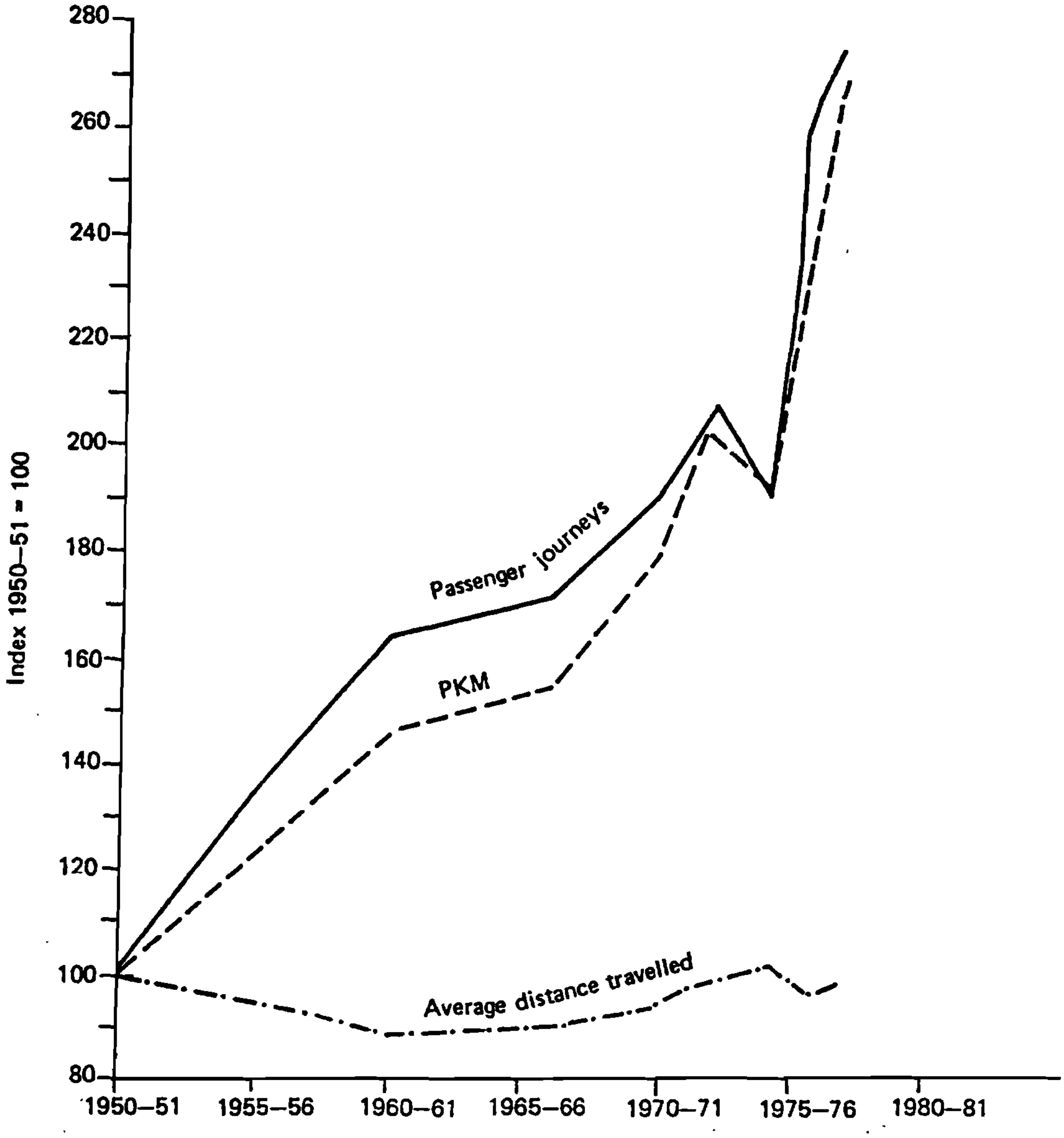


Figure 4.3. Development of Passenger Transport (Railway)

With these remarks on the data adjustments, we analyze below the passenger transport in two components, urban and regional.

4.3.1 Urban Transport

This is also referred as 'short distance' transport in the model.

(a) Public Transport:

The public transport includes traffic by suburban trains and buses. It is estimated that in 1976, 36% of the total urban passenger kilometers was by suburban trains, and 64% by buses. Setting up suburban train network requires much longer gestation periods and are today available only in three metropolitan cities, namely, Bombay, Madras and Calcutta. In spite of this, the contribution of suburban trains in the total urban passenger kilometers has been increasing indicating the rapid rate at which metropolitan areas generate traffic.

In the model, the total urban passenger kilometers are correlated with urban population and price of crude oil. No correlation with the GDP per capita was found. However, separate data of urban domestic product is not available; therefore, national average was used for the purpose of regressions. The split between buses and suburban trains is again a function of urban population and price of crude oil. It could be expected that as the urban population increases, the share of metropolitan population using the suburban train by railways in all the urban population in the country may decline.

(b) Private Transport:

The increases in the number of private vehicles - which are mainly petrol (gasoline) consuming vehicles - with respect to population and urban population are given in Table 4.1. It can be seen that the absolute consumption of gasoline declined after 1973 and has not reached the level of 1970 even in 1975. Number of cars went down slightly during 1974 and 1975. Their utilization must have gone down considerably because even the overall gasoline consumption went down. There is an indication of high

Table 4.1. Past Trends of Cars and Scooters Ownership and Gasoline Consumption

Year	Motor gas in 10^3t	Popula-tion	Urban popu-lation	No. of Cars*	No. of Cars 1000 persons	Cars per 1000 NU	No. of Scooters	Scooter per 1000	Scooter 1000 per NU
	(1)	(2) N 10^6)	(3) NU (10^6)	(4) NC	(5) NC/N	(6) NC/NU**	(7) NS	(8) NS/N	(9) NS/NU**
1960	859	439.0	79.0	310	0.706	3.924	94	0.214	1.190
1965	1093	489.0	92.0	427	0.873	4.641	202	0.413	2.196
1970	1410	547.0	109.0	618	1.130	5.670	503	0.920	4.615
1975	1261	606.0	127.0	770	1.271	6.063	1011	1.668	7.961
1978	1499	644.0	135.0	845	1.312	6.201	1509	2.343	11.18

*Cars include jeeps and taxis. Scooters include two and three-wheelers.

**For the sake of simplicity (6) and (9) are obtained simply by dividing (4) and (7) respectively by (3).

price elasticity in the data. But, it is difficult to interpret this in a meaningful way because of lack of separate data for gasoline consumption for each mode. Moreover, there are indications that the gasoline consumption at present may be almost at the bare minimum level and the use of high price elasticity derived from the recent data for future may not be appropriate.

Due to high gasoline prices, there has been a significant modal shift in the personalized transport. For example, from cars to 2-wheelers and from 2-wheelers to perhaps buses and trains. The growth rates during 1960-78 in cars and scooters ownership was 3.5% and 14.2%, respectively. During 1973-78, these growth rates went down to 1.06% and 11.9%, respectively. As gasoline consumption by each type of vehicle, or the kilometers travelled by each of them is not known, the norm of 0.85 t per car and 0.4 t per scooter is taken. This norm fits the recent data. It is assumed that vehicle utilization (vehicle km per vehicle) will increase only to the extent that energy per vehicle - km would be reduced due to technological improvements (i.e. UFC x EF and UFS x ES are constant for all periods).

It is assumed that growth rates for car and scooter ownerships would decline as shown in Table 4.1A. Then the resulting gasoline consumption would be as shown in Table 4.1B. The scenario tried here with respect to different growth in car and scooter ownerships is based on the recent (1975-78) trend, where there is already effect of price increase. This is because, the Government policy for discouraging them, particularly cars, has been very strong for many years. For this reason, GDP growth may not lead to corresponding increase in cars and scooters ownerships.

It can be seen from Table 4.1B that the cars per thousand persons increase from 1.312 in 1978 to 1.672 in the year 2000. This is a very modest increase, when one compares equivalent figure for Western Europe in 1975 which is nearly 250 per thousand persons. The scooter ownership rises from 2.343 to 12.101 in 2000 which is a larger increase than the cars but still the growth rate is considerably reduced compared to the recent past. In spite of the highly reduced growth rates, it can be seen that the gasoline consumption increases to 5.8 mt. in 2000. As

Table 4.1A. Percentage Growth Rate in Cars and Scooters Ownership: Past Data and Future Assumptions

	1960-1975	1975-1978	1978-1984	1985-1990	1990-1995	1995-2000
Growth rate of cars per 1000 (NC/N)	3.5	1.06	1.06	1.06	1.06	1.06
Growth rate in 1000 (NS/N)	14.2	11.99	11.28	7.50	6.06	7.17

Table 4.1B. Private Vehicles and Gasoline Consumption*

	1978-1979	1984-1985	1989-1990	1994-1995	2000
N	644	721	~85	845	921
NC/N (10^3)	1.312	1.412	1.483	1.574	1.672
NS/N (10^3)	2.343	4.447	6.378	8.554	12.101
NC (10^3)	845	1018	1164	1330	1539
NS (10^3)	1509	3206	5007	7228	11145
Gas C (10^3 t)	718	865	989	1131	1308
Gas S (10^3 t)	604	1282	2003	2891	4458
Total Gas (10^3 t)**	1322	2147	2992	4022	5766

*Assuming 0.4 t per scooter; 0.85 t per car.

**As calculated from the norm assumed; actual is 1499.

against this, the OLF projections by the WEP is only 3.2 mt. This would mean that WEP foresees almost no increase (or even reduction) in per capita ownership of private vehicles although per capita GDP grows by 4%. It may be mentioned that the norms of gasoline consumption per car and scooter are low and no possibility of reducing them further has been considered in the model.

This highlights substantial reduction in the growth envisaged in private vehicles ownership which is inherent in the WEP projections.

4.3. 2. Regional Passenger Transport

The total regional or "long distance" passenger transport which takes place outside the urban areas (pkml) is projected on the basis of a regression relationship which correlates pkml with urban population and price of crude. One observes 6% price elasticity based on the past data. The regional passenger kilometers per capita in 1975 was 538 per year whereas in 1960, it was 256. (In contrast, passenger transport within urban areas per capita was 705 and 299 km per urban person in 1975 and 1960, respectively.) This increase in per capita could perhaps be due to increased travels made by migrated labor between rural areas and urban areas, traffic generated between urban-urban areas and increased travels made by rural population to urban areas in search of medicare and education, for other legal and official work, etc.

In future, because of increased GDP, increased number of travellers including women, children - who travelled little in the past and increased migration, regional passenger kilometers could considerably increase. On the other hand, high crude prices would be a factor reducing the transport.

4.4. Other Transport Requirements

In addition to conventional passengers and freight transport requirements, there are also other vehicles which consumed as much as 0.58 million ton of diesel in 1975-76 by the estimates of Indian Institute of Petroleum. These vehicles are postal or police vans, ambulances, fire-brigades, bull-dozers, road-rollers, construction equipment and many other mobile equipment. Their numbers have increased ten-fold between 1960 and 1976. Between 1975 and 1976 alone, this number increased by nearly 70,000 vehicles thereby bringing the number to 0.309 millions. It is difficult to predict what the future developments of these miscellaenous vehicles could be. Therefore, based on the limited past data and expected GDP growth in services, it will be assumed that the diesel requirements by other vehicles could grow at an exogenously specified rate which could vary from one time period to another.

4.5. Role of Railways in Land Transport

Indian railways form the backbone of the transport system in India. It carries 67% of freight transport, 40% of regional passenger transport and 36% of urban passenger transport done by public mode. However, the share of railways has declined over the past. Recently, it is noted that even between two urban points far away from each other, trucks and buses have been plying with increased intensity. It remains to be seen whether this is due to the fact that recently railways' capacity to carry additional transport has been saturated and needs to be strengthened or whether it represents people's definite preference for road transport for a variety of reasons. The role of railways in future may have to be strengthened after critical examination of the choices between road and rail transport.

As far as the freight transport is concerned, per ton-kilometer trucks use 5.7 times more diesel than the railways. Moreover, in view of the diesel shortage which may worsen in future, it is expected that the past trend of increasing share of road transport may not continue. Although rail transport would be preferable for long distance passenger transport and transport of bulk commodities, it is, however, unlikely that the share of railways could increase beyond a certain level due to the following reasons:

(a) Railways are inaccessible for rural-rural transport.

(b) The railways do not provide facility from end to end point and the additional costs of money and time discourage use of railways, particularly for urban-urban transport for short distances.

(c) The Railways are inconvenient for urban-rural transport from and to those rural areas for which no railway facilities are available.

As far as the passenger transport is concerned, diesel consumed per pkm is somewhat less by the railways than by the buses. But, this saving is rather small and not as large as is the case of goods transport. (This is mainly because of the fact that the railways offer far more comfortable ride than the buses which makes the self-weight to payload ratio high in the case of trains.) But, the fact that in the railways, diesel can be substituted by coal and electricity is an important consideration.

The share of railways in passenger and freight transport as derived in the model are given in Table 4.2.

However, deriving it from the past data is only one possible scenario. In view of the diesel shortage, people's preferences and even lack of railway's present capacity may be of secondary importance. NTPC has suggested continuing shares 67:33 between railways and road for goods transport. They suggest that it is even possible that the ratio may be 72:28. As against this, the ENDIM model suggests the ratio of 57:43 and the WEP report has assumed 44:56. The difference in the ratios derived by the ENDIM model and the NTPC suggests that either severe repercussions on the economy can be expected or heavily accelerated investments are required for strengthening the railways.

It suggests that even for maintaining the present ratio of 67:33 active policy and action measures are required if the economy is not to suffer. (The investment in the Sixth Plan for road and railways does not accord high priorities for railways, if private investment in trucks is also included.)

The NTPC Report has indicated costs of transporting various commodities by various transport modes. The road transport is cheaper than block load transported by electric traction for distances varying from 150 to 300 km. depending upon the commodity.

Table 4.2. The Modal Splits derived in the Transport Sector

	1976-77	1984-85	1989-90	1994-95	2000-01
Percentage share of railways in regional transport (long)					
Low)	35	30.3	26.8	24.2	22.0
High)		35.2	33.2	31.5	30.0
Percentage share of railways in urban transport					
Low)	36	32.3	28.3	24.9	22.0
High)		35.6	32.9	29.2	27.0
Percentage share of railways in goods transport					
Low)	64.5	59.0	56.3	53.7	50.7
High)		61.0	59.3	57.7	55.9

Compared to wagon load transported by diesel traction, the minimum break-even distances increase nearly 2 to 3 times.

This indicates that even decentralization of production may not be the answer to reduce the diesel consumption because it would only make road transport more attractive.

Thus, the model suggests that when the present trend is towards declining share of the railway trnasport, keeping it steady may require hard work and reversing the trend would be even harder.

4.6 Electrification of Railways

The assumptions about electrification of railways make significant changes in either diesel or electricity requirements for transport. In 1977-78, the percentage shares of passenger kilometer transport carried by steam, electricity and diesel was 55:17:28, whereas that for the gross ton-kilometers (GTKM) carried was 16:26:58. Detailed data is given below in Table 4.3.

Table 4.3. Types of Non-suburban Traffic Carried by Different Locomotives in 1977-78

	Steam	Electricity	Diesel	Total
Passenger kilometers (10^6 pkm)	80,946	24,723	40.868	164,537
%	(55.2)	(16.9)	(27.9)	(100)
Gross-ton-km* (10^6 tkm)	51,673	83,570	187,458	322,701
%	(16.0)	(25.9)	(58.1)	(100)

*Includes the weight of the engines and wagons.

The study commissioned by the Ministry of Railways on "Relative Economics of Diesel and Electric Traction on Indian Railways" states that it requires 14 kwh per thousand gross tons-kilometers if the tonnage is hauled by electric locomotives and 3.5 litres of diesel, if carried by diesel locomotive. However, when one includes T & D losses and losses in power plants, electricity usage is barely ahead of diesel in terms of primary energy consumption. However, the important consideration is the possibility that it offers in diesel substitution. While there are choices for electricity generation such as hydel, thermal, nuclear and others, it is becoming increasingly apparent that a large fraction of diesel may have to be imported. Moreover, there are also other advantages of electrification such as reduced maintenance, speed at which the transport could be carried, etc. The study shows that there is a break-even density of tonnage at which electric locomotives begin to be more economic than the diesel locomotives.

It is interesting to note that in spite of only 4,720 route kms (8% of total) electrified, the electrified route carried 83,570 billion tkm, i.e. 26% of the total ton kms. in 1977-78. This is because the traffic pattern is such that out of the total 60,693 route kms. in the country, only 15,000 route kms. carry 80% of the traffic of which 4,720 km. is electrified. It is planned that each year additional 350 kms. will be electrified for the next 10 years. Assuming that thereafter it is 500 kms. per year, nearly 13,000 route kms. which carry 80% of the traffic today, will be electrified by the year 2000. In future, however, it is possible that with further dispersion and growth of population, these 15,000 route kms. may not carry 80% but 70% or even 60% of the total traffic.

Considering the above-mentioned facts, two scenarios for break-up of transport carried by steam, diesel and electric locomotives are given in Table 4.4.

4.7. Energy Consumption by Various Transport Modes and the Basis for Expected Reduction of Energy Consumption Norms

Energy consumption by various transport modes depends on the energy efficiency of the transport mode and its utilization. For projecting energy requirements in the future for each of the transport modes, the following two points are considered:

(a) Possibilities of improving efficiency of the transport mode; and

Table 4.4. Scenarios of Percentage Shares of Traffic carried by the Railways by Different Tractions*

	1977-78	1984-85	1989-90	1994-95	2000-01
Passenger kilometers (long)					
Steam	55	45.7	33.1	16.7	5
Electric					
Low	17	20.5	24.9	30.0	37.0
High	17	24.2	30.6	38.3	50.0
Ton-kilometers					
Steam	16	11.7	8.6	6.3	3.0
Electric					
Low	26	29.5	33.5	37.0	40.0
High	36	32.3	39.0	46.7	56.0

*Percentage shares of diesel traction case be obtained by subtracting the addition of steam and electric from 100.

(b) Possibilities of increasing its utlization. Here, one not only considers the extent of its direct use but also its occupancy (e.g. the energy used per pkm or tkm depends on the size and occupancy of the bus or utilization of truck).

The base year figures of energy consumption norms for railways are taken from Annual Statistical Statements of Ministry of Railways (1978) for the year 1977-78. The data on energy consumption for road traffic is either directly obtained from Motor Transport Statistics (1976) which give statistics for public bus transport or indirectly by making assumptions. One does not expect drastic technological changes in the Indian Railways system but changes other than major technological changes could also reduce consumption. For example, energy consumption norms in the transport sector can gradually decline due to the following reasons:

- In the case of passenger traffic, meter-gauge consumes 15% and 40% less diesel and electricity respectively than broad-gauge. On the other hand, in the case of freight traffic, broad-gauge traction consumes 12% less diesel and 10% less electricity than meter-gauge in the case of diesel and electric tractions respectively. Currently, the meter-gauge carries 13% and 30% of total pkm and tkm carried by the railways respectively. In future, broad-gauge traffic will increase compared to meter-gauge traffic, both in terms of passenger and freight traffic. It is, therefore, reasonable to assume that the average norms of energy consumption will reduce in the case of freight traffic. They may decline less rapidly or even increase in the case of passenger traffic.
- In the case of road transport, it is likely that the average capacity of the truck which is today roughly at 5.5 ton per truck may go up to 8 to 9 tons per truck in future. Already, new trucks added since 1967 are of 7.5 ton capacity. It is, therefore, expected that fuel economy per ton-km. should be achieved because of the larger capacity of the trucks, due to improved maintenance and road conditions and by decreasing the idle (empty) travelling.

- o It can be seen from Table 4.5 that there has been significant changes in the bus transport and its utilization over the last 15 years.

Table 4.5. Bus Transport

	1960-61	1970-71	1975-76
Buses	56792	91582	106399
Passenger km(pkm)	57×10^9	174×10^9	261×10^9
pkm/bus	1×10^6	1.90×10^9	2.45×10^6

While the buses have increased hardly two-fold, the passengers moved are nearly 4 times as much. Passenger kms. per bus have increased by nearly 2.5 times. This can be explained by the following three factors:

(a) The buses are mugh larger than before;

(b) The roads are better and hence buses can go much further and faster; and

(c) Occupancy rate has increased.

Of course, in future, it may not be possible to improve upon this very much. However, there are indications that it is possible to save fuel by fleet management, better maintenance of buses and some organizational changes leading to better utilization.

- o High speed diesel oil is used in the public buses and its consumption norm is obtained from the recent transport data shown in Table 4.6. It can be seen that the average consumptions of intracity bus and the re-regional buses are 7.2 kilolitre (kl) and 5.8 per million pkm, respectively.

The base-year consumption norms are gradually reduced, keeping in view the above points and are given in Table 4.7.

Table 4.6. HSD Use in Intercity and Intracity by State Transport in 1975

Intracity (Urban) Units	pkm 10^6km	Vehicle km (Vkm) 10^6km	Pkm/Vkm	Av.dist. travelled by passenger km	HSD (1000 Kℓ)	HSD/Pkm Kℓ/10^6Pkm	HSD/Vkm Kℓ/10^6 Vkm
Ahmedabad	824	29.3	28.12	4.2	8.3	10.09	289
Bombay	5957	11.09	34.15	5.8	39.7	6.67	358
Kolhapur	140	3.6	38.9	6.0	9.8	6.99	272
Pune	787	22.6	34.8	5.5	63.9	8.12	283
Delhi	6207	122.0	50.9	10.4	-	-	-
Chandigarh	209	6.0	34.8	26.1	15.6	7.28	260
Intercity (Regional) State:							
Hyderabad	12828	376	34.1	20.0	93.8	7.31	249
Ahmedabad	15236	384	39.7	18.0	88.2	5.79	230
Bombay	18622	466	40.0	26.7	-	-	-
Chandigarh	6837	155	44.1	91.5	20.1	2.94	128

Table 4.7. Assumed Energy Consumption Norms for Transport Sector
Improved Efficiency Norms*

Mode	Units	1976-77	1984-85	1989-90	1994-95	2000-01
<u>Passenger transport (long)</u>						
Electricity	kwh/pkm	0.021	0.021	0.020	0.019	0.018
Diesel	$t/10^6$pkm	3.87	3.83	3.72	3.60	3.60
Coal	t/pkm	0.066	0.067	0.068	0.068	0.068
Bus diesel	$t/10^6$pkm	4.83	5.0	4.20	4.20	4.20
<u>Passenger transport:urban</u>						
Rail electricity	kwh/pkm	0.0132	0.0136	0.0126	0.012	0.012
Bus diesel	$t/10^6$pkm	6.0	5.96	5.86	5.75	5.60
<u>Goods transport</u>						
Rail electricity	kwh/ntkm	0.0237	0.0212	0.0200	0.0195	0.018
Diesel	t/1000 ntkm	7.44	7.40	7.37	7.35	7.35
Coal	t/ntpkm	0.133	0.134	0.134	0.134	0.134
Diesel for trucks	$t/10^3$ntkm	0.0434	0.0392	0.0368	0.0342	0.032

*Low efficiency norms are the same throughout as of 1984-85 which are only marginally lower than 1976-77 norms.

4.8. Water and Air Transport

4.8.1. Water Transport

Inland transport through rivers is almost negligible. Inland water transport has received only 0.5% of total investment in transportation. It was Rs. 13 crores between 1969-74. Out of 25,000 km. of navigable waterways, only 9,500 km. is used for these purposes. Therefore, presently the oil consumption for water transport is mainly due to coastal shipping, i.e. mainly for the bunkers. It has remained practically steady at around 0.45 mt. of oil products per year between 1970 and 1977 with some fluctuations and, in fact, has declined if compared with 1967 (.74 mt.). In 1977, the proportion of fuel oil, HSD and LDO used in water transport were 71:13:16 respectively and 56% of the total oil consumption in water transport was for international bunkers. The rest was used for coastal bunkers.

The advantages that inland water transport offers for freight transport, some of which are pointed out by the NITIE Report (1979), are as follows:

(i) The capital cost of barges is about a third that of railway wagons.

(ii) The ratio of self-weight to payload is about 1:5 as against 1:1 for rail wagons.

(iii) The maintenance cost of barges is about 1/5th that of rail wagons and locos.

(iv) The labor productivity with barges is 3 times that of railways (ton-km/person/annum).

(v) Energy consumption is roughly the same as that of diesel per tkm by rail.

In view of the facts mentioned above, the energy requirement for water transport will depend upon the policies pursued. However, in view of the long gestation periods involved in changing the transportation system, the water transport may not grow significantly in future for a decade or so. Therefore, keeping in view the above points for water transport, oil requirements are projected on the basis of the assumed growth rates.

4.8.2. Air Transport

The air transport carries less than one percent of passenger and even less freight transport. ATF consumption used within India in 1978 was 0.24 mt. out of nearly 1.0 mt. of total use; the rest was used for fueling purposes and for international travels (by Air India).

Water and air transport are adequately dealt with by NTPC. Therefore, only some relevant facts are pointed out above for the sake of completeness, and the projections made in the WEP and/or NTPC Report are adopted.

4.9. Discussion of Results

The results for the land transport are tabulated in Table 4.8. Here again, the changes between present and 2000 are discussed only to assess the effects of long-term energy policy. The projections for all periods are given in Tables 4.8 and 4.9.

The ENDIM model gives much higher passenger transport compared to other models and, therefore, explanations are called for. It can be seen that long-distance PKML grows from 332 in 1976 to 1435 billion PKML in 2000. This may appear large but, in per capita terms this increase is from 533 in 1976 to 1558 pkm/person. This increase can be explained by the fact that a fraction of persons who do not travel (women, rural population and/or poor) now may travel in future, and therefore, many more persons may enter into the transport system compared to present. (The situation is similar to rural electricity demand, whose growth rates of 15% to 20% are not uncommon.)

The share of pkm by railways decline from 38% in 1976 to 22% and 30% in 2000 for low and high scenarios, respectively. This is somewhat lower compared to that envisaged by the NTPC which, to realize, will call for increased efforts and investment in the railways system for passenger transport.

The urban transport also grows at a rapid rate increasing per capita travel from 92 to 463 billion pkm in 2000, growth rate of 9%. This, however, means that travel per day increases from 1.9 km in 1976 to 5.1 km in 2000 per urban person. This may be compared with the fact that in 1976-77, in Bombay, Calcutta and Madras, pkm per trip by suburban railways work out to be

Table 4.8. Transport Projections: Low Demand

	1976-77	1984-85	1989-90	1994-95	2000-01
Urban Population: 10^6	131	165	189	214	247
Passenger Kilometers: 10^9pkm					
Regional Transport:	332	559	767	1029	1435
Road	198	389	562	780	1119
Railways	134	169	205	249	316
Urban Transport:	92	178	267	388	593
Bus	55	121	191	291	463
Suburban	37	57	76	97	130
Ton-Kilometers: 10^9	233	314	381	486	616
Road	76	122	155	205	266
Railways	157	191	226	281	337
Energy Requirements					
Electricity (10^9 kwh)*	2.06	2.7	3.5	4.6	6.1
Diesel Oil (mt)**		8.3	10.3	13.5	17.9
Coal (mt)	12.27	8.2	7.2	5.2	2.5

*Excludes consumption in workshops, services, stations, etc., approximately 20%.

**Excludes diesel consumed by other services - post, police, defense, etc.

Table 4.9. Detailed Results of Energy Demand for the Land Transport

	Low Demand				High Demand			
	1984-85	1989-90	1994-95	2000-01	1984-85	1989-90	1994-95	2000-01
Electricity (10^9 bkwh)								
Freight transport	1.20	1.52	2.02	2.48	1.33	1.86	1.79	3.93
Passenger (long) trains	0.74	1.02	1.46	2.10	1.17	1.97	3.36	6.04
Suburban railways	0.78	0.95	1.16	1.57	1.04	1.49	2.06	3.36
Total:	2.72	3.49	4.64	6.15	3.54	5.32	7.21	13.33
Diesel Oil (10^6 tonnes)								
Freight transport								
Railway	0.83	0.96	1.17	1.44	0.81	0.92	1.06	1.17
Road	4.80	5.70	7.04	8.70	5.31	6.79	9.04	12.13
Passenger (long) trains								
Railway	0.22	0.32	0.48	0.66	0.26	0.43	0.73	1.09
Road	1.78	2.25	3.12	4.48	1.91	2.60	3.92	6.27
Passenger (short) trains								
Road	0.72	1.12	1.67	2.59	0.82	1.42	2.39	4.24
Total:	8.35	10.36	13.48	17.87	9.12	12.16	17.14	24.90
Coal (10^6 tonnes)								
Freight transport	3.01	2.60	2.35	1.38	3.07	2.74	2.57	1.57
Passenger (long) trains	5.18	4.63	2.83	1.07	6.95	7.27	5.12	2.28
Total:	8.18	7.23	5.19	2.46	10.02	10.01	7.69	3.85

Due to rounding off, the total may not be exact.

19.6, 25.2 and 15 km respectively, if only those people who actually travelled are included (i.e. total pkm divided by number of passenger trips). The energy consumption, however, need not increase at the same rate due to expected reduction in energy consumption norms as discussed earlier. It is interesting to note that per capita urban passenger transport (nearly 1000 pkm/urban person) if pkm by private transport is included, has no correlation with GDP and it increases with a cubic power of urban population.

The average annual increase in tkm is 4.0%. The model gives less tkm than the WEP scenario and the explanation in terms of reduction in average lead has been given in section 4.4. The share of railways decline from 67% in 1977 to 56% in 2000. The NTPC Report expects it to remain at 67% and suggests that it may even increase to 72%. Although these scenarios of high shares of railways are feasible in acute diesel shortage, the model suggests that they may not represent likely developments in moderate scarcity of diesel. As the energy consumption for these NTPC scenarios is already worked out in their report, it is not discussed here.

The difference between the existing and expected norms in future of energy consumption could be seen in Table 4.7. It is possible to reduce energy demand without reducing the end-use activities. The break-up of energy consumption for individual activities for high and low demand are given in Table 4.9. The expected electricity, coal and diesel consumption for the low demand scenario in 2000 would be 6.15 bkwh, 2.5 mt. and 17.9 mt. of diesel respectively. For the high demand, the figures are 13 bkwh, 3.3 mt. and 24 mt. respectively.

It may be mentioned that NTPC - which envisages less traffic demand and higher share of railways - estimates diesel requirements to be around 15 mt. whereas WEP - which assumes more traffic demand and less share of railways - expects diesel requirements to be 33 mt. by 2000.

4.10. Policy Implications in Land Transport

Table 4.10 shows the effects of various policy measures on the long-term energy consumption in the transport sector. The year 2000 is taken only because various long-term policies sufficiently accentuate the implications of certain policies which are not visible in short term. It can be seen that with appropriate policies, there is a possibility of saving nearly 11.4 million tons of diesel and 6.1 bkwh of electricity (scenario 2A vs. 6B). These measures in the respective order are:

- low urbanization;
- increase in efficiencies;
- high rail passenger transport; and
- high electrification of railways.

Even if one does not want to consider urbanization as a measure for transport policy (but consider that in a much larger framework including other issues), then the possibility of saving diesel (through higher efficiencies) is almost 2.9 million tons, e.g. scenarios 1A and 1B. For identical urban population and share of rail passenger transport, accelerated development of electric traction (56%) could save 0.6 million ton of diesel as compared to slow development of electric traction (40% tkm) at the cost of 2 bkwh of electricity. Moreover, the reduction of vulnerability ability of this crucial traffic to diesel availability is an important consideration.

Improvements in efficiency is a significant scenario variable. This is also partly achieved due to economy of scale and better utilization of capacity. Here, better utilization of trucks and trains (i.e. reducing runs of unloaded vehicles, etc.) also plays a significant role. This advantage is not considered by the NTPC to be on the conservative side. However, it has significant policy implications.

High efficiency energy use, especially in railways, can be achieved in view of the fact that major transport would be on broad-gauge lines and the efficiency number (0.18 kwh/Ntkm) chosen is already the energy consumption that is seen at present in a few zones with significant broad-gauge lines. Average energy consumption norm at present for Indian railways, is, however, 0.222 kwh/Ntkm.

Table 4.10. Results of Alternative Policy Scenarios for Land Transport - Energy Requirements for the Year 2000

	L urb L rail L etr 1A	L urb H rail L etr 2A	L urb L rail H etr 3A	L urb H rail H etr 4A	H urb L rail H etr 5A	H urb H rail H etr 6A
Scenario Table A:						
HIGH EFFICIENCY ENERGY USE						
Elect (10^9 x kwh)*	6.15	7.27	7.88	9.27	10.16	13.33
Diesel(10^6 x x t)**	17.87	17.48	17.31	16.88	22.44	24.90
Coal (10^6 t)	2.46	2.85	2.46	2.82	2.87	3.85
Scenario Table B:						
LOW EFFICIENCY ENERGY USE+						
Elect (10^9 kwh)*	7.17	8.47	9.20	10.82	11.84	15.54
Diesel (10^6 t)**	20.68	20.23	20.11	19.61	25.86	28.87

*Consumption in workshops, services, stations, etc., of approx. 20% is excluded.

**Diesel consumption for "other services" such as police, post, ambulance, mobile equipment of 1 to 1.5 mt. is excluded.

+The same efficiency in 2000 as expected in 1984.

L urb = Low urbanization
L rail = Low share of railways in pkm
L etr = Low electrification
H = High

Increased urbanization (from 27% to 32% of total population) can require additional 7.5 million tons of diesel and 6.0 bkwh of electricity even for high efficiency energy use. However, whether urbanization should be increased or not should not be entirely judged by the energy consumption in transport alone. Other economies of scales emerging from urbanization have to be considered, e.g. it may be cheaper to provide electricity, drinking water, sewage facilities, education and health care in the concentrated urban areas as compared to dispersed rural areas.

5. AGRICULTURE SECTOR

5.1. Introduction

The energy used in the agriculture sector can be divided in two parts:

- o Direct use of energy for pumping and mechanization; and
- o Indirect use of energy in the form of fertilizers and pesticides.

The indirect use of energy is conventionally considered in the industries sector (e.g. by the Fuel Policy Committee and also in the WEP Report). Food processing is also included in the industries sector. Therefore, if only the direct energy use is considered, then the agriculture sector consumes less than 10% of the total commercial energy consumed in the country and that it is a small consumer of energy. However, this statement should be considered together with the following factors:

- o Indirect chemical energy:
  Indirect energy including food processing would be three to four times larger (energy of imported pesticides and fertilizers is also included) than the direct energy used in the agriculture sector. Moreover, this availability of indirect energy is a very crucial factor in advancement of the agriculture sector.

- Non-commercial and animate energy:
  If non-commercial energy and human and animal energy is also included, then the magnitude of the other energy may be nearly four to five times compared to the direct energy use. It is also estimated that presently bullocks provide energy worth of 1.8 mt. of diesel. Human energy provides also considerable energy if a large part of energy of rural population is attributed to agriculture.

- Importance of crucial timing:
  In 1978 only 12 bkwh of electricity was used in the agriculture sector out of 84 bkwh of total electricity consumed. However, considering the fact that most of it was required during only a few months, during those months it consumed high percentage of the total electricity consumed. This aspect of peaked demand has a great relevance in capacity planning power sector. It also means that considerable diesel has to be acquired and distributed during that period. Thus, energy planning for the agriculture sector has to be done considering the timing at which energy is required.

- Regional distribution

  Although at national level, the percentage use of agriculture energy may look small, for particular regions it can be as high as 50% and more during the season due to certain cropping patterns, non-availability of water, etc. Therefore, regional distribution becomes an important factor.

- Share of energy related inputs:
  Energy prices affect nearly 57% or more of the intermediate inputs in the agriculture sector. The scarcity of energy or high price of energy could have significant impacts on agricultural outputs and prices.

Various energy contributions in the agriculture sector are illustrated in Figure 5.1.

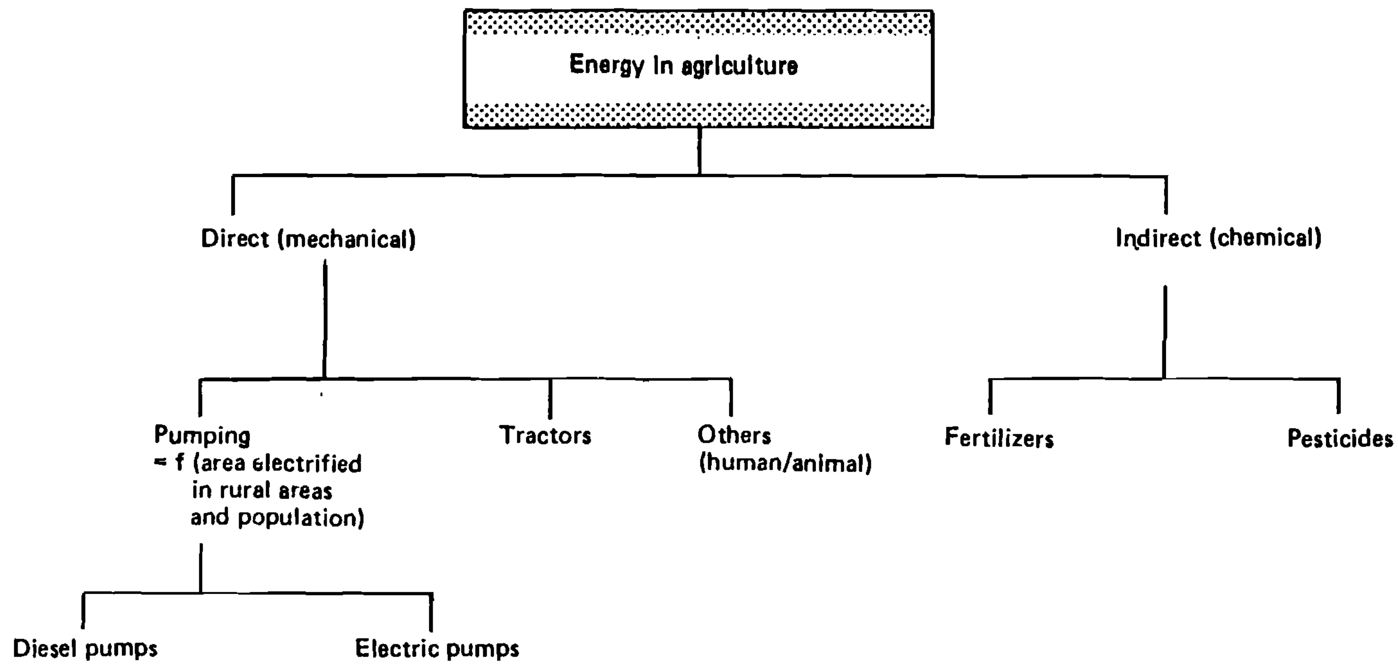


Figure 5.1. Structure of Sub-Model for Agriculture Sector

Thus, although only the direct energy use is calculated in the model, the above factors would have to be kept in view while considering the energy supply planning for the agriculture sector. Therefore, after discussing the model and results, broad issues of this kind will be discussed, which are very important for energy policy but not relevant for working out magnitudes energy demand at the national level.

5.2. Direct Use of Energy

5.2.1. Energy required for Pumping

The model first considers total energy required for pumping, i.e. both electricity and diesel are added together in coal replacement terms. (The split between the use of diesel and and electricity for pumping is derived from the model ratner than assuming it.)

From 1960 to 1976, the energy for lift irrigation went up from 25 kgcr per hectare to 100 kgcr per hectare. Thus, agriculture has become four times as much energy intensive in the past 16 years. In per capita terms (i.e. energy in agriculture required to feed one person), it has gone up from 7.75 in 1960 to 22.7 kgcr per capita in 1976. Surprisingly, in the regression models, energy required per hectare does not increase with value added in agriculture or foodgrains produced. Instead, it was found that the energy required for irrigation increases with increased rural electrification and also to some extent with cropping intensity. Why did energy in agriculture sector rose at 12% when the agriculture production rose at only 3% during the period 1971-1978? The reasons could be the qualitative changes which took place in the agriculture sector, such as:

(a) Mechanical energy produced by human and animal power was substituted by commercial energy to some extent.
(b) Instead of rain-fed agriculture, the agriculture sector moved increasingly towards irrigation.
(c) Cropping intensities increased due to population growth.
(d) More and more rural areas got electrified and the electricity was available at subsidized rates.

It was, therefore, possible to get a good correlation of energy required for capita in agriculture with net area per capita and number of villages electrified per thousand villages. In future, as net area per capita is expected to decline in future, energy per capita is expected to increase. After most of the villages are covered by rural electrification programmes, majority of agricultural land is irrigated and population growth is slowed down, there may come a period of slower growth rate for energy requirements for agriculture.

5.2.2. The Fraction of Energy for Pumping provided by Oil

Having projected the energy required for pumping, the share of oil in the total pumping requirement was calculated from a relationship correlating it with rural areas electrified and the crude price. The share of diesel oil in pumping energy has declined from 80% in 1960 to 40% in 1976.

5.2.3. Energy for Mechanization

It is found that in the recent years, e.g. 1974-76, the rate of increase of tractors as well as the increase in fuel consumption by tractors is of the order of 8% to 10%. This may or may not be desirable. However, there are indications that this trend will continue for a short-term at least. The country's capacity of manufacturing tractors is 52,000 a year out of which 41,000 tractors were produced during 1977-78. The total number of registered tractors in the country are 225,000. Thus, the production capacity is very high compared to the existing number of tractors (20%), which implies a high growth rate in the number of tractors in the near future. In India, 29% of land is owned by 4% of the land owners in plots of 10 hectares or more. The rest is divided in smaller plots. It can be expected that such high growths may not continue in 1990s by which time most of the large plot owners would have already acquired tractors. However, some surveys and studies find that even small farmers are hiring tractor services. In Japan, also, in spite of having small plots, mechanization is very high. Thus, the growth rate of energy required for mechanization is assumed to continue at high level, but is reduced after 1995. The tractors vs. bullocks issue is a very important policy issue which should not be determined by energy consumption alone. Employment, capital requirements, foreign exchange requirements, land requirements, utilization periods of tractors and bullocks, operating costs need to be considered along with savings of diesel and availability of dung from bullocks.

In addition, there are a number of harvesters, combines, thrashers and other agricultural equipment for handling the crops at various stages. The energy for mechanization for these is derived from assumed growth rates.

5.3. Discussion of Results

Table 5.1 gives the results for direct use of energy in agriculture. It was found that the most sensitive parameter is the net area sown per capita. If no increase is made in the net area sown, then it would require intensive cultivation of the existing area from which nearly 1.5 times the present population would have to be fed in 2000. Therefore, in 2000 for two different scenarios of net area sown of 140 mha and 160 mha, the difference in electricity consumption is nearly 28%. Diesel for pumping also goes up but the increase is somewhat smaller.

It is found that if the fraction of rural areas electrified are 90% instead of 85%, 50 bkwh electricity is required in agriculture pumping instead of 45 bkwh. Thus, 5% of increase in the rural areas (in absolute terms) electrified leads to nearly 10% increase in the electricity consumed.

Long-term growth rate of diesel for mechanization is estimated at 5.8%. The growth rate of electricity for pumping works out to be 6.2%.

5.4. Some Expected Changes in Agricultural System due to Energy Scarcity

As mentioned before, there are a number of issues which need to be discussed, if only qualitatively as quantification of them is difficult at this stage.

For example, to what extent could energy scarcity affect agriculture? The effects of energy prices on mechanization would depend on the wage rate for agricultural labor. Moreover, it may also lead to better design and more efficient farm machinery.

Table 5.1. Direct Use of Energy in Agriculture

	1984-85	1989-90	1994-95	2000
Irrigation				
Net Area Sown (million ha):				
High	145	150	154	160
Low	140	140	140	140
Electricity (bkwh):				
Low	16.59	22.26	28.08	35.44
High	17.71	24.91	33.34	45.75
Diesel for pumping:				
Low	0.95	1.16	1.37	1.64
High	1.02	1.33	1.67	2.17
Diesel for Mechanization:				
Tractors	0.85	1.17	1.54	2.06
Diesel total (million tonnes):				
Low	1.80	2.33	2.91	3.70
High	1.88	2.50	3.21	4.23

As far as conserving or reducing fertilizers is concerned, the following options are relevant:-

- increased use of manure or bio-gas generation which makes it possible to obtain fuel as well as fertilizer from fermentation of livestock waste;
- optimal use of fertilizers, especially in those states where the stage of decreasing returns is already reached;
- where water is plentiful, trade-off between irrigated crops vs. fertilization may be relevant;
- crop allocation may change in favor of those crops requiring less fertilizers;
- crop rotation methods may be used to fix nitrogen through legumes. This could also alter the balance between production of cereals and legumes.

These and few more changes are illustrated in Figure 5.2.

Considerable efforts would be required in developing genetic varieties which require less fertilizers, water and pesticides.

Energy related items in the intermediate consumption (operating costs) can be seen in Table 5.2. It could be seen that the share of energy related items is 57% of the expenditure in intermediate inputs. In one decade, it had gone up from 33% to 57% by 1971 even before the major hike in the energy prices. This gives an indication, to what extent, the increase in energy prices could result in increase in prices of agricultural outputs, if no subsidy is given.

6. HOUSEHOLD AND COMMERCIAL SECTOR

6.1. Introduction

The household sector in India is the largest consumer of energy if non-commercial energy is included. The share of consumption of commercial energy in the total* energy used in the

---

*Total energy includes commercial and non-commercial energy.

Fertilizers	Pesticides	Mechanization	Irrigation
o Increased use of manure or bio-gas	o crop rotation as a tool for pest management	o energy efficient machinery	o more precise application of water
o Precise use of fertilizers	o biological controls	o alternative tillage practices	o increased use of canal irrigation
o Crop rotation for nitrogen fixation	o more precise application of pesticides	o marginally more use of animal power and labour	

Possible long-term changes:

Development of genetic varieties requiring less fertilizers, water and pesticides.

Changes in food storage and transportation system and hence scale of production.

Alternative crop-mix and changes in relative prices of agricultural products (e.g. the crop requiring more water and fertilizers such as rice and sugar cane may get lower share or its price may increase.

Figure 5.2. Direct and Indirect Uses of Energy and Expected Technical Changes due to Scarcity of Energy.

Table 5.2. Changes in Share Allocation of Intermediate Consumption in Agriculture

Year	Intermediate consumption in Rs. 10^6	Fertilizers	Pesticides	Direct energy	Maintenance repair, services
		(Percentage share of each item)			
1961	2218	21.4	2.25	9.42	66.9
1970	7033	36.2	5.47	15.0	43.2

household and commercial sector has increased from 7.4% in 1953 to 20% in 1977. During this time period, commercial energy in the household sector grew at 4.7%, whereas, non-commercial energy grew at 1.5%. In 1976, 3.3 mt. kerosene, 0.36 mt. LPG, 5.8 bkwh of electricity and 3.1 mt. of soft coke were used in the household sector.

In view of the inadequacy of disaggregated data which indicate which forms of energy are used for what purposes within the household sector and how the variety of fuels used in the household sector substitute each other, it was felt appropriate to project energy demand by three alternative methods each of which has its own advantages and disadvantages. They are discussed below.

(A) End-use Method

In this method, total energy requirements for cooking and lighting (coming from a wide range of energy sources) are calculated separately so that what percentage of non-commercial energy is substituted by commercial energy and what percentage of kerosene used for lighting is substituted by electricity could be examined. However, the disaggregation of past data of kerosene into amounts used for cooking and lighting is uncertain and has to be guesstimated. Total energy required for cooking and lighting are projected. Consumption of some of the fuels are projected on the basis of likely supplies and then subtracted from the total energy to obtain the amount that would have to come from non-commercial sources.

(B) Direct-use Method

Here, the consumption of each of the fuels, in particular electricity, kerosene and non-commercial energy is projected directly as a dependant variable while the urban population, private consumption, etc., are used as independent variables. Assuming a fixed availability of kerosene supply, the remainder kerosene equivalent have to come from non-conventional sources.

(C) Income Distribution Method*

In order to assess the impacts of income distribution and to capture the differences between urban and rural energy consumption, the population in each expenditure class in rural and urban areas are projected.

Fuel-wise energy consumption is obtained using expenditure class specific energy consumption data given by the National Sample Survey.

In the following sections, each of the methods is discussed in detail.

6.2 End-use Method

The energy consumed in the household sector is divided into two parts: for cooking and for lighting and comfort.

6.2.1. Energy for Lighting and Comfort

It is necessary to combine lighting and comfort due to the fact that separate data for the use of electricity for lighting and other appliances, which are used for comfort, such as fans, refrigerators, air-conditioners, other appliances, etc., are not available.

The sample survey of NCAER indicates that in 1976 in Northern Region, approximately 60% of the kerosene consumption was used for lighting and 40% for cooking. When contributions of kerosene and electricity for lighting are compared on mtcr basis with conversion factors, it seems that only 30% of the energy for lighting and comfort is provided by electricity. The rest of it is provided by kerosene. However, kerosene is an inefficient illuminant and its efficiency is 10% of that of electricity. Thus, it is not justified to use 8.3 mtcr conversion factor for the kerosene used for lighting as conventionally used in India.

*Thanks are due to the staff of Sardar Patel Institute; in particular Prof. R. Radhakrishna, Dr. G.V.S.N. Murthy for discussions and valuable suggestions and Shri Pantuly for providing numerical inputs necessary for the ID method.

(This factor, however, is appropriate when kerosene is used for cooking.) When 10% efficiency factor of kerosene for lighting is considered, then it works out that 77% of energy for lighting is contributed by electricity. The share of kerosene in energy for lighting is expected to go down in future as the programmes of rural electrification advance.

In the model, energy for lighting is estimated as a function of urban population and the fraction of rural areas electrified. Having estimated the energy for lighting, the share of electricity in lighting is again estimated as function of the same two variables mentioned above.

6.2.2. Energy for Cooking

It should be noted that in spite of the decline of the percentage share of kerosene in lighting, kerosene consumption may rise at a very high growth rate mainly because of its increased use in cooking. While lighting may require 2 litres of kerosene per household per month, cooking can require nearly 20 litres or more per household per month if the entire cooking is done by kerosene. Thus, the rapid rise in kerosene demand is due to the fact that there is a shift from non-commercial energy to kerosene for cooking. The shift to kerosene for cooking can be explained due to the following reasons:-

- o lack of availability of non-commercial energy;
- o increased income; and
- o increased urbanization.

While projecting the energy requirements for cooking, kerosene, Liquified Petroleum Gas (LPG) and soft coke were taken jointly from the past data after multiplying the relative efficiency factors of 8.3, 10.5 and 1.5, respectively. It is found that energy for cooking is highly correlated with urban population and reduction of non-commercial energy per capita. Based on this regression, the total energy for cooking is derived from which expected supply for LPG and soft coke are subtracted, to arrive at the demand for kerosene.

6.2.3. Expected Energy Mix for Cooking

Here, expected supply of various energy forms play an important role.

(a) Availability of LPG

LPG is generally obtained as an associated gas with crude production or as a by-product from refineries. Therefore, the contribution of LPG could be determined from the total crude oil which would have to be refined within the country and from expected domestic crude production.

(b) Availability of Soft Coke

The provision of soft coke for cooking would be a matter of policy. There are the following reasons why the use and provision of soft coke has not made any significant headway in the past and may not improve in the future either:

(i) There is already a case for conserving cocking coal and, in fact, today the country is importing coke. Although, soft coke is made from weekly caking coal, there may still be a chance for using it as coke after due processing.

(ii) Soft coke is a better fuel for metallurgical purposes as it also works as reducing agent. Thus, its use for cooking should have a low priority.

(iii) It requires roughly two units of coke to produce one unit of soft coke and this makes soft coke very expensive. It is sold in Delhi in the retail markets at as much as Rs. 1300/- per ton. Thus, its relative price with respect to kerosene is high in terms of the heat delivered.

(iv) The possibility of producing soft coke exists only in two regions of India at present - Madhya Pradesh and Bihar. It would be difficult to transport soft coke from these two regions to other areas of India.

(v) The transportation of coke to the rural areas will be a formidable task as most of them are not connected with railways.

(vi) It may perhaps be better to manufacture charcoal from fuelwood which could be locally grown. The potential of supply of charcoal may not be as limited as that of soft-coke.

Considering these reasons, no significant increase in supply of soft-coke is assumed in the model. Thus, LPG and soft-coke together are exogenously specified*, keeping above-mentioned considerations in view. They are then subtracted from cooking requirements and the remainder is expected to come from kerosene, whose availability is also limited, and from programmes for bio-gas, wood plantations or solar cookers.

6.3. Direct-use Method

Here, the fuels and electricity are directly considered as dependant variables rather than end-use activities such as cooking and lighting. The use of electricity in the household sector is correlated with per capita private consumption and urban population. Two equations were tried for kerosene use which correlations were obtained with:

(i) per capita non-commercial energy availability and private consumption; and
(ii) share of urban population, private consumption and crude price.

Price elasticity of 7% with respect to price index of petroleum crude (1970 = 100) is observed. LPG and soft-coke are taken exogenously from the supply possibilities as already discussed before. The share of non-commercial energy in total energy is correlated in the SIMA model with the share of urban population and private consumption per capita. The same equation is used here.

6.4. Income Distribution Method (ID Method)

In the above methods, it is not possible to use the data obtained in the 28th Round of the National Sample Survey (1973-74) which provides the share of expenditure on fuel and lighting as well as the mix of fuels used by the families of various

*Figures for LPG availability are taken from the WEP.

expenditure classes in rural and urban areas. The per capita energy consumption is given in Figures 6.1 and 6.2. The expenditure distribution patterns are shown in Figure 6.3.

Figure 6.1 shows that in the urban areas, the share of non-commercial energy declines as the per capita monthly expenditure increases. This is not so in the rural areas as can be seen in Figure 6.2. This is because, rich families in the rural areas have an easier access to non-commercial energy as they own cattle and large farms. The Figures clearly show that it is important to distinguish urban and rural population and to take into account their income distribution.

On cross-checking the results of the sample survey, discrepancies were found in the case of total electricity and kerosene consumption derived from the sample survey and actual national level consumption. In these cases, correction factors (ratio of national consumption from sample results/actual consumption) were applied. In the model, it is assumed that the consumption pattern for each expenditure class in urban and rural area is fixed and as and when the population shifts from one expenditure class to the other, the consumption pattern of the latter class would be adopted.

The percentage distribution of population in the urban and rural areas for the year 2000 are derived assuming a log-normal distribution pattern and per capita income growths as per low and high GDP scenarios. For each GDP scenario, three distributions were tried reducing and increasing inequalities by 20% and also one with continuation of the inequality as at present. Thus, this method considers substitutions of better fuels with increasing income and increasing urban population, but does not consider substitution effects due to non-availability of particular types of fuels and due to relative prices.

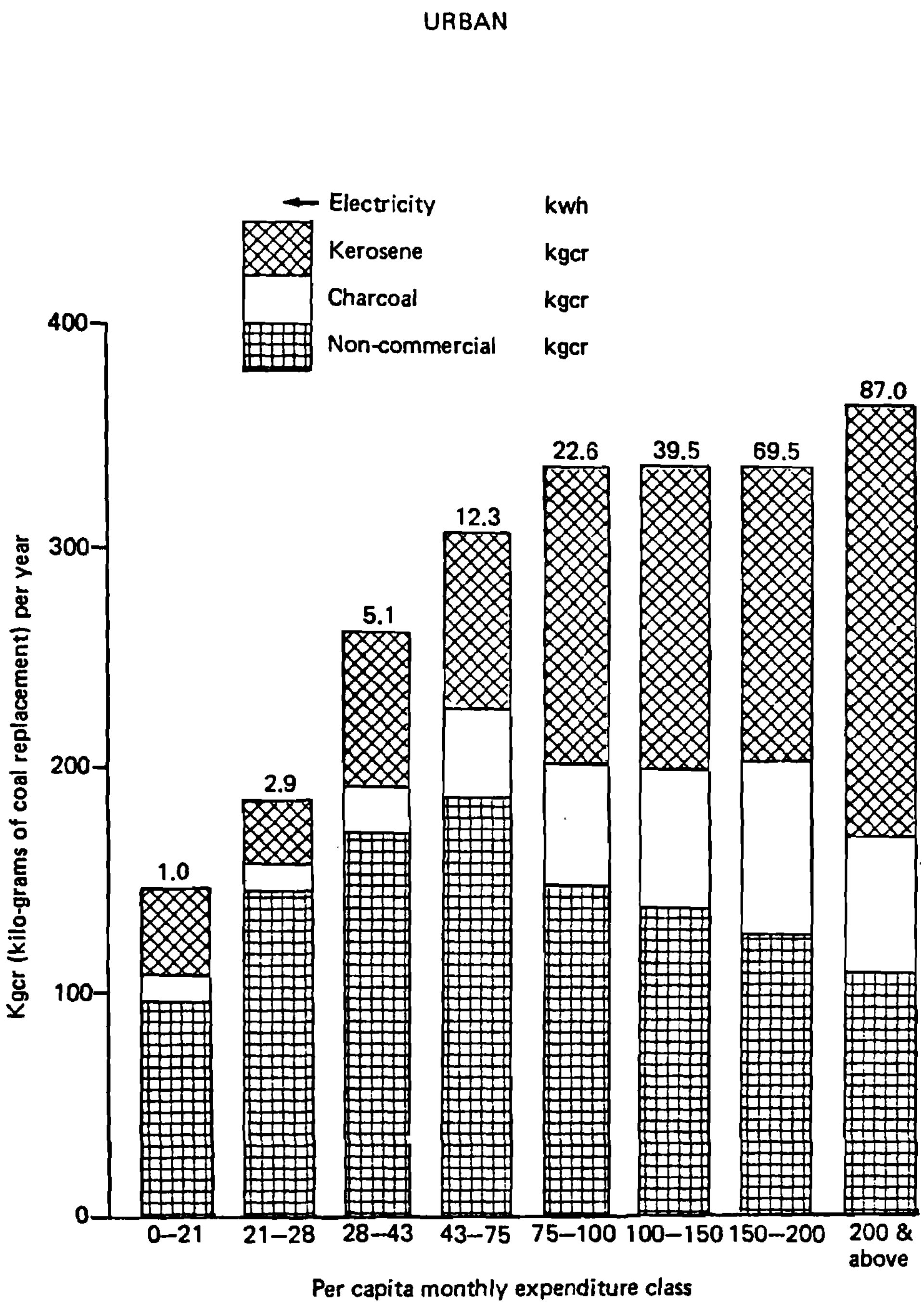


Figure 6.1. Per Capita Energy Consumption in Urban Household Sector for different Expenditure Classes.

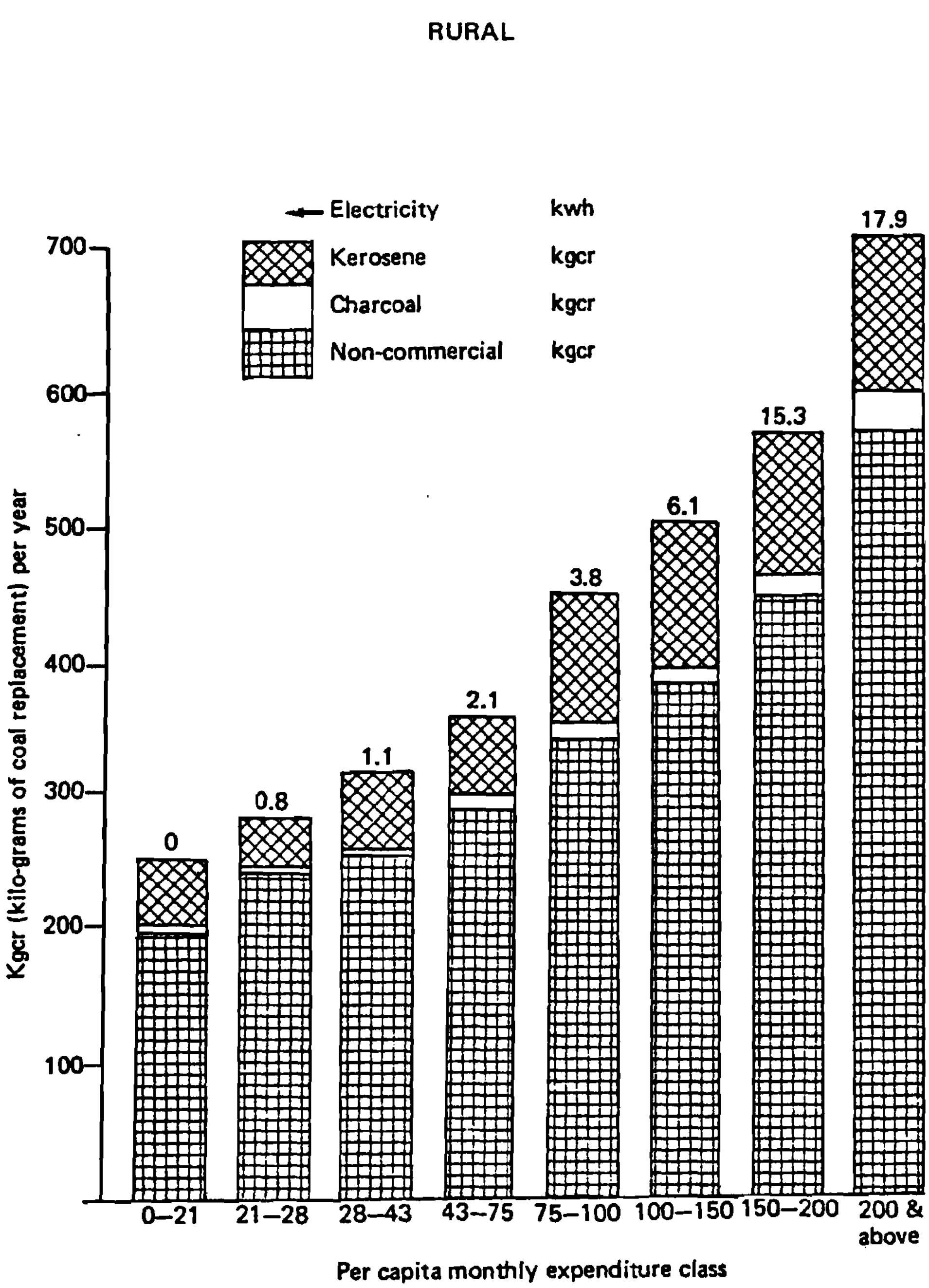


Figure 6.2. Per Capita Energy Consumption in Rural Household Sector for different Expenditure Classes.

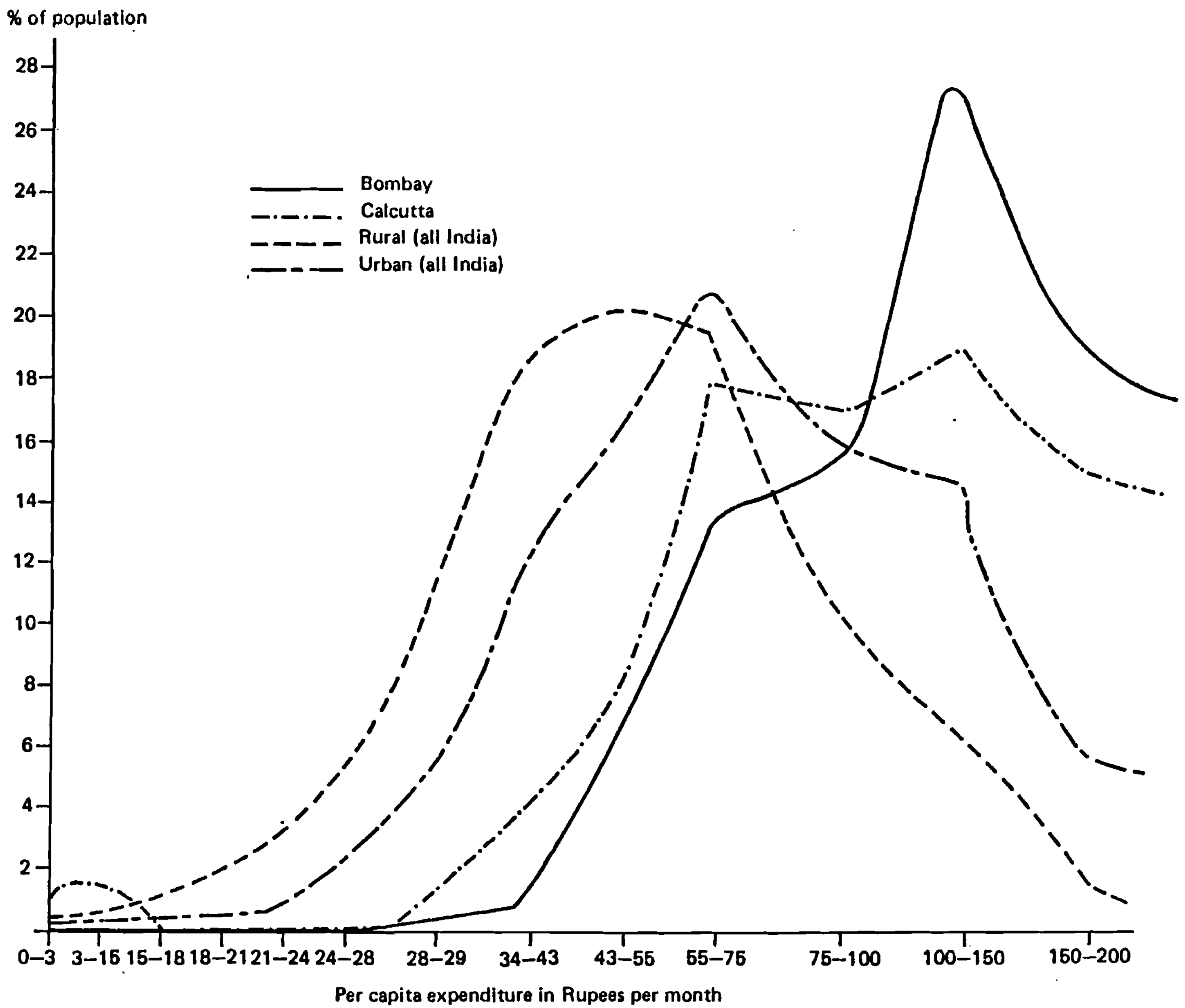


Figure 6.3. Income Distribution of Urban and Rural Households.

6.5. Discussion of Results*

The results of the direct use method and the ID method and their comparison are given in Tables 6.1 and 6.2. Following are the relevant points.

6.5.1. Electricity Requirements

The results of both the methods are reasonably close for both the GDP scenarios (with low urban population). It should be noted, that the price elasticities have not been considered in either of the methods and one would expect some effects due to rise in price of electricity. Unfortunately, one does not observe significant price elasticity from the past data. This, however, does not mean that in future, there would not be any effect of price on the electricity demand.

6.5.2. Non-electrical Energy Demand

The demand for kerosene, soft-coke (plus charcoal) and non-commercial energy should be viewed simultaneously (in terms of mtcr), as these fuels together represent demand for substitutable energy in the household sector. As far as cooking is concerned, one can be substituted by the other and, therefore, although differences between the two methods appear large if individual fuels are considered, they are not so large if the demand for all the fuels is taken together. ID method and direct use method project 0.426 and 0.468 tcr per capita per year in 2000. As against this, in 1973-74, the NSS estimate shows 0.4 tcr consumption.

In the past, supply of soft-coke has remained around 4 mt. since 1970. During the same time, kerosene demand has considerably risen. Soft-coke demand given by the ID method is without consideration of supply constraints. The direct use method based on regressions on the other hand, extrapolates the rise of the kerosene demand observed in the past into the future assuming that the supply of soft-coke would continue as it has been in the past. If, therefore, the soft-coke supply

---

*The end-use method has not given satisfactory results; because of uncertainty in the data. Therefore, they are not reported here. The method, which is interesting, is described in detail in section 6.2, only to document the efforts made.

Table 6.1. Energy Demand for the Household Sector - Direct Use Method

	1984-85	1989-90	1994-95	2000
Electricity (billion kwh)				
Low	11.01	16.02	22.80	34.25
High	13.05	21.17	33.77	58.19
Kerosene (million tons)				
Low	4.59	6.93	9.68	19.90
High	4.82	7.60	12.52	23.45
Soft coke[1]	5.10	5.94	6.85	8.00
LPG (mt)[2]	0.87	1.41	2.09	3.50
Non-commercial energy (mtcr)[3]	217	224	228	230

[1]Based on 3.06% growth rate (1970-1978 growth rate is 0.0).
[2]Based on the WEP from supply considerations.
[3]From SIMA Model.

Table 6.2. Summary of Energy Requirements for Household Sector by the ID Method for 2000 and Comparison with the Direct Use Method

	I.D. Method			Total direct use method
	Rural	Urban	Total	
Electricity (billion kwh)				
Low	9.12	22.62	31.74	34.25
High (L)	12.04	27.10	39.14	36.36
Kerosene (million tonne)				
Low	7.10	4.01	11.11	19.24
High	7.70	4.37	12.07	23.45
Soft Coke (million tonne)				
Low	9.12	14.26	23.38	8.0
High	10.45	14.82	25.27	8.0
Non-commercial fuel (mtcr)				
Low	246.51	34.72	281.23	229.0
High	269.36	32.78	302.14	-

were to continue at a low level then the ID method would indicate correspondingly that kerosene demand should go up. Thus, viewed this way, apparent contradiction between the two methods is not significant. Alternatively, additional commercial energy requirements in the household sector may come from the renewable resources such as bio-gas, wood plantation and solar devices. This method, therefore, stresses the need for pursuing these options and identifies the magnitude of the contributions required from these sources in order to curb the kerosene demand. For example, if kerosene demand has to be kept at 9.4 mt. in 2000, as suggested by the WEP, then nearly 11 mt. of kerosene equivalent energy has to come from other sources.*

6.5.3. Non-commercial Energy

ID method gives high demand for non-commercial energy because the effects of increases in the size of villages in rural areas, due to which the availability of non-commercial energy may be reduced, are not considered in this method. Therefore, increase in per capita rural income leads to higher consumption of non-commercial energy indefinitely as per the data of 1973. Considering the fact that cattle population in the country has stabilized recently and the prospects of even maintaining current supply of wood are not good (in the absence of crash action-programmes), the increase of non-commercial energy can come from only increased use of agricultural waste. It should be noted that even agricultural waste is increasingly used for purposes other than fuel, such as raw material for pulp, fibre, building material (thatching), etc. Thus, it seems unlikely that non-commercial energy supply of 302 mtcr, suggested by the ID method, could be obtained.

Rural-urban differences of energy consumption in 2000 can be seen from the ID method. It is interesting to see that nearly 70% of the electricity and 36% of kerosene are consumed in the household sector in the urban areas. This is in spite of the fact that urban population constitutes only 27% of the total population. Even so, there is a remarkable reduction in the urban-rural differential as compared to 1973.

---

*Considering 5.6 mt is suggested in the Sixth Plan by F1984 itself 9.4 mt suggested by WEP seems low. Not considered in the model is the possibility of using recently found natural gas for cooking.

Part of the problem in the ID method is that the data given by NSS is not disaggregated enough for higher income classes. The highest expenditure class considered by the NSS is that having greater than Rs. 200/- and above expenditure per capita per month. In the year 2000, 30% of the population is in this class. Further disaggregation of the data of this class could improve the projections. This could lead to increase in the demand for electricity and commercial energy. In fact, initially only 5 expenditure classes were considered, the highest class having expenditure greater than Rs. 75 per month per capita. Then disaggregated data was used for this class into four further classes: viz. 75-100, 100-150, 150-200 and above Rs. 200. It was found that the requirements for electricity and kerosene increased by 40% and 10% respectively when such disaggregation was carried out.

Although several income distributions - with increased reduction (by 20%) and continuation of inequality - have been considered, they do not lead to significant change in the energy consumption. However, distribution appeared to be much favorable to lower income class when reduction of inequality was considered. On the whole, GDP growth effects are more prominent compared to effects of changes in income distribution. The expenditure distribution for various scenarios are given in Figures 6.4 and 6.5.

In conclusion, it could be said that direct use method should be considered for the fuel mix it gives and the ID method is valuable for rural and urban break-up it gives and insights into effects of growth of income and changes in income distribution.

The electricity projections for the commercial sector (viz. offices, Government and other service sector) has been obtained by assuming growth rates which take into consideration increased price of electricity and growth of GDP in the service sector. The consumption grows from 5 bkwh in 1978-79 to 36.2 bkwh in 2000.

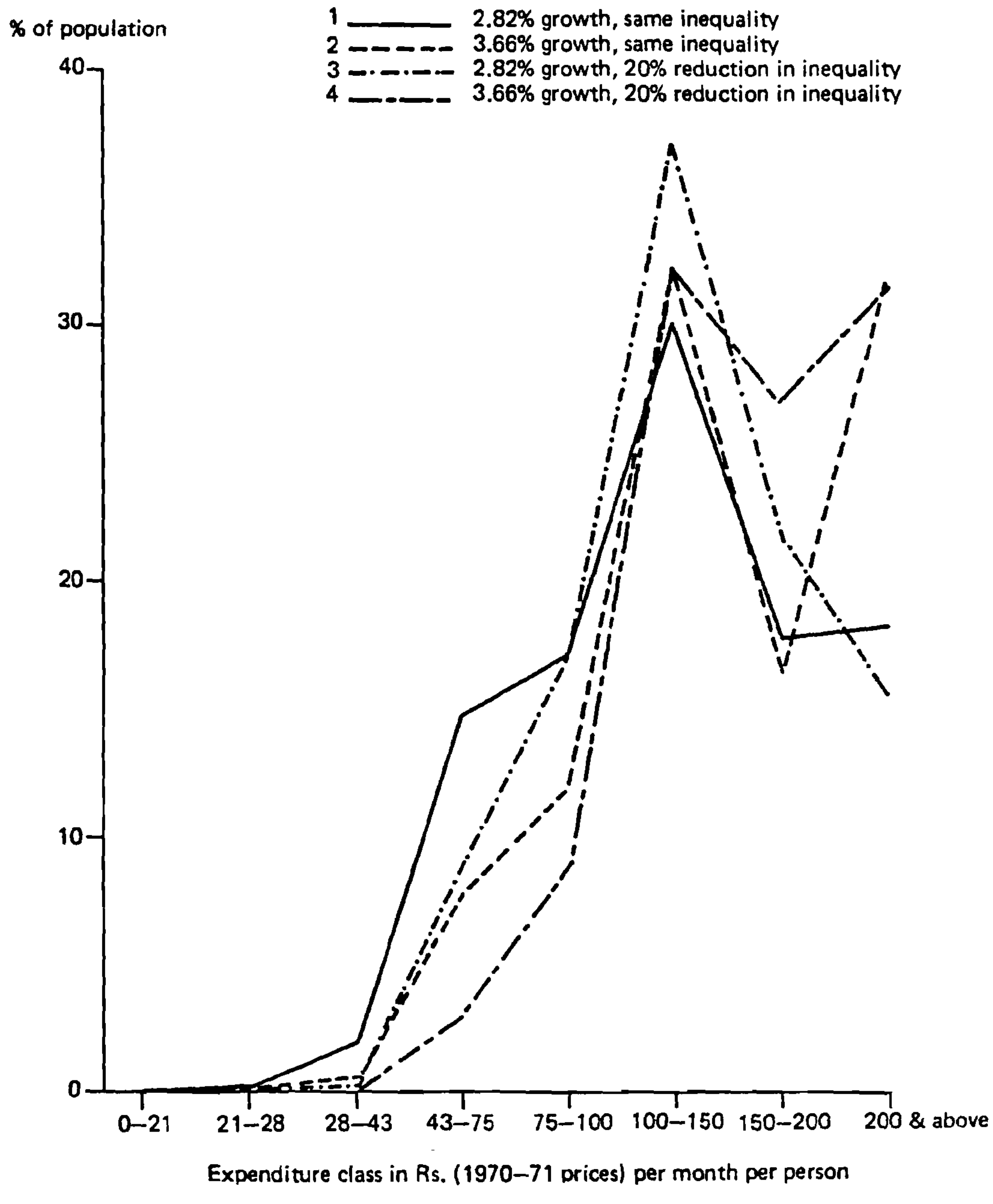


Figure 6.4. Percentage Distribution of Population in Various Expenditure Classes in 2000 - URBAN.

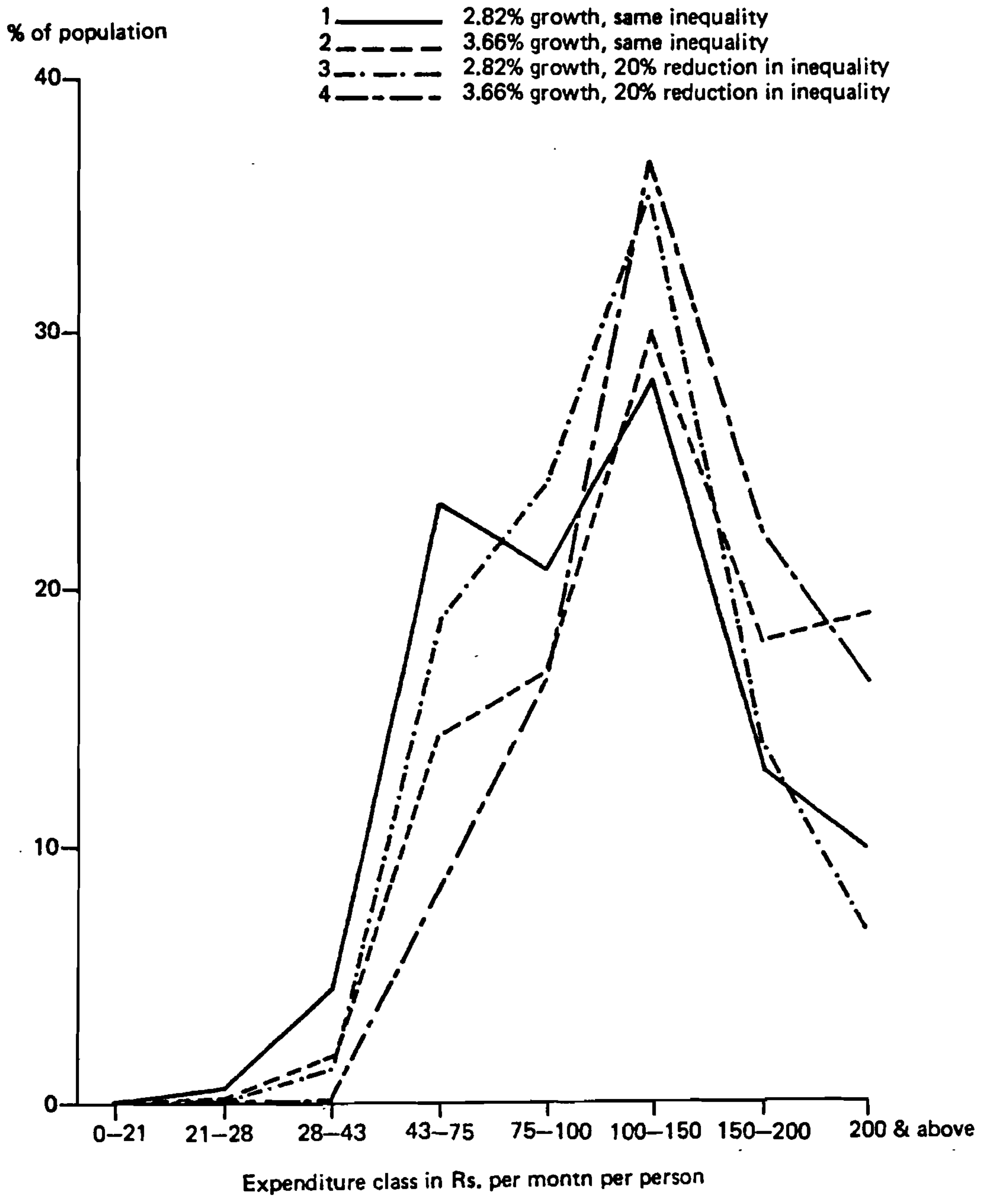


Figure 6.5. Percentage Distribution of Population in Various Expenditure Classes in 2000 - RURAL.

7. TOTAL ENERGY DEMAND AND COMPARISON WITH THE WEP

What do the sectoral requirements discussed in the preceding chapters add up to? What broad highlights are there for the energy supply sector of each kind? How do the results of the model compare with the WEP scenarios?

This chapter is divided in two parts:

- o Discussion of the range of overall energy demand for low and high demand scenarios (however, a tabular summary tables for high and low scenarios is provided in chapter 10).
- o Comparison with the WEP scenarios. In principle, this should be done at the end of all chapters, but as the WEP report does not deal with the following two chapters, viz. investment and regional distribution, comparison of the two efforts at this stage is possible.

It should be noted that the model has been constructed to look into major energy uses and minor miscellaneous uses such as colliery coal consumption, heavy oil products, electricity for water supply, etc., have been taken either from other sources, such as WEP, or from judgement based on study of other indicators.

In order to give a wide range for the energy demand, the results of low and high - both GDP and urbanization - are given. However, if high GDP and low urbanization are considered together, i.e. High (L) scenario, then the demand reduces. While making various runs, it was found that this combination, i.e. High (L) scenario, is the one which compares better with the WEP scenario of the optimal level forecast (OLF).

7.1. Summary of the Overall Demand

Demand emerging from each sector is added to obtain the total requirements of each energy resource. Following are the observations for each major energy source.

7.1.1 Electricity Requirements

For the high demand, the model gives approximately similar electricity requirements given by the Sixth Five Year Plan for 1984-85, i.e. 144 and 145 bkwh respectively. The major difference is in the projections of the energy for agriculture, which is 17.7 bkwh and 20.5 bkwh by this method and the Plan respectively.

For the year 2000, the model projects electricity requirements of 342 and 452 bkwh for low and high GDP and urbanization respectively. WEP projections of RLF and OLF are 471 and 401 bkwh of electricity respectively. If high GDP is considered with low urbanization in the ENDIM model, i.e. High (L) scenario, then the demand is 400 bkwh.

However, the share of industrial requirements comes down to 59% by 2000. The electricity intensity increases from 0.690 kwh/Rs. of V.A. in 1976 reaches a level of 0.900 kwh/Rs. of V.A. in 2000 (Rs. is in 1970-71 prices).

7.2 Oil Requirements

Unfortunately, minor oil products such as Bitumen, lube oils, LSHS, MTO, etc., are difficult to project and so also are minor uses of major products and to that extent, there would be uncertainty in total oil requirements. The projected oil requirements of major oil products for major uses in 1984-85 is 25.9 mt. and is less than approximately 28 mt. envisaged in the Plan. Unless the reduction is enforced in the Sixth Plan itself, it will be difficult to obtain the desired value of 53.7 mt. in 2000.

Most important oil conserving policies are:

(a) Curbing kerosene demand: If WEP targets of 7.3 mt. in 1992 and 9.4 mt. in 2000 are to materialize then equivalent amount of 5.2 mt. and 11.0 mt. respectively in 1994 and 2000 would have to come from other commercial energy sources. We consider that bio-gas, solar and wood-plantation are commercial energy schemes which require planning, investment and management. Only then the energy could be provided on a sustainable basis. Thus, the present method provides time table for the energy supply necessary from "new" energy sources.

(b) Curbing diesel demand: With appropriate transport policies, it is possible to save nearly six million tons of diesel per year in 2000 out of 26.4 mt. projected in the absence of such policies.

(c) Curbing fuel oil demand: As fuel oil is used in industries, demand could be reduced through price measures and by ensuring availability of coal and power which can substitute fuel oil.

The most important concern for the supply of oil products is that the percentage of middle distillates (diesel, kerosene and ATF) increase from 54% in 1977 to 65 to 70% in 2000. This does not conform with the present refinery pattern where middle distillates constitute roughly 48% of crude through put. Thus, secondary refining may be necessary. Even with it, there would be need for imports of middle distillates or exports of light distillates.

7.3. Coal (and Charcoal) Requirements for Direct Use

It is not attempted to arrive at the coal requirements for power generation as this question requires analysis of the question of optimal mix of hydro, thermal and nuclear which can be best addressed in the supply model. The projections for direct use of coal are 111.6 mt. for 1984-85 and are in line with the 6th Plan targets. The demand for 2000 is 238 mt. and 334 mt. for low and high demand, respectively. Urbanization does not have any effect on coal demand. For industries alone, the model predicts 318 mt. of coal in the year 2000 for high demand scenario. There are a very few conservation measures identified today as far as coal demand is concerned (although some measures of coal conservation through appropriate mining are being thought of). The results given here also include charcoal requirements for the non-LEC industries. In future, the share of demand for coal reduces in transport sector and household sector and the share of industries sector increases.

7.4. Comparison with the WEP Scenarios

It should be mentioned that it is difficult to compare the WEP scenarios with the model results because no explicit assumptions are made about the urban population by the WEP. Moreover, ad hoc cuts are made to go from reference level forecast, RLF, to optimal level forecast, OLF. (RLF are the energy requirements if the past trends were to continue; OLF are the 'desirable' level of energy demand.) It appears that WEP has assumed high GDP growth with low urbanization. The nearest way to compare the two is to consider High (L) scenario of the model with the OLF scenario by the WEP. A summary of the differences, in the assumptions and approaches is given in Table 7.1. The differences in the results are given below.

There are three possibilities. The model supports, disagrees and/or supplements the assumptions and results of the WEP scenario. Each possibility is discussed below with the year 2000 as a reference point. Comparison of only OLF and High (L) scenario is made.

1. Where the model supports the WEP scenario:
   This is the case for many issues. They are:
   (a) General total magnitude of electricity and oil products demand where the differences are small.
   (b) Small miscellaneous energy uses such as colliery consumption, etc., and figures for certain small energy supply such as LPG, ATF, etc.

2. Where the model differs:

The model differs with the WEP scenario in the following matters:

   (a) The shares of industries and agriculture in the total electricity consumption are 71% and 7% in the WEP scenario and 58.8% and 10% in the model. The reduction in the share of industries are due to conservation and changes in production technologies in the industries. It is also due to increased shares of household and commercial sectors because of increase in

Table 7.1. Highlights of Differences in the Approaches of the WEP and the ENDIM Models

ENDIM MODEL	WEP APPROACH
1. Macroeconomic	
o Two scenarios, low and high GDP. "High", the same as WEP and 6th Plan, "Low" from the "SIMA" model (4.4% growth).	o Only one scenario of 5.8% average annual growth in GDP for the period 1982-2000.
o Consumption, investment rate, etc. endogenously determined in SIMA.	o Variables not used.
2. Demographic	
o Two scenarios of urban population considered.	o Variable not considered.
3. Industries	
o Two levels of disaggregation in the macro-method.	o Industry-GDP coefficient at one aggregate level.
o Nineteen levels in the end-use for power sector.	
4. Transport	
o Variations of 4 oil saving policy variables considered viz. low and high scenarios for: a) Urbanization b) Improvements in efficiency c) Increased Transport by railways d) Increased railway electrification	o One scenario given and the savings estimated in an aggregate manner.
o Transport found to be insensitive to GDP but highly correlated with urban population.	o Transport-GDP coefficients used as the basis for projections.
5. Agriculture	
o Effects of policy of rural electrification and area expansion vs. policy of intensification of agriculture worked out.	o Projections based on assumed number of irrigation pumps.
o Increase in population and electrified villages considered.	
6. Household	
o Effects of increased income and changed income distribution.	o Use of NSS data assuming unchanged income distribution.
o Substitution of commercial energy	o Income effects ignored.
o Urbanization considered. Three methods given.	o The other two effects mentioned are not considered.
7. Investment requirements	
o Investment with gestation periods considered and the conditions under which economy could provide this investment are spelled out.	o Gestation periods and consistency with macro-economic assumptions not considered.
8. Regional distribution of energy demand	
o Implications for demand and distribution for Eastern, Southern, Western, and Northern regions worked out.	o Not considered.

Note: Variations in numerical values for different parameters, such as energy intensities, transport efficiencies, etc., are not listed here but are given in the text in respective chapters.

rural electrification, urbanization increase and income; increase in transport sector because of railway electrification and increase in agriculture sector because of rural electrification and increased intensification of agriculture.

(b) The electricity demand for the agriculture sector given by the WEP is only 28 bkwh which is small compared to nearly 46 bkwh expected in the model.

(c) The coal use in the industries is 265 mt. in the WEP and 317 mt. in the model. The substitution of oil and non-commercial energy lead to high use of coal. The assumed provision of soft-coke for the household sector is 16.8 mt. and 8 mt. by the WEP and the model respectively.

(d) The projections for the end-use activities in the transport sector, especially tkm, are very high by the WEP (900 tkm) as again 720 tkm given by the model. The diesel consumption, therefore, differs drastically.

(e) Petrol consumption is 3.2 mt. and 5.4 mt. by the WEP and the model respectively. If the WEP scenario is to materialize, the per capita car ownership would have to decline in spite of the fact that GDP increases at 5.8%. Thus, the OLF projections appear to be unrealistically low.

(f) The commercial energy requirements of the household sector as expected by the model is high as it considers substitution of non-commercial energy and effects of increased urbanization and increased income. In High(L) scenario, contributions required from alternative energy sources are 0.6 mt., 5.2 mt. and 11 mt. of equivalent kerosene by 1989-90, 1994-95 and 2000 respectively. The model thus highlights the time table for the new energy sources, for which action is required <u>now</u>.

(g) In general, the WEP growth rates of demand for all energy forms are high in the near future and low after 1987-88 indicating abrupt decline or change in the next 7 years in spite of the fact that GDP growth assumed after 1987-88 is 6% whereas from 1977-78 to 1982-83 it is 4.7%. In the model, the growth rates of energy consumption decline gradually.

3. Where it supplements the WEP efforts:

In some cases, the model makes some of the underlying, but unstated, assumptions of the WEP more explicit. For example, as stated earlier, it was established that the share of urban population would have to be around 26% in the WEP; this is, however, not stated in the WEP report. What do the reduction and cuts introduced to go from RLF to OLF projections mean for individual sectors? How does one go from the RLF to OLF levels? The model quantifies the expected changes specifically - in terms of identifiable parameters - as follows:

(a) The expected decline in the energy-intensities of the LEC and non-LEC industries are indicated in Table 3.2.

(b) The reduction in consumption norms for each of the transport modes are indicated for the desired reduction in diesel consumption in Table 4.7. The reduction for each mode is assumed after a detailed examination of the possibilities of such reductions.

(c) The role of urban population in the energy demand for transport and household sectors has been highlighted.

(d) In the agriculture sector, the trade off between area expansion policy vs. intensification of agriculture to grow more food are made explicit. The effects of rural electrification have been illustrated.

(e) The household sector has been examined in more detail to find effects of income-distribution, rural-urban difference, fuel-mix, etc. The implications for each are discussed in Section 6.5.

In the end, it must be stressed that in view of the considerable uncertainties that the future holds, the aim of this exercise is not only to make projections but to understand the implications of alternative energy policies. The model tries to do this by giving a number of alternative projections under different energy policies in each chapter.

8. INVESTMENT AND IMPORT REQUIREMENTS FOR THE ENERGY SECTOR

8.1 Introduction

Whether the projected energy requirements can be met or not could be determined if the required investment in the economy is forthcoming. During the period 1960-1978, commercial energy production grew at 6.1% and electricity production in particular grew at 9.3% whereas the GDP grew at only 2.8%. How was this growth achieved in the past, and can such a trend continue in the future? Similarly, percentage of export earnings required to purchase imported oil has gone up from 27% in 1973 to 35% in 1978 and will go up further. To what extent is it possible to increase oil imports if the price of oil also increases?

In a market economy, demand is a function of price and the response of the demand as a function of price (elasticity) is estimated from the past data. However, in India, only some items, not consumed by the poor, such as petrol, are subjected to steep price increases. Where a large fraction of people live in abject poverty, it is not always possible to use the price as a tool for demand management. Therefore, in general, very little effects of prices (price elasticity) can be observed in the data. Instead, foreign aid, deficits, direct and indirect taxes, rationing, and limiting supplies are used for financing subsidies and for controlling demand. How does one consider constraint of the availability of investment. In order to do so, for high and low demand scenarios and given GDP scenario, percentages of total investment that need to be allotted to the energy sector are worked out.

In order to do this, some assumptions concerning the energy supply system have to be made, even though the primary purposes of this study is to go into energy demand systems.

In 1949, from a low base of 1537 MW of power capacity and 4.91 bkwh of generation, the electricity sector grew to nearly 28,000 MW of capacity and 112 bkwh of generation in 1978-1979.

This has been possible because while the economy grew at 3.3% between 1960 to 1976, capital formation in the economy grew at 5.0%. The share of energy sector in total capital formation has grown from 6.7% to 11.9% during the same period. Some of these relevant figures are given in Table 8.1.

Thus, if the energy sector has to grow at a much higher rate than the economy, then the capital formation and the share of electricity sector in the total capital formation, both have to rise at a much higher rate. It is the purpose of this model to identify what would be the required growth of both of these to meet the energy requirements and whether such growth rates are feasible.

8.2. Components of the Investment Requirements

Items to be considered in the investment sector are illustrated in Figure 8.1. The total investment required in the energy sector consist of the following:

Coal	-	mining, reorganizing mines, transport of coal.
Oil & Gas	-	exploration and drilling, pipelines, refineries and import requirements.
Electricity	-	generation, transmission, distribution and rural electrification.
Renewable resources	-	solar, wood, bio-gas.

There are further disaggregation such as mix of hydro, thermal, nuclear, etc. In the present procedure, these are taken from the WEP and should be replaced by the mix obtained from optimization model, when available.

In deriving investment requirements, additional capacity to be created has to be first calculated from the energy demand after subtracting the amount that can be supplied by the existing capacity. However, investments would have to be made according to the gestation periods required for creating new capacity. Moreover, phasing of this investment on a year-to-year basis from the starting period to the completion of gestation period has to be also considered. Initially, newly created capacity may not be in operation with full capacity but may operate at reduced capacity. This also is considered in the model.

Table 8.1. Growth and Changes in the Indicators of Power and Economy

(In Rs. 1960-61 prices)

		F 1960	F 1965	F 1976	Growth rate F 1960-1976
1.	GDP (Rs. billion)	132.63	150.82	222.38	3.28
2.	Total capital formation (Rs. billion)	18.08	25.06	46.30	6.05
3.	Value added by mf. (Rs. billion)	19.94	28.37	42.51	4.84
4.	Capital formation in public sector (Rs. billion)	10.25	16.11	25.59	5.88
5.	Value added by mfg./GDP	0.150	0.188	0.191	-
6.	Capital formation in public sector/GDP	0.077	0.107	0.115	-
7.	Capital formation in public sector/ total capital formation	0.567	0.568	0.553	-
8.	Capital formation in industries (Rs. billion)	7.07	9.91	16.18	5.31
9.	Capital formation in energy (Rs. billion)	1.22	3.24	5.12	9.38
10.	Capital formation in energy/total capital formation	0.067	0.129	0.110	-
11.	Capital formation in industries/ total capital formation	0.391	0.395	0.349	-
12.	Capital formation in industries/ capital formation in public sector	0.690	0.615	0.632	-

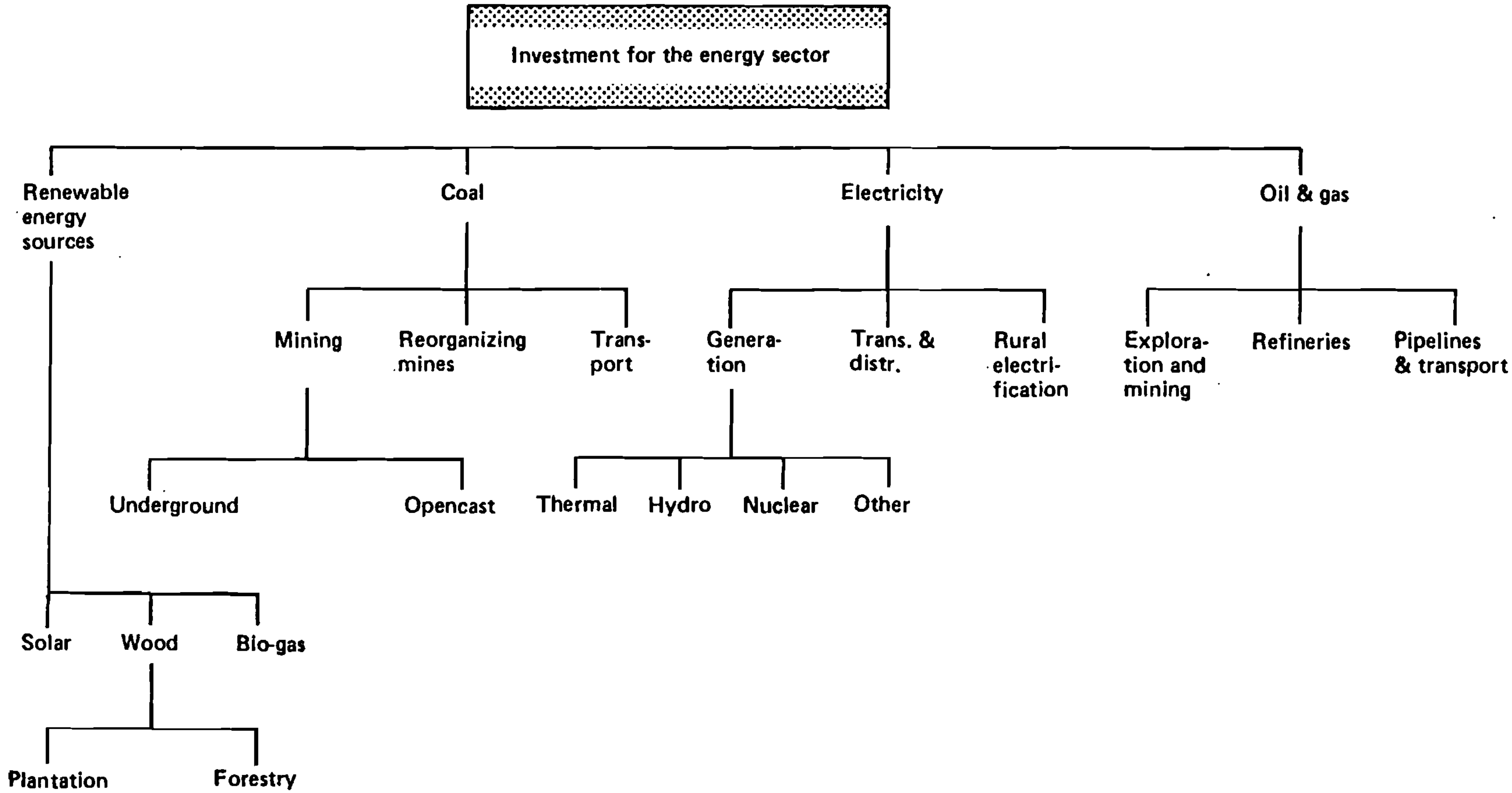


Figure 8.1. Items to be considered in Investment for the Energy Sector

Therefore, in a given year, many projects may require investment simultaneously for different projects at different stages of their completion. It is only when the investment requirements are calculated in this manner, economic constraints in providing the investment become perceptible. Often, it requires 8-10 years before full capacity utilization takes place of an energy project. Thus, these long gestation periods make the economy bear an extra burden for the future demand that may arise as much as 10 years later. An example of such calculations is indicated in Section 8.3.

8.3. An Example of Investment Calculations with Phasing Capital Requirement for Electricity Generation

$C_{generation}$:

Five-year growth rate of electricity:

$$gel\ (t) = [elec(t + 5)/elec\ (t)]^{1/5}$$

Electricity requirements for in between years:

$$elec\ (t + i) = [elec\ (t) \times (1 + gel\ (t))^{1 + i}]$$

Additional electricity requirements each year:

$$d\ el\ (t + i) = elec\ (t + i) - elec\ (t + i - 1)$$

Additional capacity requirements:

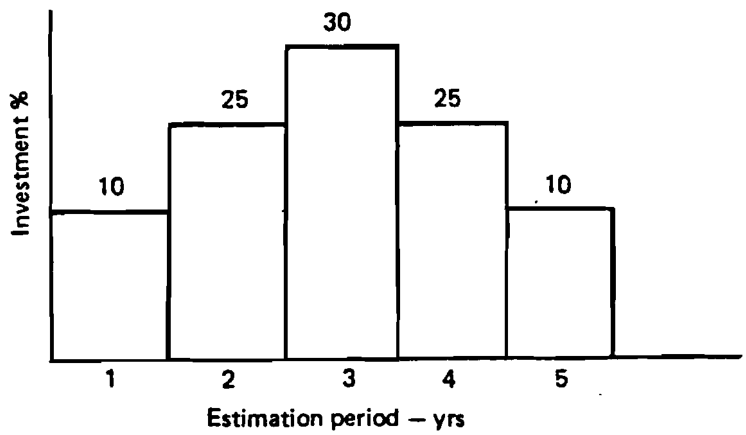
$$d\ k\ w\ (t+1) = \frac{1}{P1}\ [d\ el\ (t + i) - d\ el\ (t + i - 1)]$$

$C_{generation}(t) =$

$$[\ .10 \times dkw\ (t + 5) + .25 \times dkw\ (t + 4) + .30 \times dkw(t + 3) + .25 \times dkw\ (t + 2) + .10 \times dkw\ (t)] \times Cap\ kw$$

Cap - kw = Capital requirement per kw.

P1 = Plant-factor in kwh/kw



Phasing of investment in thermal plants

Similar phasing of investment transmission - distribution and rural electrification would have to be worked out.
Similarly, capital and import requirements for coal, oil and gas as discussed in the preceding page would be considered.

8.4. Inputs in the Investment Model

While the above outline is a rather detailed one, in order to achieve quick results, it is necessary to simplify the model in view of the data situation. Since the data for investment in coal and oil are not available on annual basis for two decades, only power sector is considered. It is worth noting that in the Sixth Five-Year Plan, 20% of the public investment of the Plan is expected to be in the power sector. The investment for the entire energy sector is expected to be 27%. Thus, power sector alone calls for 73% of the investment of the Plan in the energy sector. Therefore, as an approximation, it is possible to understand whether investment will be a constraint in meeting the future demand or alternatively, whether the demand obtained from the model is consistent with the economic assumptions made in the model by considering the investment for the power sector only. In order to simplify the calculations even further, average capital costs and average plant factors for thermal, hydro and nuclear plants are considered.

The basis for numerical values of these are explained below. As mentioned before, assumptions concerning the energy supply systems such as plant factors, capital costs, systems losses, etc., would have to be made.

8.4.1. Plant Factors

It is observed that total kwh/kw has gone up from 2283 in 1939 to 4115 in 1976-77. In 1976-77, the values for hydro, steam and nuclear power plants were 3850, 4351 and 5082, respectively. As gas and diesel provide mostly peak power only, their kwh/kw was 1147. It is possible that plant factors of steam and nuclear power plants may go up in future. However, in case of hydro power plants, this will not be the case as more and more peak power stations come on to the grid. It is also to be noted that in 1964-65, the average kwh/kw for all power plants was 4011. After 1964-65, there has been considerable fluctuations and this number has been exceeded to only in 1976-77. It is therefore, reasonable to assume that in future, average kwh/kw can be at most 4400 under the most optimistic circumstances.

8.4.2. Capital Cost of Power Plants

The capital cost of power plants vary for each type of power plants and also depend on the size, the location and other similar factors. Recent reference figures taken for hydro, steam and nuclear are Rs. 6,000/-, 5,600/- and 7,000/- per kw of capacity. These are, of course, distributed over 5 to 8 years during which the power plants are constructed.

The capital costs for transmission and distributions (TD) are very difficult to quantify on a kw basis. Therefore, for long-term planning, they are generally taken on a percentage basis such that the ratio of investments for generation: TD is approximately 3:2.

Future increase in capital costs: It is shown in Table 8.2 that considering simply the plan figures divided by kw capacity created in the plan, it can be seen that capital costs per kw has gradually gone up particularly after 1960s in real terms. In view of the fact that in future, the capacity for hydro and

Table 8.2. History of Plan Allocations for the Power Sector

Plan Period	Planned Expenditure on electricity sector (Rs. crores) (Rs. crores)	Additional Capacity MKW	Average Capital per kw Rs./Kw*	As a percentage of total plan expenditure
Ist Plan (1951-56)	320	1.10	2909	16.3
IInd Plan (1956-61)	625	2.25	2778	11.2
IIIrd Plan (1961-66)	1334	4.52	2951	15.6
Three Annual Plans (1966-69)	1817	4.12	4910	27.43
IVth Plan (1969-74)	2523	4.58	5509	16.0
Vth Plan (1974-79)	7294	10.2	7151	18.6
VIth Plan (1980-85)	19265	-	-	19.8

*This is a crude average because in a given plan there could be a number of projects, extensions, etc., at various stages of completion.

nuclear power plants, which are highly capital intensive, would be increased more than the thermal power plants, it is reasonable to assume that the average capital cost per kw will increase further. Therefore, in one scenario, it is assumed that the capital costs to generate and distribute 1 kw of power will increase linearly by Rs. 560/- per kw (in 1970-71 prices) in every plan period. In another scenario, it is assumed to stay constant in real terms.

8.4.3. System Losses

System losses are due to three factors: transmission, distribution and auxiliary. It is expected that auxiliary losses will continue to be around 6% of generated electricity. Transmission and distribution losses are expected to go down from the present 20% to roughly 14% by the year 2000 as high voltage lines increase and power network strengthen. Therefore, the TDA losses are reduced gradually in the model and the necessary electricity to be generated to meet the calculated demand is derived by considering the TDA losses which are given in Table 8.3.

8.4.4. Economic Assumptions

Assumptions regarding the investment availability in the economy, have to be also made. It is assumed that in the case of high GDP scenario, the total investment rate will increase from 23.4% as of present to 25% and 28% in the year 2000, for the low and high performance standards, respectively. The share of public investment in this total investment will increase from 50.2% in 1982-83 to 55% in the year 2000. The required percentages of public investment for the power sector then give the indication whether the investment to fulfill the demand will be available in the economy.

Two scenarios of 'efficiency' or 'performance standards' were constructed for each demand scenario. The first scenario 'Low efficiency' assumed high (increasing) capital costs, reduced kwh/kw and no improvements in the investment rate in the economy (25.5% throughout). The second scenario 'High efficiency' scenario assumed improvements in the power and economy. These assumptions made pertaining to the future power system and economy are given in Table 8.3. Using these figures, the investment required for the power sector to meet the required demand of electricity is calculated.

8.5. Discussion of Results

Number of parameters were varied in order to project investment requirements, e.g. different performance scenarios, namely, improvements in plant factors, reduction of T.D.A. losses, capital cost for generating and supplying powers and fraction of investment that would be generated for a given GDP growth rate. The results are given in Table 8.4. It gives the lagged investment required for meeting the low and high demand.

(a) Can economy provide the investment required for the power sector? The answer is 'yes' only if:

- (i) The efficiency standards namely the average plant factor is improved from 4200 kwh per Kw to 4400 kwh per Kw.
- (ii) No further rise takes place in the capital cost of power generation and distribution in real terms (i.e. in 1970 prices).
- (iii) The T.D.A. losses reduce from 26% as of present to 21% of generated electricity.
- (iv) Total investment in the economy goes up to 28% of the GDP rather than 22% as of present.
- (v) The demand itself is reduced because of the energy conservation measures (already assumed before in all the sectors of the economy).

If these conditions are met, then the fraction of public investment required goes up from 23% as of present to only 24% in future (2000) in case of high demand. In case of the low demand high efficiency scenario, the fraction of investment required actually declines to 19% in 2000 because of the improvements mentioned above.

Table 8.3. Assumed Inputs for calculating the Investment in the Power Sector*

	1984-85	1989-90	1994-95	2000-01
Electricity supply				
Average capital cost per Kw[1]				
High	5061	5600	6060	6469
Low	4852	4852	4852	4852
Plant factor (Kwh/kw)				
Low	4200	4160	4075	4000
High	4240	4340	4400	4400
Systems losses[2] (TDA) %	23.6	22.6	21.7	21.0
Economy				
Fraction of investment in total GDP %				
Low	25.5	25.5	25.5	25.5
High	25.9	27.1	27.6	28.0
Fraction of total investment in the public sector	50.8	52.6	53.5	55.0

*"Low efficiency" scenario takes all the figures of the first alternative.
"High efficiency" scenario takes all the figures of the second alternative.

[1] Including transmission and distribution in Rs. 1970-71.

[2] High and low values corresponding RLF and OLF given in WEP. Auxiliary consumption of 6% is added.

Table 8.4. Investment required in the Power Sector and its Relation to Economy

	Low demand				High demand			
	1984-1985**	1989-1990	1994-1995	2000-2001	1984-1985	1989-1990	1994-1995	2000-2001
Electricity demand (bkwh)	133.6	185.3	249.3	342.0	147.4	214.9	308.4	452.8
Electricity to be generated*	165.1	227.2	304.2	413.8	182.2	263.4	375.5	547.9
Capacity to be created (1000 MW)								
Low	44.9	62.3	85.2	118.1	49.5	72.3	105.2	156.4
High	44.6	60.4	79.9	107.4	49.3	70.1	98.3	142.1
Investment required (Rs. 10^9 in 1970-71 prices)								
Low	18.7	27.4	33.3	45.6	24.4	39.8	51.5	78.5
High	15.3	18.8	21.8	31.1	20.3	27.8	34.3	53.5
Percentage of total investment in the public sector								
Low	27.1	31.1	29.8	30.4	32.6	38.7	37.1	38.7
High	21.8	20.2	18.0	18.9	26.5	25.7	22.8	24.1

*In Rs. of 1970-71.

**The figures for 1984-85 exclude the investment for on-going schemes initiated during 1975 to 1980 and include only those necessary for future requirements. To this extent, the figures may be low.

(b) However, past data do not seem to indicate even the trend of the expected five changes mentioned above. In fact, plant factors are expected to decline because of expected increase in hydro capacity only for peak purposes, and capital costs usually increase by 2% a year in real terms. Thus, under 'low efficiency' scenario, which expect only small improvements compared to present, investment requirements would be as high as 38.7% and 30.4% of the public investment in the year 2000 for the high and low demand scenarios, respectively. This should be considered such a large increase that it will not be realistic to assume that such a large fraction of investment can be forthcoming for the power sector alone, and, therefore, it could be concluded that the derived demand cannot be met in the investment generated by the economy under the 'low efficiency' scenario.

The model, therefore, underscores the need for improving efficiency standards of the power supply systems, maintaining the present capital costs and increasing the investment in the economy, if electricity demand has to be met as specified by the model and desired in the WEP scenario.

8.6. Import Requirements for the Oil Sector

This aspect is dealt with by the WEP showing that in case of reference level forecast, RLF, the oil imports exceed total exports if the exports grow at 6.0%. Even the OLF scenario will require 69.3% of export earnings for purchasing oil. There are considerable uncertainties about issues like the oil prices, future supply of indigenous oil production, growth of exports, etc., which cannot be dealt with by this model. If, however, some assumptions are made in the model as by the WEP, the WEP observations on this matter may be also supported apart from small differences in the magnitude of the percentages required.

9. REGIONAL DISTRIBUTION OF ENERGY DEMAND - SOME ISSUES*

9.1. Introduction

Allocation of the Plan targets to individual States has been a major problem in the planning process in India. Disaggregation of national level demand is not only necessary for the purpose of going into further details, but also to develop a methodology for matching energy demand with the energy supply centres at a later stage. Unfortunately, WEP report does not discuss the problem of regional distribution of energy demand. In the preceding sections, all-India levels of demand and their implications on an aggregate level have been discussed. However, India is a vast country, where spatial aspects or, regional distribution of energy, give an additional dimension to the energy problem.

In general, national level models, such as the one discussed here or the input-output model of the Planning Commission, do consider sectoral allocations of natural and financial resources. Thus, the disaggregation of Plan targets in terms of sectors, such as industries, agriculture, etc., is available. However, breaking-up of these targets into State-level targets has been a difficult task partly because of the constitutional autonomy of the States and partly because of the lack of methodology for optimally allocating the resources over a long-term and even a framework in which such an optimality for a long-term can even be theoretically considered. Moreover, even if it is theoretically possible to determine such an optimal strategy, national level optimum may not be suitable to individual State's desire for their own chosen paths of development. Since a bulk of financial and natural resources are contributed by the States themselves, it is necessary that allocation of the Plan targets should be acceptable to the States as well. While the coal and oil could be transported over long distances, it is not so easy for power. In addition, electricity can also not be stored. Therefore, it is essential to have indication of regional distribution of demand, especially for electricity and also for coal and oil so as to reduce transport and its bottleneck.

---

*This chapter is a modified version of a published article in 'Urja' by J. Parikh (1980).

Regional disparity in terms of per capita income and many other variables is rather significant in India and it is desirable that some regional imbalances are corrected through planning process. However, this does not mean that energy per capita in all the States should be equal. Energy is a necessary infrastructural requirement for development and depending upon the activities for which energy is required and their distribution, allocation of energy to each State may differ. Although, desire of each State to have equal per capita income and to that extent investment (or even higher share for those States which are lagging behind) and even equal energy per capita in the household sector is legitimate, it is not so for the total per capita energy because different activities require different amounts of energy. Those States having large energy consuming industries (such as steel, fertilizers, metallurgy, etc.) may require more energy than the others, and by making equal per capita energy itself as a goal, considerable unoptimal development may take place leading into knots which may be difficult to untangle in the future.

Of course, those States which do not possess such large (investment) industries may wish to acquire them depending upon the availability of other raw materials and energy resources to develop them. Yet, recently, it is increasingly becoming evident that many of these large industries are also highly energy-intensive. They do not always produce employment in large numbers nor do they produce high value added (income) per rupee of investment. In addition, assuming these, the provision of power, water and many other raw materials can be a significant responsibility. Thus, it might be more desirable for them to look for those industries which require less energy per rupee of value added. In general, such industries have shorter gestation periods and require less capital as well and, therefore, often give lower capital output ratios. Emphasis on those industries may be desirable for them in the long run.

The desire of the States for having such large industries (some of which are also large energy consuming) in their own States could, to some extent, stem from the fact that the investment for many of these industries are put up by the Centre.

To that extent, States can have additional investment in their Plans from the Centre. This aspect of allocation policy needs to be thought in detail such that unoptimal development is avoided.

9.2. Level of Disaggregation of All-India Projections

It is difficult to project energy requirements of the individual States and for our purpose, broad regional allocations may suffice. In particular, in case of power, there exist already Regional Electricity Boards whose roles may inevitably strengthen in future as more and more Centrally-funded power plants come to their regional grids. Even States themselves may cooperate in developing joint projects. Commercial agreements concerning sharing regional investments and the outputs by the individual States would require careful consideration so that regional developments could be strengthened.

For convenience, consider the following definition for four regions of India:

Region		*States which comprise the region
N = Northern region	:	Uttar Pradesh, Rajasthan, Punjab, Haryana, Himachal Pradesh, Jammu and Kashmir.
W = Western region	:	Madhya Pradesh, Maharashtra and Gujarat.
S = Southern region	:	Andhra Pradesh, Kerala, Karnataka and Tamil Nadu.
E = Eastern region	:	Bihar, West Bengal, Orissa and North Eastern region (i.e. Assam, Manipura, Nagaland, Meghalaya, Tripura, etc.)

* For want of adequate data, the Union Territories have not been included in economic data but included in electricity consumption data.

For the purpose of optimal development of coal and oil also, the same definition of regions could be used.

9.3 What should be the criteria for regional allocation?

Having rejected the criteria of equal per capita energy on the basis of avoiding unoptimal development, the question is what should be the criteria for regional allocations of energy demand? The following points need to be considered:

(i) Trend considerations and sectoral shares for the asssessment of the present: It is necessary to examine the past trends, not particularly with the desire of continuing them but, to assess the kind of development each region has. While doing this, it is essential that the sectoral shares of energy consumption for each region be considered so that the nature of development in each region is obvious. For example, the Northern region has predominantly agricultural development whereas the Western Region is industrially developed.

(ii) Availability of energy resources and their optimal use: It may just so happen that the regional imbalances of energy consumption may after all need to be corrected not by making that itself a goal *per se* but because of the fact that in India, the regions having the maximum energy resources are the ones which utilize them the least. For example, North-Eastern Region, which has oil, forest area as well as hydro potential, has the lowest per capita energy consumption. On the other hand, Western Region, which has small coal and hydro potential, most of which are in Madhya Pradesh, has the highest share of electricity consumption. It should be noted that availability of skills, investments and infrastructure is the major cause of such imbalances and cannot be corrected in a short time by mere wishful thinking.

(iii) Considerations of sectoral energy intensities: Sectoral GDP elasticities are a measure of what is the marginal energy required to generate an additional rupee worth or value added in that particular sector. These could be also one of the major considerations. These may differ from region to region and, to some extent, reduction of these need to be encouraged. However, it should be recognized that in the initial stages of development, the GDP elasticities tend to be high and a judicious choice of cut-off may have to be exercised.

(iv) Regional energy-mix and possibilities of substitution: The share of individual resources, i.e. energy-mix in each region varies. In the Eastern Region, for example, the share of coal in total commercial energy is much higher compared to oil and electricity. On the other hand, in the Western Region, the share of oil is higher. Thus, proximity to energy resources and the availability - or the lack of it - of one resource affects the share of another. Availability of non-commercial energy resources also can affect the requirements of coal and oil and, to this extent, shares of individual commercial energy resources may vary in each region.

It is necessary to quantify the above-mentioned four criteria in order to make quantitative assessment of the regional shares in the national energy demand.

9.4. Trends of Regional Shares in National Energy Consumption

The trends of the regional shares from 1960 to 1975 are given in brackets of Table 9.1. It may be pointed out that for want of better units for energy consumption, mtcr units are considered which give somewhat high weightage to oil and electricity consumption compared to coal. Therefore, the regions which consume more oil and electricity may appear to consume more energy.

9.4.1. General Trends

It can be seen that during 1960-75, the regional shares in total national commercial energy has shown considerable increase in the Northern Region, moderate increase in the Southern Region and considerable decline in the Eastern Region. The share of Western Region has remained practically the same at 30%. It should be noted that the shares of population in N, W, S and E Regions are 26.4%, 21.8%, 24.3% and 26.0%, respectively in 1975-76.

Table 9.1. Region-wise Consumption of Commercial Energy and Energy Mix (1960-61 to 1975-76) in m.t.c.r.

Year	Item	Northern	Western	Southern	Eastern
1960-61	CECT in m.t.c.r.	13.16 (17.8)	22.48 (30.4)	14.47 (19.5)	23.90 (32.3)
	Coal as % CECT	33.7 (19.5)	17.8 (17.7)	11.5 (7.3)	52.7 (55.5)
	Oil as % CECT	50.0 (17.7)	63.7 (38.6)	62.6 (24.4)	30.0 (19.3)
	Elec as % CECT	16.3 (15.2)	18.5 (29.3)	25.9 (26.4)	17.3 (29.1)
1965-66	CECT in m.t.c.r.	25.58 (19.8)	39.52 (30.7)	25.40 (19.7)	38.42 (29.8)
	Coal as % CECT	30.9 (21.2)	19.5 (20.6)	9.8 (6.7)	50.0 (51.5)
	Oil as % CECT	46.6 (18.4)	61.4 (37.4)	65.0 (25.4)	31.9 (18.8)
	Elec as % CECT	22.5 (21.8)	19.1 (28.2)	25.2 (24.0)	18.1 (26.2)
1970-71	CECT in m.t.c.r.	39.78 (22.4)	56.65 (31.9)	38.38 (21.6)	42.92 (24.1)
	Coal as % CECT	20.6 (21.7)	15.7 (23.5)	7.3 (7.4)	41.7 (47.4)
	Oil as % CECT	51.9 (22.3)	60.0 (36.8)	60.0 (25.2)	33.9 (15.7)
	Elec as % CECT	27.5 (23.1)	24.3 (29.0)	31.9 (25.8)	24.4 (22.1)
1975-76	CECT in m.t.c.r.	56.80 (24.6)	70.30 (30.5)	54.42 (23.6)	48.95 (21.2)
	Coal as % CECT	28.7 (29.4)	16.8 (21.3)	18.3 (17.9)	35.5 (31.4)
	Oil as % CECT	45.2 (22.4)	57.6 (35.3)	53.2 (25.2)	40.2 (17.1)
	Elec as % CECT	26.1 (24.6)	25.6 (29.9)	28.5 (25.8)	24.3 (17.7)

Note: i) Figures in the brackets are the regional percentage shares in total national consumption.

ii) Coal consumption excludes coal used for power generation and railways.

CECT = Commercial energy consumption total compiled by Shri A. Chaitanya, Planning Commission.

9.4.2. Regional Shares of Coal, Oil and Electricity

The shares of coal, oil and electricity in national level consumption in the case of Northern Region have increased during 1960-1975 and all of them have decreased in case of the Eastern Region. In the Western and Southern Regions, however, only the shares of coal have slightly increased. The share of oil has shown a very small decline in case of Western Region and small increase in case of Southern Region. The shares of electricity consumption have increased in all the regions.

9.4.3. Changes in the Energy Mix

The trends of changes in the energy mix from 1960 to 1975 are also given in Table 9.1.

(a) It can be seen that the share of coal in the total commercial energy has declined for the Northern and Eastern Regions whereas that of the Southern Region has increased. The Western Region has shown slight decline.

(b) The share of oil in total commercial energy has declined in all regions except Eastern Region where it has increased from 30% in 1960-61 to 40% in 1975-76. This can be due to the proximity of oil fields in Assam and comparatively slow increase of direct coal and of electricity consumption.

(c) The share of electricity has increased in all the regions but the increase is rather small in case of the Southern Region.

9.5. Regional Distribution of Energy Resources

Here, only conventional energy resources, i.e. fossil fuels, uranium resources and forest areas are considered. Their distributions in the four regions are given in Table 9.2. The region-wise observations are as follows:

Northern Region has the lowest shares of oil and gas resources and the highest for hydro potential. It has almost no resources of coal and its share of forest area is also low.

Table 9.2. Regional Distribution of Major Energy Resources

	Northern	Western	Southern	Eastern	All-India
Coal (MT)[1]					
Proved	-	6079	2129	18021	26219
Indicated	-	5978	2433	32241	40652
Inferred	-	8559	3942	32103	44604
Total:		20616 (18.5)	8505 (7.6)	82365 (73.9)	111475 (100.0)
Oil (MT)[2]	60 (40)	790 (52.0)	170 (11.3)	490 (32.7)	1500 (100.0)
Gas (MTOE)[2]	280 (6.6)	1870 (44.3)	430 (10.2)	1640 (38.9)	4220 (100.0)
Hydro[3] potential (Twh)	147.3 (37.2)	37.7 (9.5)	68.2 (17.2)	143.4 (35.1)	396.3 (100.0)
Forest Area[4] (1000 ha)	10707 (16.3)	21506 (32.7)	12316 (18.7)	21164 (32.2)	65693 (100.0)

Figures in the brackets are regional percentage shares.

[1]The figures include Gondwana coal fields and tertiary coal fields and exclude lignite resources which exist in Kashmir, Rajasthan, Gujarat, etc.

[2]Include on-shore and off-shore recoverable reserves. MTOE = Million tons of oil equivalent.

[3]Includes already exploited potential.

[4]All-India figure excludes few Union Territories.

Data source: Geological Survey of India, Total Reserves of Coal in India in Seams 0.5 M and above in thickness, Coal Wing, September 1978.

It is, therefore, reasonable that the share of electricity consumption of this region, which could be provided by hydro electricity, may go up compared to other energy resources.

Eastern Region has very high shares of all energy resources ranging from coal, oil, gas, hydro potential and forest area. It is, therefore, ironic that this region has the lowest per capita energy consumption. Efforts for integrated development of this whole region including development of its energy resources need to be put in. However, it should be realized that 'Eastern'* and North-eastern are rather far apart and difficult to connect. While hydro and forest area are mainly in the North-eastern Region, the coal is in the 'Eastern' Region.

Western Region has the highest share for oil and gas resources and lowest of hydro potential. Although, in coal resources, it is the second highest, most of it is in Madhya Pradesh. The major shares of the forest areas, coal and hydro potential are in Madhya Pradesh and are very low in Gujarat and Maharashtra. In future, it may perhaps be necessary to use gas for power generation in this region considering the fact that Gujarat and Maharashtra are industrially developed and have very low coal, hydro and forest resources for their future development.

Southern Region has moderate shares of energy resources such as coal, oil, gas, hydro and forest area and, in fact, could be even considered on the low side considering the fact that it uses 26% of the national electricity.

The above points illustrate, what type of energy mix may be desirable for each of the regions considering their endowments, and the need to restrain certain developments within regions or the need to develop some others in future.

9.6. Socio-Economic Distribution and Electricity-Economy Relationships of the Regions

Structure of economic developments of each region and its implications on electricity consumption is given in Table 9.3.

Northern Region produces less net domestic product compared to its share of population. Its predominant development is in the agriculture. However, for 30% of its share in the

---

* 'Eastern' consists of Orissa, West Bengal & Bihar.

Table 9.3. Regional Distribution of Economy, Consumption of Electricity and Energy-Economy Relationships - 1975-76.

Indicators	Northern	Western	Southern	Eastern	All-India
Economy*(Rs. 10^6- current prices)					
Net domestic product	145329 (23.5)	153981 (24.9)	142992 (23.1)	134891 (21.8)	618640
Industrial NDP	14900 (14.2)	32870 (31.3)	22334 (21.3)	20190 (19.23)	104970
Agricultural NDP	76273 (30.1)	53001 (20.9)	57917 (22.8)	41933 (16.5)	253420
Population (10^6)	159.7 (26.4)	131.8 (21.8)	146.7 (24.3)	157.3 (26.0)	604.0
Electricity (Mkwh)					
Total Sold	14806 (24.6)	19032 (29.9)	15520 (25.6)	11888 (19.7)	60246
Industry	7308 (18.5)	12032 (30.4)	9769 (24.7)	10459 (26.4)	39568
Agriculture	3580 (41.0)	1843 (21.1)	2778 (31.9)	570 (6.5)	8721
Energy-Economy (Kwh/(Rs.10^3)					
Elec./NDP	101.9	117.1	108.5	88.1	97.0
Ind.Elec/(Ind.NDP)	490	366	437	518	377
Agr.Elec./Agr. NDP	46.9	34.8	48.0	13.6	34.0
Kwh per capita	92.7	136.8	105.7	75.6	99.7

*Only major States are considered for N, W, S and E Regions. The regions, therefore, do not add up to all-India as some of the Union Territories are excluded.

Note: Numbers in brackets are regional percentage shares.

agricultural NDP, it required 41% of the national electricity consumption in the agriculture sector. Therefore, the electricity consumption per thousand Rs. of GDP is high compared to the national average. Its industrial development is also such that it requires high electricity consumption per value added (490 kwh/Rs. 1000).

Western Region produces the highest net domestic product in comparison with its population. It has 31% share in the national industrial NDP. For this, it requires 30.4% national electricity consumption. However, due to its high share in services and other sectors, it has the highest electricity consumption per capita (137 kwh). Its agricultural share is only 20.9% which is the lowest among the other regions and its agriculture requires 34.8 kwh per Rs. 1000 of value added which is close to the national average.

Southern Region is evenly developed in both the sectors, namely industry and agriculture. Its agriculture consumes 31.9% of the total electricity sold, but the share of agriculture NDP (in total NDP) is only 22.8%. Thus, its agricultural intensity is the highest among all the regions (48 kwh/Rs. 1000).

Eastern Region has small share of electricity consumption in agriculture sector. It consumes as low as 13.6 kwh per Rs. 10^3 of value added in agriculture. The per capita consumption of electricity is only 75.6 kwh vs. 1000 kwh, the national average. Because of the highly power intensive industries located in this region, its industrial electricity intensity - such as steel, locomotives, heavy industries - is 518 kwh/Rs. 1000 which is very high compared to the national average (377 Kwh/Rs.1000).

It is interesting to see that when the share of industrial NDP increases in the economy, the electricity-intensity reduces. This may be because as diversification takes place, spurt in less energy-intensive but high value adding activities may take place. State-wise comparison is illustrated in Figure 9.1. Of course, raw materials play important role and several isoquants rather than one line may be more appropriate. It can be seen that intensity declines for Maharashtra, West Bengal, Gujarat, etc., which are most industrialized.

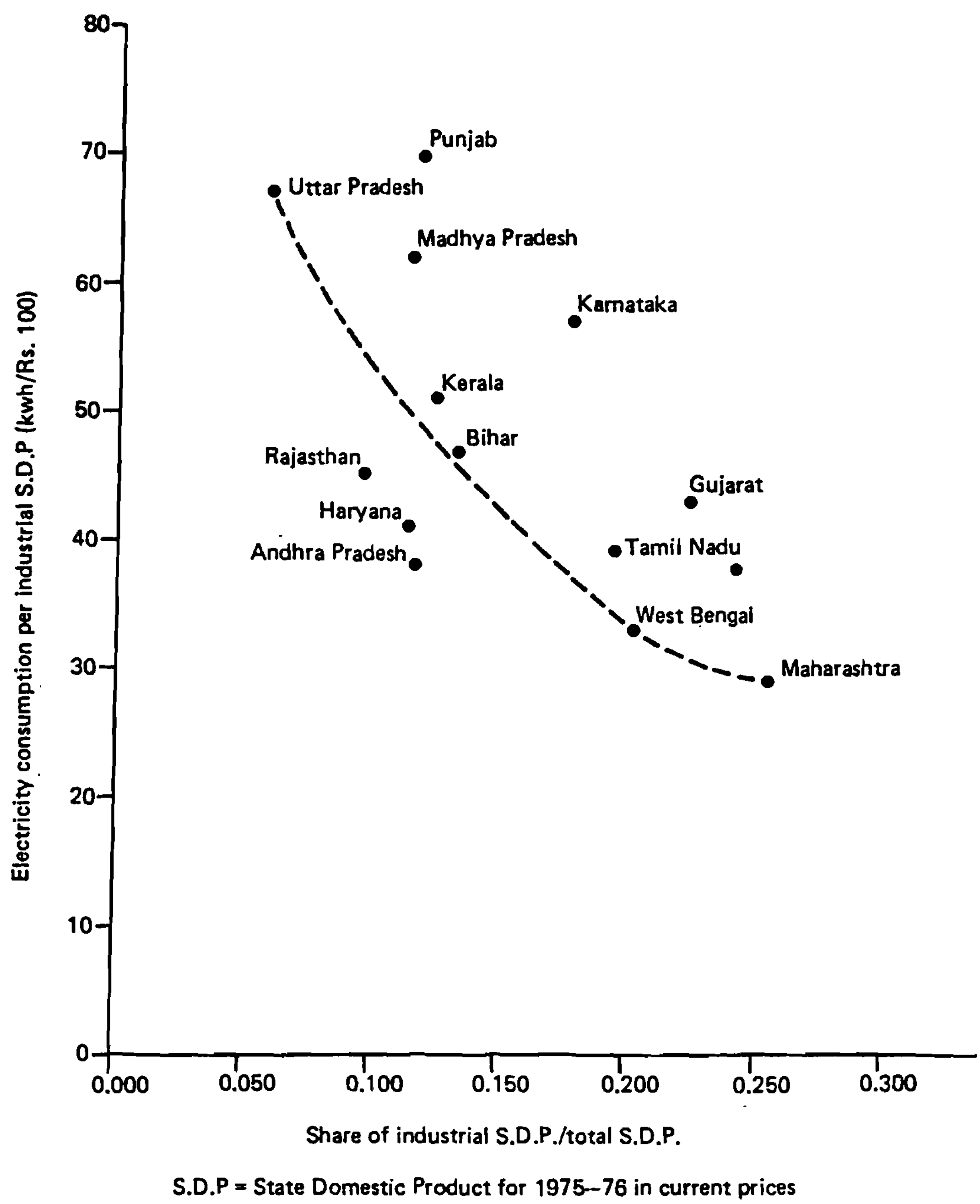


Figure 9.1. The Share of Industrial S.D.P. vs. Electricity Intensity of Industries.

9.7. Sectoral Shares of Electricity Consumption

Since there are some uncertainties about the sectoral disaggregation of the data of coal and oil consumption at regional levels, only the electricity consumption for 1976-77 is discussed at sectoral levels. The data for 1976-77 is given in Table 9.4.

i) The percentage shares of Northern, Western, Southern and Eastern Regions in total electricity sold was 25.4, 30.3, 25.1 and 19.1, respectively.

ii) Other sectors such as domestic, commercial, public water works also have approximately the same shares as above.

iii) However, the difference can be seen particularly in case of industries where the regional shares for the N,W, S and E Regions are 21.7, 31.9, 24.9 and 21.5% respectively. Thus, industrial share for the Northern Region is comparatively smaller. The shares of the industries sectors of Eastern and the Western Regions are higher compared to their shares in the total energy sold which are 19.1% and 30.3% respectively.

iv) In case of agriculture sector, opposite can be seen. The respective shares of the N,W, S and E regions in national consumption of electricity in the agriculture are 41.7, 21.5, 31.2 and 5.60%.

9.8. Constructing a Scenario of Regional Distribution

The above analysis of the past and present situation enables us to deduce likely developments in the future. The present trends given in Table 9.1 could be altered by the following forces:

(a) The existence of energy resources in different regions and difficulties of transfer of energy between the regions.

(b) Increase in energy intensities either due to change in the product mix in industries or, due to intensification of cultivation in agriculture which may make some products uneconomic to produce in a particular region in the future.

Table 9.4. Regional Distribution of Electricity Utilization for 1976-77 (Mkwh)

	Northern	Western	Southern	'Eastern'+ North-East	All-India
Total sold	16946 (25.24)	20200 (30.32)	16743 (25.14)	12719 (19.10)	6608 (100)
Domestic	1945 (30.69)	1870 (29.12)	1557 (24.57)	964 (15.62)	6337 (100)
Commercial	914 (22.07)	1284 (30.23)	1151 (27.79)	793 (19.14)	4142 (100)
Industrial Total	9037 (21.72)	13261 (31.87)	10351 (24.88)	8957 (21.52)	41606 (100)
L.T.	2180 (32.13)	1883 (27.75)	1344 (19.81)	1378 (20.31)	6785 (100)
H.T.	6857 (19.69)	11378 (32.68)	9007 (25.87)	7578 (21.76)	34821 (100)
Public Lighting	122 (20.54)	206 (34.68)	204 (34.34)	63 (10.61)	594 (100)
Traction	261 (12.05)	979 (45.16)	49 (2.26)	874 (40.31)	2168 (100)
Agriculture	4015 (41.73)	2071 (21.53)	2999 (31.17)	535 (5.56)	9621 (100)
Public Water Works	379 (26.27)	487 (23.72)	334 (23.13)	245 (16.97)	1444 (100)
Miscellaneous	272 (38.97)	42 (6.01)	285 (40.83)	98 (14.04)	698 (100)

Numbers in brackets are the shares in the national consumption.

Data Source: Public Electricity Supply - All India Statistics General Review 1976-77.

(c) Some Government policies such as:

(i) Investment allocation policy for various regions.

(ii) Pricing policy of energy in each region (e.g. if power tariffs are relatively low in one region, it may increase the consumption in that region compared to other regions).

(iii) Regional development policy (e.g. if the policy is such that each region should move towards as much self-sufficiency as possible then the energy resources of the respective regions could be utilized more in those regions themselves).

(iv) Changes in the freight equalization policy in the transport sector. Presently, the freight charged is the same for all distances for some of the commodities. Such a policy does not encourage dispersal of commodity production, even when the availability of other raw materials is not a constraint.

(v) Policy concerning coal-mine-pit-head power stations and large scale hydro power plants. With the advent of such power plants, the States far away from coal mines or hydro sites can also get electricity and their shares of electricity need not decline.

Taking 1975-76 percentages as the base figures, the impacts of the above-mentioned forces have to be heuristically incorporated in envisaging future developments. This would require some judgment of the strength of the forces which may cause departures from the present trends and assessment of the need for changing the present pattern. One possible scenario of trends is constructed below keeping the afore-mentioned issues and is given in Table 9.5.

The assumptions behind the construction of the scenario are as follows:

(a) National level demand of coal, oil and electricity projections are assumed to be similar to those projected by the Working Group on Energy Policy.

Table 9.5. Regional Distribution of Energy Consumption

Year	Item	REGIONS			
		Northern	Western	Southern	Eastern
1984-85	CECT in mtcr	112.3 (23.85)	142.3 (30.23)	109.4 (23.24)	106.8 (22.68)
	Coal as % CECT	26.4	15.0	18.3	32.5
	Oil as % CECT	44.1	56.6	51.7	40.9
	Elec as % CECT	29.5	28.4	30.0	26.6
1989-90	CECT in mtcr	147.3 (23.23)	188.2 (29.68)	145.0 (22.87)	153.6 (24.22)
	Coal as % CECT	25.6	15.2	18.7	35.2
	Oil as % CECT	42.2	54.5	49.6	37.8
	Elec as % CECT	32.2	30.3	31.7	27.0
1994-95	CECT in mtcr	193.2 (22.44)	252.2 (29.30)	194.8 (22.63)	220.6 (25.63)
	Coal as % CECT	23.8	16.0	19.9	37.4
	Oil as % CECT	38.9	49.7	45.2	33.9
	Elec as % CECT	37.3	34.3	34.9	28.7
2000-01	CECT in mtcr	270.3 (21)	373.2 (29)	283.1 (22)	360.4 (28)
	Coal as % CECT	20.0	17.2	22.0	40.4
	Oil as % CECT	35.5	41.5	40.5	30.2
	Elec as % CECT	44.5	40.3	37.5	29.4

Note: Figures in the brackets are the regional percentage shares in total national consumption.

CECT = Commercial Energy Consumption Total.

(b) Since the percentage share of oil consumption has to go down in each of the regions, corresponding increases in coal and electricity consumption are necessary.

(c) The percentage given above will, of course, depend on the level of demand projections. The variations in the oil consumption for high and low demand scenarios are not expected to be very large. Therefore, in a low demand scenario percentage shares of oil in the total energy consumption would be larger than in the (high demand) scenario given in Table 9.5. As the Working Group on Energy Policy only deals with the high demand scenario, the regional distribution of a low energy demand scenario has not been attempted for convenience.

(d) It is assumed that the share of the Eastern Region, which has the lowest per capita energy consumption at present, will increase in future, not only because of energy resource availabilities but also due to the other raw materials availability in that region. The shares of other regions may, therefore, be correspondingly reduced.

Table 9.6 gives the regional energy requirements considering WEP scenario as the national-level projections.

9.9. Some Implications of the Scenario

(a) Eastern and Southern Regions which will have less oil production compared to their needs may require as much as 34 mt. of oil products by the year 2000. Western Region is expected to produce substantial portion of the domestic crude oil. This underscores the need for receiving large shipments of the imported crude at ports on the Eastern and Southern side of the country.

(b) Many of the States do not have coal resources. These are: Gujarat, Rajasthan, Himachal Pradesh, Punjab, Haryana, Jammu and Kashmir, Uttar Pradesh, etc. Lignite resources of some of the States may be difficult to mine. In any case, lignite supply cannot cope up with the kind of

Table 9.6. Regional Distribution of Energy Consumption in mtcr terms

Year	Item	REGIONS			
		Northern	Western	Southern	Eastern
1984-85	CECT in mtcr	112.3	142.3	109.4	106.8
	Coal in mtcr	29.7	21.3	20.0	34.7
	Oil in mtcr	49.5	80.5	56.6	43.7
	Elec in mtcr	33.1	40.4	32.8	28.4
1989-90	CECT in mtcr	147.3	188.2	145.0	153.6
	Coal in mtcr	37.7	28.6	27.1	54.1
	Oil in mtcr	62.2	102.6	71.9	58.1
	Elec in mtcr	47.4	57.0	46.0	41.4
1994-95	CECT in mtcr	193.2	252.2	194.8	220.6
	Coal in mtcr	46.0	40.4	38.8	82.5
	Oil in mtcr	75.2	125.3	68.0	74.8
	Elec in mtcr	72.0	86.5	68.0	63.3
2000-01	CECT in mtcr	270.3	373.2	283.1	360.4
	Coal in mtcr	54.1	64.2	62.3	145.6
	Oil in mtcr	96.0	154.9	114.7	108.8
	Elec in mtcr	120.2	150.4	106.1	106.0

Energy requirements at the end-use and not at the point of production (or generation).

requirements that may be there in these States. It appears that for the Western and Northern Regions coal requirements of the order of 125 mt. (including that for power generation) may have to be obtained by transporting coal from the nearby mines. This underscores the need for developing Singrauli coal fields of Madhya Pradesh which are close to the States which do not have coal in these two regions.

(c) As far as the electricity generation is concerned, within a region, the distribution of coal resources and hydro-potential among its various States is uneven. Particularly, resource deficient States, such as Gujarat, Maharashtra, Haryana, Punjab, Rajasthan, Assam, and to some extent, West Bengal, etc., would need to work out commercial agreements with the neighboring States for sharing electricity generation and its distribution.

(d) The States having adequate forest areas or those deficient in coal resources need to step up wood production for direct use or for charcoal supply. For this, long-term afforestation and wood plantation programmes would be necessary.

10. SUMMARY AND POLICY IMPLICATIONS

10.1. Introduction

The purpose of this work is to provide a modeling framework using which, effects of various sectoral policies on energy-use can be examined. It is thus meant to supplement on one hand, the efforts of working group on energy policy (WEP) for working out implications of long-term energy policies upto the year 2000 and on the other hand the efforts of perspective planning (PPD) and energy division of the Planning Commission by providing another reference scenarios - whose long-term implications are worked out - for the present and future five year plans.

The projections given here are to be interpreted as 'if' and 'then' statements and are by no means absolute numbers. Yet, the efforts put into making various assumptions internally consistent, analyzing data at considerable disaggregated levels, understanding relationships of energy system with socio-economic developments and constructing and analyzing a number of scenarios, make this exercise useful for understanding energy system and therefore, assessing implications of various energy policies.

The model constructed is a simulation model for various end-use activities where some of the basic relationships are worked out using multiple-regression techniques and some on other considerations which are elaborated in the text.

10.2. Objective and Approach

The objective of the modeling system is:

- To assess future energy demand for various sectors of the economy.
- To assess the impacts of various energy policies on energy requirements.
- To identify energy supply mix for meeting the above energy requirements, i.e. optimal mix of various energy supply technologies such as coal, oil, electricity, renewable energy resources (such as wood, bio-gas and solar energy), etc.

The energy modeling system completed has three parts:

(i) A model to project macro-economic aggregates;

(ii) Dynamic, multi-sectoral models for simulation of energy demand;

(iii) Calculations of the investment and imports required for the energy sector and cross-checking the consistency with the results of the macro-economic model;

It is necessary to look at energy problem with long-term perspective because:

- The gestation periods of energy supply projects are of the order of 5 to 10 years.
- The gestation periods for changing the energy user system such as industries, transport system, etc., can be even larger than 10 years.
- Major part of the energy resources used presently are non-renewable.

Moreover, to ensure the stability of the model, it is necessary that the model gives targets for successive 5 year plans up to two decades. Thus, the forecasts for the 6th, 7th and 8th Plans, along with the projections for the year 2000 are given. As the model is computerized, it has the flexibility to give projections for any year desired and analyze the effects of various policies relating to energy consumption.

Energy demand projections made have to be consistent with the socio-economic parameters assumed. In particular, energy demand in the following four sectors are considered:

- Industries
- Transport
- Agriculture
- Household and Commercial.

The effects of various policies in these sectors on energy requirements are highlighted.

In this work, the description of the model is accompanied, at times with the data base to provide the context in which the model has to be interpreted. However, as much of the data base is already given elsewhere such as Working Group on Energy Policy, NTPC, etc., major emphasis is on the model description, analysis of results and policy implications.

The modeling system begins with a macro-economic model which gives scenarios for macro-economic projections, i.e. GDP growth rates, private consumption, industrial GDP etc. In addition, there are other inputs given exogenously such as population, urban population, net area sown, villages electrified, etc.

Two macro-economic scenarios* - for low and high demand - are considered.

- The 'High' scenario is the one used by the Working Group Policy (WEP) which assumes long-term GDP growth to be 5.87% but has high share of urban population (32% of the total in 2000).

---

*While 'high' scenario represents aspirations of WEP and the revised draft 6th Plan, the 'low' is somewhat higher than the growth rate in the past.

- The 'Low" scenario uses the results obtained from the simulation (SIMA) model developed at I.I.A.S.A. Although, this has been used to construct a number of scenarios, the lowest one of them is taken to provide two different scenarios. In the low scenario, long-term GDP growth is 4.4% and low share of urban population (26% of the total in 2000).

The results of the macro-economic model are used as input parameters for the demand model which is split into four sectors. The results are summarized in Table 10.1. The salient features of each of these sectors are described below.

10.3. Industries Sector

In the macro-method, industries sector is split into two groups - large energy consuming (LEC) industries from the organized sector and the remaining industries from organized and unorganized sectors referred as the non-LEC industries. The energy intensities, i.e., coal, oil and electricity required a rupee* of value added are 0.812 kg, 0.061 kg and 0.690 kwh respectively in 1976-77 which are assumed to change to 0.899, 0.019 and 0.817 respectively in 2000.

The question of an appropriate industrial mix from the point of view of energy has been examined. It is, expected that the energy intensities of the non-LEC industries would increase in future because of substitution of energy for non-commercial energy and human and animal energy. On the other hand, it is possible to expect some decline in the energy intensities of the LEC industries because of introduction of more efficient technologies. Presently, the energy intensities of the non-LEC industries are 25% to 30% of the energy

*Through the paper, the rupee of 1970-71 is used.

Table 10.1. Summary of the Energy Requirements

	Low Demand					High Demand			
	1977-1978	1984-1985	1989-1990	1994-1995	2000-2001	1984-1985	1989-1990	1994-1995	2000-2001
	Electricity (bkwh)								
Industries	44.17	82.9	109.2	148.2	188.2	90.6	132.4	192.6	266.0
Household }	11.21	11.0	16.0	22.8	34.2	13.1	21.2	33.8	58.2
Commercial }		10.2	16.3	23.9	36.2	10.2	16.3	23.9	36.2
Agriculture	10.01	17.7	24.9	33.3	45.7	17.7	24.9	33.3	45.7
Transport[1]	2.44	4.0	4.4	5.8	7.7	4.4	6.6	10.3	16.7
Miscellaneous	2.05	8.4	14.7	22.1	30.0	8.4	14.7	22.1	30.0
TOTAL:	69.88	134.2	185.5	256.1	342.0	144.4	216.1	316.0	452.8
	Major Oil Products (million tonnes)								
LPG									
Industries		0.2	0.4	0.6	0.8	0.2	0.4	0.6	0.8
Household		0.9	1.4	2.0	3.3	0.9	1.4	2.0	3.3
	0.40	1.1	1.8	2.6	4.1	1.1	1.8	2.6	4.1
Mogas	1.50	2.0	2.6	3.3	4.4	2.0	2.6	3.3	4.4
Diesel Oil[3]									
Agriculture		1.9	2.5	3.2	4.2	1.9	2.5	3.2	4.2
Transport		9.5	11.8	15.4	20.4	10.4	13.9	19.6	26.71
	8.67	11.4	14.3	18.6	24.6	12.3	16.4	22.8	31.6
ATF	1.16	1.4	2.0	2.9	4.4	1.5	2.3	3.2	5.7
Kerosene[4]									
Household	3.95	4.6	6.9	7.3 (9.7)	9.4 (19.9)	4.8	6.4 (7.6)	7.3 (12.5)	9.4 (23.4)
Fuel Oil[5]									
Industries	3.00	3.9	4.7	4.9	4.8	4.3	6.2	7.0	7.5
Total oil products for major uses:	18.68	24.4	32.3	39.8 (42.0)	51.7 (62.2)	25.9	35.3 (36.5)	46.2 (51.1)	62.5 (76.5)
	Coal (million tonnes)[6]								
Industries	52.8	84.6	109.9	151.7	220.2	92.6	135.4	201.2	317.8
Household (soft-coke)	4.0	5.1	5.9	6.8	8.0	5.1	5.9	6.8	8.0
Transport	13.2	8.2	7.2	5.2	2.5	10.0	10.0	7.7	3.8
Colliery[2]	3.3	3.9	5.2	6.1	7.0	3.9	5.2	6.1	7.0
TOTAL:	73.3	101.8	128.2	169.9	237.7	111.6	156.5	221.8	336.6
	Non-commercial (million tonnes coal rep)								
Household		217.3	224.2	228.0	229.9	217.3	224.2	228.0	229.9

[1]Includes auxiliary electricity requirements for stations, workshops, etc.

[2]As of WEP.

[3]Exclude diesel for power generation.

[4]The figures in the brackets represent commercial energy requirement whereas the figure above represents the optimal level forecast. The difference is to be either met by new energy resources or kerosene itself.

[5]Fuel oil for power generation excluded.

[6]Excluding power generation.

intensities of the LEC industries. This gap reduces in future to some extent, but even so, it pays to pursue the policy of shifting in the industrial mix to non-LEC industries. What is also important is to watch the energy consumption of non-LEC industries, for example, 20% reduction in their electricity intensities leads to the saving of 37 and 50 billion units (Kwh) in 2000 for the low and high scenarios respectively. This reduction will call for R & D efforts in the non-LEC industries as well.

Scope of contributions from other resources lies in increased use of natural gas, if new fields are found and solar energy for hot water use in industries and solar ovens and furnaces for small industries.

10.4. Transport Sector

Only the land transport is discussed in detail here and the comments on water and air transport can be seen in Chapter 4 and the WEP report (1979).

Analysis of the data shows the following:

- Passenger transport: Both urban and long distance transport increases with urban population and has no correlation with per capita income. The metropolitan areas generate considerable traffic where the distances of average trip by sub-urban railways as in Bombay, Calcutta, Madras are 19.6, 25.2 and 15 kilometers respectively. Per capita urban travel was 700 km. whereas per capita regional travel is 585 km per year in 1976.
- Ton-kilometers increase with industrial production. However, average distance by which the originating tons move is not increasing as fast in the seventies as it did during sixties and may saturate soon around 750 km.

- The truck transport is the largest consumer of diesel and it is to control this phenomena that strong energy and transport policies are required.

The objective of the transport sector sub-model is to analyze the effects of the policy measures which could reduce oil consumption in the transport sector. Some of the oil conservation policies considered are:

(i) Low urbanization;
(ii) Increased efficiency in transport vehicle utilization;
(iii) Increased transport by rail; and
(iv) Railway electrification.

The relative importance of each of these policies are quantified and evaluated.

10.5. Agriculture Sector

Conventionally, while considering the energy use in agriculture, only the direct use of energy is included, i.e., direct use of diesel and electricity, for irrigation and mechanization. In the model these requirements are calculated on the basis of cropping intensities that would be required for supporting increasing population with limited land. The energy required for irrigation is found to have good correlation also with rural areas electrified. The split of this energy for irrigation into diesel and electricity is a function of rural electrification and crude oil prices.

It is pointed out, that in addition to the direct use of energy, there are a number of points relevant for planning for energy for the agriculture sector. They are:

(i) Indirect energy inputs required in fertilizers, pesticides and food processing is three times larger than the direct inputs of energy.
(ii) Non-commercial and muscular energy provides nearly as much energy as the direct use of commercial energy in the agriculture sector.

(iii) Agriculture is one sector where timing for supplying energy is very crucial. This factor has to be taken into consideration for power capacity planning and supply of diesel.

(iv) Nearly 50% of the intermediate inputs used in the agriculture sector are related to energy.

(v) The regional distribution of demand for energy for agriculture is also an important factor in planning the supply.

It is found that if net area sown is not increased in future, then the long-term electricity growth required for irrigation would be 6%. This is low compared to the recent past, but the growth rate reduces due to leveling of pace of rural electrification in the nineties and reduction of population growth.

10.6. Household and Commercial Sectors

The availability of non-commercial energy, which at present provides more than 80% of the use of energy required in the household sector cannot be taken for granted in future to provide required energy unless strong measures are taken for ensuring the renewability of supply. It is envisaged that the share of demand for commercial energy would keep increasing due to:

- High urbanization;
- Increased income and its distribution; and
- Non-availability of non-commercial energy.

All the three factors have been examined and it appears that the reduction in per capita supply of non-commercial energy would contribute significantly to the rise of demand for kerosene.

Three methods have been used in order to cross-check and to get insights into substitutions, urban-rural break-up of demand, effects of income distribution, etc. These are:

- End-use method;
- Direct energy use method; and
- Income distribution method.

It is assumed that the supply of soft-coke and LPG for the household requirements would be 8 mt. and 3.3 mt. in 2000 respectively. Non-commercial energy is projected to be around 220 mtcr in year 2000. It is estimated that in order to keep WEP targets of kerosene demand of 7.7 mt. in 1994 and 9.4 mt. in 2000, the contributions that would have to come from alternative energy sources is 5.2 mt. and 11.0 mt. of kerosene requirements in 1994 and 2000 respectively. These options could be bio-gas, wood plantation, solar energy, etc., and also LPG. Whatever they are, they must be provided on a sustainable basis, as the demand rises because of high income, lack of non-commercial energy supply and urbanization and therefore, would have to be provided on the same basis as commercial energy requiring investment and management.

Few more observations are:

- Long-term electricity consumption growth for low and high urbanization is 7.2% and 9.7% respectively.
- The share of electricity and kerosene consumption in rural areas in 2000 given by the ID method is 30% and 64% respectively.
- Per capita consumption in the household sector increases from 0.33 in 1973 to 0.468 tcr per year in 2000.
- The share of commercial energy in the household sector increases from 20% to 48.1% during the year 1973 to 2000. The growth rates for electricity in the commercial sector for different time periods are taken keeping the growth rate of the service sector and expected increase in price of electricity.

10.7. Summary of Sector Energy Demand for the Economy and Comparison with WEP

10.7.1. Total energy demand for All Sectors:

What do all these sector requirements add up to? As the sectoral conclusions are given above, only over-all energy supply aspects are illustrated below. The total demand is tabulated in Table 10.1.

Electricity requirements: The figures for 2000 are 342 and 452 bkwh for the low and high demand scenarios. These figures include conservation measures in the industries and transport sectors. Price effects for the household sector are not considered, which may give further reduction. The need for sectoral load considerations for power planning is emphasized so as to accommodate increased use of electricity in the agriculture sector where timing is very crucial.

Oil requirements: If appropriate policies to curb the demand for kerosene, diesel and fuel oil are adopted, then the saving could be 10 mt., 6 mt. and 6 mt. respectively per year by 2000. Thus, the requirements for major oil products could be kept at 51.4 mt.† per year in 2000. The policies required for this reduction are identified. The share of middle distillates increases from 54% in 1978 to 65-70% in 2000.

Coal (and charcoal) requirements: Due to the necessity to conserve fuel oil and the need to substitute non-commercial energy, coal intensities are likely to go up. The coal demand for direct use, i.e., excluding power generation in 2000 works out to be 238 mt. and 334 mt. for low and high scenarios.

10.7.2. Comparison with the WEP Scenario

It was first found that the WEP projections for the OLF* correspond to low urbanization. Therefore, High (L) scenario was constructed to examine the consistency of the WEP scenarios.

(a) The model results agree with overall magnitudes of oil and electricity consumption and small consumption items such as colliery consumption, LPG and ATF requirements, etc.

(b) The model results differ with sectoral allocations of these overall magnitudes and indicate higher share of electricity for agriculture:

---

†Excludes minor products and non-energy uses, e.g. Naptha, Bitumen, etc.

*Refers to Optimal Level Forecast.

- Magnitude of coal requirements and its share in industries.
- Projections for the transport sector such as tkm, diesel and petrol requirements.

(c) The model results supplement the WEP efforts by extending the analysis and working out certain policy implications. It shows, for example:
- Effects of rural electrification policy.
- Effects of urbanization on various sectors.
- Implications of going on to OLF levels from the RLF levels on energy consumption norms.
- Identification of contributions expected
- of the alternative energy sources.

In addition to differences in the results, there are fundamental differences in the two approaches which are highlighted in Table 7.1.

10.8 Investment Requirements in Energy Sector

Can the economy provide the investment required to fulfill the energy demand? Power sector requires 21.8% of the public investment at present. This could increase up to 30% and 38% in 2000 for the low and high demand scenarios, if the present trends of the efficiencies continue. These figures could be only 18% and 25% respectively <u>if</u>:

- Capacity utilization of power plants is increased.
- No cost-escalation in real terms takes place in new power projects.
- The share of investment in the GDP increases from 23.5% to 28% in 2000.

10.9. Regional Distribution of Energy Demand

What are the issues relating to distribution of energy in a vast country as India? The quantification is made of certain issues such as:

- Regional distribution of energy requirements per capita energy consumption in the Eastern Region is the lowest where the resource is maximum. Western region, which has small coal and hydro resources is the highest user of energy.

- Trends of regional shares: The shares of total energy for Northern Region has considerably increased and Eastern Region has declined, while the other two have remained stable.
- The mix of energy: The share of electricity has increased in each region and the share of oil has decreased in each region except in the Eastern Region.
- The efficiency of energy-use: The electricity intensity declines when the region gets industrialized. The Western Region, which is the most industrialized region, has the lowest electricity intensity.
- The agriculture is power intensive in Northern and Southern Regions and this trend is to be expected in Western and Eastern Regions where agriculture would be more developed in future.

Implications for energy distribution:

- In future, coal, resources for which are located in the Eastern Region, has to be transported to the states in Northern and Western Regions, the oil to Southern and Northern Regions, etc., in much larger quantities.
- To strike a supply-demand balance, the Eastern Region would have to be more developed, and Western region should shift its pattern of industrial development towards less energy consuming industries.
- Forest areas and hydro-potential of Northern and Southern Regions would also have to be developed.

ANNEXURE I: Coal Replacement and Equivalent Units of Different Fuels used in India

Coal equivalent units convert calorific content of each energy form into coal having 5000 kcal/kg - Indian Standard Coal. This differs from the UN standard coal taken at 7000 kcal/kg. The concept of coal replacement units used by the working group on energy policy approximately corresponds to the "Useful energy" concept described in Chapter 1. However, after converting a particular fuel in a particular use to useful energy, it is translated into coal required to obtain the same amount of useful energy in the same end-use. This is a concept of particular relevance in a country whose major energy resource is coal, and the major policy question is usually how much coal is required to replace a particular fuel. Therefore, the efficiencies are relative efficiencies to coal efficiency and not absolute efficiencies as in the case of useful energy.

Take, for example, a fuel f, with energy content x kcal/kg, which is generally used with efficiency e_f in a particular end-use from which coal is used with efficiency. e_c - The coal replacement value of that fuel f can be worked out as follows:

Useful energy in kcal from 1 kg of fuel f = $e_f \cdot x$.

Useful energy in kcal from 1 kg of coal = $e_c \cdot 5000$.

Coal replacement unit for fuel f

$$= \frac{e_f \cdot x}{e_c \cdot 5000} \text{ kg of coal.}$$

Conversion factors for various energy forms are tabulated below:

Fuel	Unit	Coal equivalent in tons (tce)	Coal replacement in tons (tcr)
Coal (coking 6,640 kcal/kg; noncoking coal used in steam generation 5,000 kcal/kg)	1 ton	1.0	1.0
Hard coke	1 ton	1.3	1.3
Soft coke	1 ton	1.5	1.5
Firewood and agricultural waste (4,750 kcal/kg)	1 ton	0.95	0.95
Charcoal (6,900 kcal/kg)	1 ton	1.0	1.0
Animal dung (3,300 kcal/kg dry)	1 ton	0.66	0.4
Oil products (10,000 kcal/kg)			
Kerosene and liquefied petroleum gas	1 ton	2.0	8.3
Diesel oil	1 ton	2.0	9.0
Motor spirit and jet fuel	1 ton	2.0	7.5
Natural gas (9,000 kcal/kg)	10^3m^2	1.8	3.6
Electricity	10^3kWh	0.172 electric or 0.6 thermal	1.0

ANNEXURE II: Model Equations for the ENDIM Model

II.1 Model Equations for the Industry Sector

YIND	=	GDP in the industry sector in Rs. 10^9.
Y_{LEC}	=	Value added by the Large energy consuming industries in Rs. 10^9.
$Y_{non-LEC}$	=	Value added by the non-large energy consuming industries.
$Y_{non-LEC}(t)$	=	$YIND\ (t) - Y_{LEC}\ (t)\ (1 + a_1)^t$
a_1	=	Growth rate of the LEC industries.

First Mode: All LEC's are aggregated.
All non-LEC's are aggregated.

Second Mode: LEC's are split into 19 individual industries.
Non-LEC's are split into individual industries.

Energy consumption:

$$\text{Coal}\ (t) = \sum_i C_i^1\ (t)\ Y_{LEC}^i(t) + \sum_k C_k^2\ (t) Y_{non-LEC}^k(t)$$

$$\text{Oil}\ (t) = \sum_i O_i^1\ (t)\ Y_{LEC}^i(t) + \sum_k O_k^2\ (t) Y_{non-LEC}^k(t)$$

$$\text{Electricity}(t) = \sum_i E_i^1\ (t)\ Y_{LEC}^i(t) + \sum_k E_k^2\ (t) Y_{non-LEC}^k(t)$$

C_i^1, O_i^1, E_i^1 are the coal, oil and electricity intensity coefficients for LEC and C_k^2, O_k^2, E_k^2 for non-LEC industries respectively.

II.2 Model equations for the Transport Sector: Land Transport

Freight Transport

Net ton kilometers (10^9 tkm): TKM

$$TKM = (NU/N)^{-1.464} \times (YIND)^{1.10} \times e^{-1.391}$$

(1.82) (6.11)

$\bar{R}^2$ = 0.963 DW = 2.056 F = 185.65

NU/N = Fraction of population urban

YIND = GDP in industries in Rs. 10^9.

Fraction of ton-kilometers by Railways: TKMR

$$TKMR = (NU/N)^{-0.547} \times (PTLPR)^{-0.002} \times e^{-1.284}$$

(4.71 (0.26)

$\bar{R}^2$ = 0.816 DW = 1.39 F = 32.080

PTLPR = Petroleum (crude) price index (1970 - 100)

TKMR = $A^C \times TKMR + A^D \times TKMR + A^E \times TKMR$

A^C, A^D, A^E are fractions of TKM travelled by steam, diesel and electric tractions respectively given in Table 4.3 such that:

$A^C + A^D + A^E = 1$.

ECTR, EDTR, EETR are the coal, diesel and electricity consumed for 10^9 TKM and are functions of time - given in Table 4.7.

Fraction of ton-kilometers by trucks: TKMT

TKMT = (1 - TKMR) x TKM

ETRK = energy consumed per 10^9 tkm by trucks.

Diesel required for trucks: DTRK

DTRK = ETRK x TKMT

Passenger Transport:

Regional (long) passenger transport: PKML

$$PKML = NU^{2.494} \times PTLPR^{-0.0621} \times e^{-5.958}$$

(18.03) (1.97)

$\bar{R}^2$ = 0.98 DW = 1.18 F = 363.95

Fraction of long passenger kilometers by Railways: PLR

$$PLR = (NU/N)^{-3.682} \times PTLPR^{-0.002} \times e^{-6.798}$$

(6.85) (0.06)

R^{-2} = 0.898 DW = 0.93 F = 63.1

B^C, B^D, B^E are fractions travelled by steam, diesel and electric tractions given in Table 4.3. CEP, EDP, EEP, coal, oil and electricity consumed per 10^6 PKM given in Table 4.7.

Diesel consumed in Railways:

$$DRAIL = EDTR\ (t) \times A^D\ (t) \times TKM\ (t) + EDP\ (t) \times B^D\ (t) \times PKML\ (t)$$

Coal consumed in Railways:

$$CRAIL = ECTR\ (t) \times A^C\ (t) \times TKM\ (t) + CEP\ (t) \times B^C\ (t) \times PKML\ (t)$$

Electricity consumed in Railways:

$$ERAIL = EETR\ (t) \times A^E\ (t) \times TKM\ (t) + EEP\ (t) \times B^E\ (t) \times PKML\ (t)$$

Urban passenger kilometers (10^9 pkm)

$$PKMS = NU^{3.141} \times PTLPR^{-0.064} \times e^{-10.394}$$

(22.921) (2.048)

$\bar{R}^2$ = 0.989 DW = 1.19 F = 607.324

Fraction of urban passenger kilometers PKMS by suburban:UPS

$$UPS = \frac{NU}{N}^{2.999} \times PTLPR^{-0.002} \times e^{-6.800}$$

ESUB (t) and EBUS (t) are energy consumed per 10^9 PKMS.

Electricity consumed in urban transport:

$$EUPS = UPS\ (t) \times PKMS\ (t) \times ESUB\ (t).$$

Diesel consumed in urban passenger transport:

DUPB = (1 - UPS (t)) x PKMS (t) x EBUS (t).

Private passenger transport:

NC/N and NS/N are private cars* and scooters* per capita. UFC and UFS utilization factors for cars and scooters in 10^3 PKM.

EC and ES gasoline consumption for cars and scooters in t per 10^3 PKM.

Gasoline consumption by cars:

$$\text{Gas C} = \frac{NC}{N} \times N \times UFC \times EC$$

Gasoline consumption by scooters:

$$\text{Gas S} = \frac{NS}{N} \times N \times UFS \times ES$$

Total gasoline consumption:

Gas = Gas C + Gas S

Air Transport

Internal Transport:

ATF 1 = PAIR/N x N x AD1 x EAIR1

PAIR/N = Passengers travelling by air in total population.

AD1 = Average distance travelled.

EAIR1 = ATF consumption per 10^6 pkm.

International Transport:

ATF2 = PASS x AD2 x EAIR 2.

PASS = Passengers travelling by AI.

AD2 = Average distance travelled.

EAIR2 = ATF consumption per 10^6 pkm.

---

*Cars include jeeps, taxis, and scooters include two and three-wheelers.

II.3 Model Equations for Energy in Agriculture Sector

Energy forirrigation (million tonnes coal replacement)

$$EAG/N = (AREA/N)^{-2.080} \times FREL^{0.284} \times e^{-1.572/1000.0}$$

(31.28) (19.90)

$\bar{R}^2$ = 0.987 DW = 2.10 F = 505.90

AREA = net area sown in 10^6 ha.

Fraction of energy in irrigation from diesel oil

$$OIL/EAG = REL^{-0.269} \times PTLPR^{-0.011} \times e^{0.693}$$

(10.48) (0.81)

$\bar{R}^2$ = 0.930 DW = 1.65 F = 87.63

Electricity in irrigation:

ELEC = EAG x (1 - Oil/EAG)

Diesel oil for mechanization:

DAGM = NTRACT (t) x NHA x ETRACT (t)

NTRACT = No. of tractors in thousands per HA.

ETRACT = Oil in t per tractor.

II.4 Model equations for the Household and Commercial Sector

(A) End-use Method:

(1) Energy for lighting and comfort (mtcr)

Includes kerosene x (relative efficiency of kerosene to electricity for lighting) and electricity for lighting.

$$E_{light} = 0.046017 \times NU + 0.005207\ FREL - 0.43257$$

(2.447) (1.87) (-0.219)

$\bar{R}^2$ = 0.980 DW = 1.348

NU = Urban population in 10^6

FREL = Fraction of village electrified per 1000 villages.

(2) Commercial Energy for Cooking (mtcr)

Includes koresene, soft coke and LPG.

$$\frac{E_{cook}}{N} = -0.212494 \frac{ENC}{N} + 0.5617 \frac{NU}{N} - 0.01554$$

(5.522) (21.31) (-1.1606)

$\bar{R}^2$ = 0.972 DW = 1.759

ENC = Non-commercial energy in 10^6 mtcr.

(3) Share of Electricity in Lighting

$$\frac{E_{elec}}{E_{light}} = (FREL)^{0.2563} \times (NU/N)^{-0.227} e^{-2.2189}$$

(8.09) (0.78)

$\bar{R}^2$ = 0.959 DW = 0.515

(4) Kerosene for lighting (mt)

$K_{ero(L)} = E_{light} (1. - Elec./E_{light})$.

(5) Commercial Energy for the Household Sector

$= E_{cook} + E_{light}$

Electricity, kerosene for lighting worked out separately.

(B) Direct energy use method:

Electricity in Household Sector (million kwh)

$$ELEC = \left(\frac{CP \times 1000.0}{1.803 \times N}\right)^{0.199} \times NU^{2.640} \times e^{-5.303}$$

Kerosene in Household Sector (MTCR)

$$KEROSENE = \left(\frac{ENC}{N}\right)^{-5.33} \times (CP \times 1000.0)^{0.660} \times e^{-11.19}$$

(6.99) (7.69) (-7.69)

$\bar{R}^2$ = 0.958

$$KEROSENE = \left(\frac{NU}{N}\right)^{0.768} \times (CP \times 1000.0)^{1.058} \times PTLPR^{-0.072}$$

(1.48) (4.25) (2.30)

$\bar{R}^2$ = 0.883 DW = 0.912

Soft coke, LPG to be taken exogenously.

(C) Income-distribution method:

$$E^K = \sum_i CR_i^K \times NR_i \ (t) + \sum_i EU_i^K \times NU_i \ (t)$$

where

E^K = Energy consumption of the energy resource K.

ER_i^K and EU_i^K are per capita per year energy consumption of energy resource K by the ith expenditure class in rural and urban areas respectively.

NR_i and NU_i are rural and urban population in expenditure class i. They are obtained from log-normal distribution of income. The distribution is derived by per capita expenditure (K) and correlation index (L).

$Y = \log x$ $\quad \mu$ = mean per capita income.

$$\Lambda \ (x + \mu, \sigma^2) = P\{ X \leq x \}$$

Probability of income distribution:

Logarithmic transform:

$$N \ (y | \mu, \sigma^2) = P\{Y \leq y\}$$

mean $x = e^{\mu+G^2}$

L = Lorenz measure of inqeuality

$$= 2 \ N \ (\frac{\sigma}{\sqrt{2}} | 0, \ 1) - 1$$

urban-rural ratio of mean income:

$$\frac{\mu_u}{\mu_r} = b$$

$$b \cdot \mu_r N_U + \mu_r N_R = \mu_N$$

N = NR + NU.

$$NR = \sum_j a_j \cdot NR, \ \sum_j a_j = 1,$$

or, $NR_j = a_j \ NR$

This is substituted in the first equation.

REFERENCES

Basile P., (1980). The IIASA Set of Energy Models: Its Design and Application. Research Report RR-80-31, IIASA, Laxenburg, Austria.

Häfele, W., (1981). Energy in a Finite World - Report by the Energy Systems Program Group of IIASA. Ballinger Press, Cambridge, Mass. U.S.A.

Khan, A., and A. Hölzl (1981). Evolution of Future Energy Demand till 2030 in Different World Regions - An Assessment made for the Two IIASA Scenarios.(Forthcoming IIASA Research Report)

Kravis, I. et al., (1977). A System of International Comparisons of Gross Product and Purchasing Power, Johns Hopkins, Baltimore, USA.

Lapillonne, B., (1978). MEDEE-2 A Model for Long-Term Energy Demand Evaluation, Research Report RR-78-17, IIASA, Laxenburg, Austria.

Ministry of Energy (1976). Public Electricity Supply All-India Statistics General Review, New Delhi, India.

National Council of Applied Economic Research (1978). Rural Household Consumption in Northern Region, I.P. Estate, New Delhi, India.

National Institute of Training, Information and Education, NITIE Report (1980), Bombay, India.

National Transport Policy Committee (NTPC), 1980. Report by the Planning Commission, Government of India, New Delhi, India.

Parikh, J., (1980). Energy Systems and Development - Constraints, Demand and Supply of Energy for Developing Regions, Oxford University Press, Delhi, India.

Parikh, J., (1980). Regional Distribution of Energy Demand - Some Issues. 'Urja' Journal, Vol. VII, No.6, New Delhi, India.

Parikh, J., (1981). Energy: A Resource for Industrial Development in India. Working Paper WP-81-13, IIASA, Laxenburg, Austria.

Parikh, J., and K. Parikh (1979). Simulation of Macroeconomic Scenarios to Assess the Energy Demand for India (SIMA). Research Report RR-79-15, IIASA, Laxenburg, Austria.

Parikh, J., and A. Chaitanya, (1980). Are our Industries Energy Efficient? Economic and Political Weekly, Vol. XV, Number 11, Bombay, India.

Report of the Working Group on Energy Policy (1979). Planning Commission, Government of India, New Delhi, India.

Sixth Five-Year Plan, 1980-85 (1981). Planning Commission, Government of India, New Delhi, India.

Statistical Year Books of various Governmental organisations, such as Central Statistical Organization, Ministry of Railways, Ministry of Petroleum and Petro-Chemicals, Ministry of Energy, Motor Transport Statistics, Fertilizer Association of India, National Sample Survey Organisation (NSSO), India.

World Development Report (1979). World Bank, Washington, USA.