198

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ENERGY CONSUMPTION IN INDIA

Recent Trends and the Problem of Demand Forecasting

by

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1. INTRODUCTION

Energy sector in India has been receiving increasing attention even before the energy crisis of late 1973 precipitated due to the increase in the price of oil. This was mainly due to the increasing trend in the import requirements for the oil sector and the growing consumption of non-conventional energy sources, specially in the rural areas, which has wide ecological consequences for the country. The first systematic study of the energy resources, demand, investment and pricing for India was carried out by the Energy Survey Committee of India appointed by the Government in January 1963 and the recommendations of the Committee were submitted in 1965.[1]

The energy study covered present and perspective demand and supply of energy, both total, and in respect of different forms of energy on a national, regional and sectoral basis. This study looked into the consumption trends for both conventional energy sources such as coal, oil and electricity and non-conventional sources including firewood, animal and vegetable wastes, and projected future consumption trends until 1980-81. The study also included a thorough analysis of the available energy resources of India and made recommendations regarding the judicious development of indigeneous resources for meeting future energy demands. The availability of reliable energy consumption and price data were main bottlenecks that the committee have faced in carrying out detailed studies and using analytical models for energy demand forecasting. However, the committee made reasonable assumptions regarding economic growth rates and designed a suitable framework for considering different forms of energy on an equivalent basis by defining the coal replacement measure. The study also developed norms for domestic energy consumption both in the urban and rural areas based on sample surveys conducted by various organizations. The work of the Committee laid a good foundation for future energy studies in India.

During the sixties, the oil sector in India has grown at a very rapid rate at the cost of stagnation in the coal sector. In retrospect, this is hard to explain, in spite of the decreasing price of oil during the sixties, because India is endowed with a large amount of coal resources, whereas the known petroleum reserves of this country are quite limited even after the recent discovery of various offshore fields. Due to the rapidly growing import requirements from the oil sector and apprehension in the early seventies that the price of petroleum might rise in the near future, it was considered necessary to have a thorough look at the Fuel Policy in India and the Government appointed the Fuel Policy Committee in October 1970 with similar terms of reference as the Energy Survey of India Committee earlier. The Fuel Policy Committee submitted its interim report[2] in May 1972 dealing with the Fifth Five Year Plan period and submitted its final report[3] in August 1974. The general recommendations of the Fuel Policy Committee has been accepted by the Government and the broad outline on national energy policy has been approved.

The national energy policy considers coal as the principal source of energy in the country, and accordingly recommends its exploitation and utilization to a maximum amount for meeting the energy demand in India. In case of Oil, the policy is to substitute oil wherever technically and economically feasible by other forms of energy to reduce the quantity of import and to maximise indigeneous production. The electricity production should be based on the use of hydro power, coal and nuclear energy, and the growth of electricity production should be adequate to meet future needs including additional demand arising from the use of electricity in place of oil. The national energy policy also gives high priority to meeting rural energy needs and recommends a rapid increase in the use of biogas, setting up of a social forestry programme and development of non-conventional energy source, like solar, wind, tidal, and geothermal energy. The policy also recommends appropriate pricing measures to promote the desired pattern of energy use and energy conservation and provide an adequate return to the industry. The research and development programme relating to the energy sector and specifically the introduction of non-conventional energy sources were also recommended in the national energy policy.

In spite of the interim recommendations of the fuel policy committee in May 1972 based on a scenario of increasing oil price in the future, there was no apparent switch in the general energy strategy to move to the use of coal in place of oil until the oil crisis in late 1973 which affected India very adversely in increasing the import bill for oil to the extent of almost 40% of the total export earnings. Following the increase in the international price of oil, the domestic prices for oil products were increased substantially, specially for motor gasoline and diesel oil. Conscious efforts were made to substitute coal in place of oil wherever possible, and to increase the coal production. The effect of increased domestic prices for oil products and physical controls in their availability has reduced the consumption of oil both in the domestic, transport and industrial sectors considerably during 1974 and 1975. Specifically the consumption of motor gasoline was reduced by almost 20% in 1974 following more than 100% increase in the domestic price.

The exploration for oil was also speeded up and this was rewarded by the quick discovery of the Bombay High Offshore fields. The subsequent development of the Bombay High fields will ease the pressure on the economy due to increasing import requirements for petroleum as more oil and gas become available from these offshore fields. At the same time, the production of coal has increased substantially from the earlier level of 75 million tonnes to approximately 110 million tonnes within three to four years and has outpaced the growth of demand for coal. The substitution of oil by coal in the industrial sector has not been as successful and there are areas such as power generation in which petroleum products are entering in spite of the general energy policy of not using oil and gas for power generation.

The perspective in the interim future is thus a mixed one. Increasing domestic oil production will perhaps slacken the effort in substituting coal for oil, and coal production and consumption are not expected to reach the targets projects for the end of the Fifth Five Year Plan. The outlook in the rural sector and specifically the consumption of non-conventional sources of energy has not changed very much. Though the introduction of biogas plants is being pursued vigorously in the rural areas, its total contribution to meeting rural energy demand will remain limited during the next decade. It is yet to make wide acceptance as a community energy source and for the poorer sections of rural population. The consumption of firewood and dried cowdung in the rural areas has not yet been substituted by coal, biogas or any other energy source. Solar energy is still in an experimental stage and is considered too expensive. The consumption of kerosene for domestic cooking in the urban areas has decreased to some extend due to the entry in liquified petroleum gas (IPG) but the availability of the later is still limited. The suggestion of large scale construction of coal carbonization plants made by the Fuel Policy Committee to provide gas and smokeless solid fuel has not yet materialized due to the high cost of low temperature carbonization plants. Liquifaction of coal has not yet proved commercially viable in India.

The energy situation in India is totally dominated by the continuing power crisis due to the shortage of adequate generating capacity and low utilization of the existing capacity, due to improper maintenance. Specially during years of low rainfall when hydro power availability is poor. Any large-scale substitution of oil demand by electricity as once visualised in the railway sector would only accentuate this problem. Energy sectors in India still suffer from the absence of long term planning which is specially serius in the power sector. The energy planning situation in India was also affected by the continuing uncertainty in the economic front as specific economic scenarios including alternative targets for industrial and economic growth are not always available as the basis for reliable forecases of energy demand. In this context, forecasting future rates of energy consumption in India becomes a hazardous task. The future energy consumption in India would be determined not only by the growth in various economic sectors and the growth of population, but also by the ability of the economy to make available increasing amounts of energy of appropriate form for specific use and successfully carry out programmes for energy conservation and substitution of oil.

The present paper analyses the past trends of energy consumption in India in the urban as well as in the rural areas and for both commercial and non-commercial sources of energy. The consumption data available for the period following the oil price rise shows a discontinuity and a change in the pattern of energy consumption from the past trends set up during the fifties and sixties and early seventies. But it is still too early to predict whether the current trend will continue, or following a discontinuity in 1974-75 the energy consumption trend will continue to grow as in the past. However, the changes in the relative prices of different fuels appear to be playing an important role even if the market economy in India is considered imperfect. This is seen in the decreased rate of growth in consumption of selected oil products and in the increased rate of growth of consumption of coal and electricity. It is expected that this trend will continue until there are any substantial changes in the relative prices and the availability of various energy sources in India.

2. RECENT TRENDS IN ENERGY CONSUMPTION IN INDIA

It is convenient to list the main energy resources of India under five headings. Four of these can be grouped under the general description of "Commercial Energy" namely, Coal; oil & Natural gas; hydro-electric power and nuclear fuels. These can be transformed before consumption into secondary forms such as electricity and gas. But the transformation of primary sources into secondary energy forms is usually costly and capital-intensive. The fifth category comprises of various kinds of resources in India which provide "non-commercial" energy, so called because much of it is not ordinarily bought or sold, at any rate in recorded transactions. In this last category, the most important item is forest resources, which provide the basis for a considerable volume of firewood and charcoal consumption. The other main forms of non-commercial fuel in India are animal and vegetable wastes, which chiefly consist of crop residues and dried cowdung. Table 1 shows the total consumption of commercial energy in India through major fuels measured in terms of original units, whereas Table 2 shows these in replacement terms.

Commercial energy in the country mainly serves the growing needs of modern economy, therefore, it constitutes the principal source of tapping future energy requirements for modernisation. It can be seen from table 2 that over the whole period covered by the figures, i.e, from 1953 to 1976, the estimated consumption of commercial energy measured in coal replacement terms has increased more than 4 times. Over this period the consumption of all three fuels rose considerably. The figures of coal and oil consumption in tables 1 and 2 exclude the amounts that are converted into electricity before being used as direct energy, while all electricity data include whatever the source of energy that is used in its generation. The direct use of coal, as shown in Table 2 shows that its consumption has approximately tripled since 1953-54, though almost the whole of its increase took place in the earlier part of the period upto 1965-66. Since then coal consumption has increased, but not very significantly (though this does not take into account the amount of coal consumption in thermal power station, which continued to rise).

Simultaneously significant increase in the consumption of direct use of oil since 1953-54 explains the reason of the low consumption of coal. The oil consumption has increased more than ten times since 1953-54 and the electricity consumption has increased more than 9 times between 1953-54 and 1975-76. As a result of such a large increase the share of coal fell from just 50% to just over 25% and that of oil rose from 40% to almost 50% and the share of electricity has just doubled from 13% to 26%.

The consumption pattern of commercial energy is more clear when we study the pattern of the average annual growth rate of different fuels. It shows a 6.58 percent compound annual growth rate over the last two decades, the highest growth rate being recorded by electricity 10.3 percent, followed by oil 8.17 percent and coal 4.53 percent during the period 1955 to 1975-76.

The most striking point is the inconsistency in the consumption of coal and oil. During 1965-70 coal shows a very little growth rate. The same pattern is followed in every alternate years after 1970-71. The cause of these little growth rates of less than 2 percent per annum may be due to railway transport bottlenecks (whereby the coal stocks at mind heads have increased) leading to insufficient availability of coal. However, due to this reason it is likely that people's interest turned towards other forms of energy, such as, hydro-electricity or oil based power resources.

From Table 3 we note that the production of coal from the period 1960-61 to 1975-76 has almost doubled, though the increase in last few years had been small. The level of output reached a plateau in 1969-70 above which upto the end of 1973-74 it had not risen appreciably. But in the recent years it has again shown a significant rise in the production. The obvious reason is because of the price hike of oil, people slowly changed to coal from oil.

In the early 1970s, one of the main consumers of coal, the railway, gradually changed from steam to diesel and electric locomotives. Similarly the consumption of coal in industries, such as iron and steel which is the main single industrial consumer declined during 1970-73 due to shift in technology to oil burners. After the 1973-74 price rise of oil the consumption pattern of coal has increased significantly. It shows a highest annual growth rate of 8.93 percent during 1973-74 and 1974-75 and 6.16 percent during the 1974-75 and 1975-76 period. The consumption by Thermal Power Station was always high.

The average annual rate of growth of coal consumption by principal industries and others are shown in the Table 3 where steel plants show a significant rise after oil prise rise. From 1970 to 1975 the growth rate has increased to 20.6 percent per annum while the growth rate of coal consumption was less than 2% during 1972 to 1974. Cement industry also shows a significant consumption of coal. During the last 5 years its growth rate of coal consumption has increased to more than 30% per annum. The insignificant growth rate of coal consumption by railways shows that it has not shifted to more of coal consumption after oil price hike. Railways are thinking of introducing more electric locomotives rather than diesel locomotives in future. The coal consumption by power station always shows a high rate of growth; during the last 5 years it has risen to more than 30%. During the last 5 years export of coal has also come down to less than 2%. Coal consumed by colliery and other industries have risen to more than 30% per annum during last 5 years. On the whole, total coal consumption by these different sectors and industries have increased to more than 30% per annum, while maximum consumption was during 1974-75, which is obvious due to oil price rise.

The demand for energy derived from oil shows almost an average annual rate of growth of 8.17 percent per annum during the period 1955-56 to 1975-76 as given in Table 1. During the period 1970-71 and 1971-72 the coal consumption figure shows less than 2% average growth rate per annum whereas oil shows a reasonably high growth rate of more than 30 percent per annum. Comparatively electricity consumption is also less during this period.

. Consumption approximately doubled in 10 years from 1955-56 to 1965-66, and further increased by a factor of about two and a half in the following decade. The growth rate came down to less than 2 percent per annum during 1973-74 to 1974-75 because of remarkable increase in oil price. (See table 4)

Aggregate consumption in India in 1976-77, exclusive of refinery boiler fuels, as shown in the last line of Table 4 was approximately 24.1 million tonnes. In this product-wise classification not all petroleum products are used for meeting energy demands. The main exceptions are naphtha (which is mainly used as a feedstock for the petrochemical and fertilizer industries) bitumen, lubes and greases. But although the share of these non-energy items in the total consumption of petroleum products has been increasing, it is still relatively small, so we find that the demand for petroleum based energy products are consistent with the growth of total consumption of petroleum products. The total consumption shows a significant decrease in consumption trend which is because of oil prise rise during 1973-74 to 1974-75.

Table 7 shows average annual rate of growth of consumption for all products taken together for the four main product groups, and also for selected products within each of these groups. The comparative study of consumption pattern of different petroleum products is more clear when we study a simple graph (Figure 1) for the years 1972 to 1977. The table 7 shows that the total consumption of all products almost doubled during the last 11 years from 1965 to 1976, while the consumption of oil during 1951 to 1976 shows almost seven-fold increase. Till 1972-73 the oil consumption rate was increasing. Only after 1973 August, when there was price rise of indigeneous oil to $2.48 per barrel and again at the beginning of November 1973 to $3.58 per barrel, the consumption growth rate fell to 2.76% per annum. Again because of the rise in the price of domestic crude from August 1, 1974 to $4.58 per barrel the growth rate showed a negative trend. During 1975-76 the consumption rate started increasing slowly by less than 2 percent per annum and during the recent year it shows a significant increase of 7.34 percent per annum. This sudden rise in growth rate is mainly because of the extremely rapid growth from the mid of 1960s in the use of naphtha as a feedstock in fertilizer industry. During 1976-77 it shows a growth rate of 19.6% per annum, while during previous ten years it shows a comparatively less growth rate of 7.18 percent and 11.67 percent per annum.

There was also a considerable increase in the rate of growth of consumption of kerosene and HSDO and LDO - which between them accounts for over 90 percent of consumption in middle distillates in 1976-77. Kerosene which was largest single item in consumption until the early 1960s , is mainly used for household lighting and cooking. However, during recent years a considerable quantity of kerosene was illegally used in vehicles as a substitute for HSDO, which was more expensive because of a higher rate of duty. In November 1973, the rates of duty on the two products were equalized. Afterwards suddenly the rate of growth of kerosene consumption showed sharp decline and a negative trend, which is very clear from the graph, while the share of HSDO rose correspondingly, following the equalization of the rates of excise duty - HSDO being very largely associated with the growth of road transport and also with the replacement of steam by diesel locomotives on the railways shows an extremely rapid increase of 13.29% during 1973-74 to 19% per annum during 1974-75.

Afterwards HSDO rate of growth slowed down, while in contrast the kerosene growth rate grew significantly to 10.5 percent per annum and ultimately both adopted a stablized pattern of 7.72 and 7.02 per cent growth rate per annum. In the graph we notice the trend of kerosene and HSDO is almost parallel to each other.

The third main product in the middle ditillate product is light diesel oil, which shows a 22.78 percent growth rate per annum. It is mainly used in agriculture for energizing pumpsets, while a small amount is used for power generation, transportand in some industries. The rate of consumption of LDO was declining during 1972 to 1975.

As is evident from Table 7, the rate of increase in furnace oil consumption has been high during 1960s and then slowly decreased to 4.23 per cent during 1973-74 and then further reduced to negative consumption rate from 1974 to 1976. Main consumers of furnace oil are forpower generation, textile industries, transport, iron and steel and wide variety of other industries for steam raising.

The consumption pattern of motor spirit although increased considerably during 1951 to 1971 but later declined to negative growth rate of less than 2% till 1975-76 and only afterwards it increased to a rate of 3.05%.

Finally we may say that the LPG shows an average growth rate of more than 7.06 percent per annum. Only during 1975-76 it shows a rapid growth rate of 16.67 percent per annum. Consumption in the category of "other products" has also grown since 1960s which is mainly resulted from an increase in the consumption of bitumen, together with a rapid growth in refinery boiler fuels from an initially very small total.

From Table 1 we find that in thepast the rate of growth in electricity consumption in India has increased that of two main commercial fuels, coal and oil, so that the share of electricity in total energy consumption has steadily increased. Table 5 give figures of total electricity consumed by different sectors, for a number of past years. The consumption figure of electricity is obtained by adding electricity consumed by ultimate consumers and electricity generated by non-utilities and then substracting from this electricity purchased from non-utilities. From Table 1 we find electricity consumption corresponds to an average annual growth rate over the whole twenty-year period, from 1955 to 1975, of about 10.3%. During the period 1965-70; 70-75 the growth rate was on an average of 9.71% per annum and 6.59% per annum respectively, while during 1955-65 it was 12.5 percent per annum. Since 1960-61, electricity consumption by ultimate consumer has grown at a somewhat slower rate than the gross generation.

During recent years, the rate of growth of electricity consumption has been very inconsistent. During 1971-72 and 1972-73 it was as high as 13.32 percent while during 1972-73 and 1973-74 and 1973-74 and 1974-75 the consumption growth rates are 2.36 percent and 5.15 percent per annum respectively. After oil crisis again consumption has increased to the maximum of 13.23 percent per annum. The slower rates of increase are the result of difficulties with respect to electricity supply which shows a fall in consumption.

Tables 8 and 5 give further details of electricity consumption. In table 8, the relative shares are given for selected years in total consumption. It is obvious from the table that industry is undoubtedly the main single consumer of power. During 1965-66 its share was 72.8 percent which had slightly fallen to 62.4 percent during the recent periods of ten years, i.e. 1975-76. While agricultural sector has increased its share of consumption over last ten years period, mainly due to rapid use of electric pumps for irrigation purposes. Domestic sector shows a very little increase over the last decade.

In Table 5 we find the amounts consumed by eight largest consuming industries for the last ten years period 1965-66 to 1975-76. The last column of the table gives the average annual compound rate of growth for each of these industries over the period as a whole. From the last two rows of the table we note that the electricity consumed by these eight major industries is almost half of that consumed by all industries. The average rates of growth of the two series is almost same, which was 7.58 percent per annum for eight selected industries, while 6.9 percent per annum for the total industries. As between the eight major consumers, however, therewere notable variations in the rate of growth of electricity consumption.

Engineering and chemicals shows a significant rate of growth in comparison with other six industries. The average annual growth rate by 1975-76 had increased to 15.1 percent and 13.79 percent per annum respectively. Fertilizers and aluminium come next in the list of high electricity consuming industries. During the last decade its growth rate per annum has increased to 9.35 percent to 8.97 percent respectively. By contrast, in each of the remaining four industries which were the leading consumers in 1964-65, the rate of consumption has been relatively low. Paper industry shows slightly higher growth rate of 6.68 percent, while cement and cotton textiles give 5.18 percent and 5.56 percent per annum respectively. Last comes the iron and steel industry with a growth rate of consumption of electricity of 4.93 percent per annum.

Table 7 shows a rapid growth rate of electricity consumption in agriculture which is reasonably because of the electrification of an increasing proportion of villages in India. When we study the table 6 we understand that the number of villages electrified during 1975-76 was 12,273, which brought the total number of villages electrified to 1,85,806. This figure is 32.26 percent of the 5,75,936 registered villages in the country. In the States and Union Territories of Haryana, Pondicherry, Delhi and Chandigarh, 100 percent villages electrification has been achieved, while in the States of Tamil Nadu and Kerala a very near target of 100 percent electrification with 98.56 percent and 94.79 percent respectively are made. In the rest of the two southern States Andhra Pradesh and Karnataka more than 50% of the villages are electrified. However, other States and Union Territories of India are still below the all India average of 32.26 percent. The rural population benefitted by the availability of electricity was 54.40 percent.

In the third column of Table 6 the number of irrigation pumpsets and tube wells energized is shown. During 1975-76 about 1,72,243 irrigation pumpsets were energised bringing the total number of pumpsets energised as on 31 March 1976 to 2,786 thousands in India. The average capacity of the pumpset was 5.43 HP and the average annual consumption was 3130.46 kwh. The reason for such a fast improvement in rural electrification is because of a strong support by Central Government in finance. Since 1965-66 the percentage of villages electrified shows a four-fold increase. After 1965-66, Central Government's attention was increasingly concentrated on agricultural demand for irrigation as against public lighting and domestic consumption as they show a 1 percent and 3.6 percent shares respectively in the net electricity consumption during 1975-76. The main channel of Central support; both technical and financial, is now the Rural Electricity Corporation, a public sector financing institution established in 1970, which lends money to the State Electricity Boards on a project basis for the financing of rural electrification schemes, which meet specified criteria of acceptability.

3. ENERGY POLICY FOR INDIA - SOME ISSUES:

A national energy policy for India must relate to the three basic areas of concern - those related to (1) development of indigeneous energy resources, (2) energy conservation and (3) energy pricing policy. Some of the important policy issues related to these three areas are discussed briefly in this section. Besides these basic issues related to an energy policy in the country, there are other policy issues in the other sectors of the economy which also have a direct bearing on the energy sector and a proper analysis of the energy policy should also examine these policy issues. As there is an intimate link between energy consumption and economic growth in a country, the basic policies regarding the pace of economic growth would to a great extent determine the requirements for energy and consequently any shortage of energy will tend to constrain the rate of economic growth. Thus proper development of the energy sector may influence the economic growth prospects of a country. The investment needs for the energy sectors also must be provided by the general economy and this relationship is a two-way process.

A national energy policy then must be decided within a framework of energy-economic planning so that the demands made by a growing economy for energy as well as the investment and other needs of a growing energy sector can be analysed within the same framework.

DEVELOPMENT OF INDIGENEOUS ENERGY RESOURCES

The development policy for energy resources in India should give due consideration to the development of coal, petroleum (oil and gas), and electric power resources in the country, both for the needs of development and also for providing basic social needs of the population. Though India has been endowed with vast amount of coal resources and hydro-electric potential, the oil and natural gas resources available in India are quite limited, considering the needs of the country. In the field of nuclear energy, our uranium reserves are very limited, though with the development of the fast breeder technology, it is expected that the vast thorium resources available in the country could be utilised for providing energy requirements in the future, possibly after 2000 A.D. However, the most dependable energy form in the medium term appears to be coal and other forms of sec ondary energy derived from coal. Inspite of this, during the sixties, in the absence of any clear cut energy policy, the coal production stagnated while the demand for oil rose very sharply. India's limited oil resources also were not explored properly, mainly because of low prevailing price of oil, the absence of domestic technology and expertise in this area, and the dominance of the oil sector by the big foreign oil companies which preferred to import oil for the requirements of their refineries at a favourable price from other countries. The oil policy has been changing during the sixties with the emergence of the Oil and Natural Gas Commission (ONGC) as an agency for oil exploration and development. With the formation of Indian Oil Company, the dominance of the foreign oil companies in the refining and marketing field were curtailed. However, due to the low domestic prices for oil products, the demand for oil products as well as the import requirements for crude oil were rising quite rapidly until the energy crisis in late 1973 due to the almost four-fold rise in the international prices of crude oil. Following this, the domestic prices for oil products were increased substantially except for kerosene and naphtha and other measures for conservation of oil and substitution of oil products by coal were being encouraged.

Simultaneously the tempo of oil exploration was increased and quick success was obtained from the off-shore oil fields of Bombay High. The development of Bombay High and other off-shore oil fields and steady production from Gujarat has since increased the total oil production in India and it is expected to cover about 50% of the domestic demand by 1980-81 when the full potential of the Bombay High field would be realised. The discovery of off-shore oil fields has given a sense of euphoria in some quarters and there has been claims regarding India becoming self-sufficient in the field of oil production. But it should be realised that our total oil resources including those under development and those yet to be developed are not abandant or even sufficient considering the potential demand that could be expected from the large population if any reasonable rate of economic progress is achieved within the next two decades. Since the oil crisis, India has been spending large percentage of its export earnings, for the import of crude oil. The development of off-shore oil resources might stem this flow for a decade or two but with the tendency for the international price of oil to rise on a regular basis, one could not be very optimistic regarding this.

Following the oil crisis, the development of the coal sector was given a higher priority and subsequently all the coal mines were nationalised. Though in the initial years, the capacity utilisation and the coal production increased quite rapidly, the total production of coal is not going to reach anywhere near the target of 135 million tonnes forecast in the draft fifth five year plan. The coal industry is plagued with problems of high development cost, labour unrest, shortage of power, and low prices as well as transport bottlenecks in the railways. The quality of Indian coal has traditionally been poor being of high ash content but it has gone down so much recently that the steel industry has been seriously considering to import coking coal from Australia to meet the requirements for the domestic steel mills. The low quality of Indian coal has also created tremendous problems in the power sector leading to a very high rate of breakdown of thermal power plants and also consequent low rate of utilisation. In spite of the high investment needs for developing additional coal mines required for the growing needs of the industry and the power sector, the coal prices have been kept at a much lower level and the coal industry have been incurring heavy losses since its nationalisation.

With the realisation that we are very heavily dependent on coal and will continue to be so in the foreseeable future, we should have been developing modern conversion technologies for making coal usable in industries and making it a more versatile form of energy by gasification, liquifaction and other technologies. But until now we have not given enough attention to the development of these technologies to make coal a more versatile and adaptable energy resource and to make it comparable to oil, in terms of convenience in use and high thermal efficiency. Unless the coal industry becomes economically viable, it would not be able to invest in any such technologies. Thus coal prices should be raised to reflect its production costs. We should also devote some attention to produce a cheap and convenient form of domestic fuel from coal either in the form of a gas or a smokeless fuel which can replace kerosene as a cooking fuel from urban and rural areas but no appropriate action appears to have been taken in this area also.

The problems of the power sector are quite well known by now as these have become cronic problems over the years. The absence of long term planning for the development of the power sector and subsequent failure in time implementation of projects scheduled for construction have led to almost perceptual power shortages in the country. But even now, the authorities responsible for planning development of the power sector are thinking only in terms of five year plans for power development, whereas it takes anywhere from 5 to 8 years for the construction of a Thermal power plant, and even longer in case of a hydro plants. A recent expert group appointed by the Planning Commission have suggested that the development plans for the power sector should be prepared for eight years in advance. The absence of modern methods of systems planning also leads to non-optimal choice in the location of the power plants and also in inadequate transmission capacity. Though India has increased its power generating capacity considerably over the last three decades, the modernisation in planning methodology and in the maintenance of complex large sized power plants have not kept in phase with the growth of the power sector. The absence of integrated planning and operation of power systems on a regional and national basis often leads to non optimal investments as well as unbalanced distribution of power resources in the various regions of the country. It is quite usual to see one state experiencing actute power shortage and generating costly thermal power using inefficient plants whereas a neighbouring state might be having excess hydro electric potential which is not being utilised.

We have not yet adequately utilised our hydro electric potential. Projects designed long ago on inter state rivers such as Narmada have not yet been implemented because of inter-state rivalries in the share of power and water resources.

The power sector in India is characterised by a very high rate of growth often reaching 12-15 percent in some regions of the country specially in areas of high industrial growth. The shortage of power in India is accentuated by the high energy loss in the distribution system and through theft and illegal use of power. Often the distribution systems of old design has become in adequate to serve higher demands of power, thus resulting in higher losses. The poor maintenance of the generation and transmission equipment also leads to increased failures in the power system, thus lowering the utilisation of the existing power system. The low tariff, high energy loss and low operating efficiencies leads to poor financial performance of the State Electricity Boards which are unable to raise the development funds needed for investment in replacement or increase in their capacity.

ENERGY CONSERVATION

The per capita energy consumption in India is quite low but that does not mean that we are more efficient in energy consumption. In fact even with a low per capita consumption we are wasteful in our energy consumption pattern. As most of the major energy resources (except perhaps hydro) are exhaustible in nature, energy conservation acquires additional importance for developing countries like India. Energy prices are deliberately kept low in India on the plea of subsidizing the poorer sections of the population, but it is the rich who enjoys this subsidy as his energy consumption is much higher and often a large consumer is entitled to a lesser rate or discount. Electricity consumers are not always mindful , thus encouraging wastage. Energy losses in power networks are very high. The efficiency of energy use is very low specifically in the rural areas thus the useful energy obtained per unit of energy consumed is much less. Thus energy conservation measures are a must for India specifically as devices for management of shortages in the supply of energy.

The present policy of the Government and ONGC is to go ahead with developing the discovered offshore and on-shore oil resources as quickly as possible and increase domestic oil production to reduce the quantum of present oil import, but a long term policy of optimum rate of development for the limited oil resources of India has not yet been worked out. If the international price of oil continues to rise rapidly, it might be better for us to conserve our limited resource for years when the oil price might reach $ 25-50 per barrel. Also there appears to be some laxity in enforcing the oil conservation measures that were introduced following the oil crisis in late 73 due to the increase in domestic oil production from Bombay high fields. The consumption pattern of oil products are again showing rising trends following the levelling of for about 3 years beginning 74. As yet no long term policy has been worked out either to reduce the consumption of kerosene which is widely used as a domestic fuel for heating in urban areas and for both heating and lighting in the rural areas. A domestic stove with higher efficiency of combustion is yet to be developed and marketed which could increase the efficiency of combustion from the meagre 40% available now to a level of around 60%, thus reducing kerosene consumption by one-third. The dependence on the small scale sector for the manufacture of existing ill-designed kerosene stoves of very low combustion efficiency appears to be one of the disadvantages in this area. It is reported that IOC has developed an improved stove but no action has yet been taken for large scale manufacture and marketing of this device. Growth of automotive transport, as well as the use of diesel powered agricultural machinery have also contributed to the high rate of growth of diesel oil consumption in the country. The refining capacity and the total requirement of crude oil in India is essentially determined by the demand for middle distillates (i.e, kerosene and diesel oil) and not by the demand for lighter products such as motor gasolene as in the developed countries. Inspite of the high value of other products that could be obtained from the oil and natural gas available from Bombay High and other off-shore fields, it appears that the current policy has been to burn some of the available gas for the generation of power. This is in contradiction to the recommendations of the Fuel Policy Committee which were accepted by the government.

ENERGY PRICING POLICY

Proper pricing of energy goes a long way in conserving energy, developing a healthy energy supply sector and encouraging substitution among various energy forms. Traditionally energy forms including electricity have mostly been subsidized. In spite of the high international price of crude oil, domestic crude oil is sold at a much lower price as also a few of the oil products, mainly Naphtha, the raw material for fertilizer production and kerosene used widely as a cooking fuel in urban and rural areas. As a result the oil consumption is again picking up following the levelling of for 2-3 years following the oil crisis.

Low coal prices is affecting the financial institution of public sector nationalised. Coal industry mainly due to increased wages, production cost, need for mechanization and increased mine development arts. The low price of fuel is not usually passed on to the consumers by the industrial establishments which enjoys higher profit due to subsidized coal. As rail transportation is usually a bottleneck, new forms of coal transportation such as slurry pipelines should be tried out, but this require additional financial resources which could be obtained by changing higher prices for coal.

The power tariff has been historically low and often lower than the cost of generation. Recently some of the State Electricity Boards have increased the power rates but still not much attempt has been there to revise the structure of the power tariff. Most of the existing tariff structures encourage increase power consumption and the large consumers pay a lower rate for power. There is no attempt to curb the consumption of power during the peak hours of the day by introducing some form of peak load prising. In case of power long term marginal or incremental costs should be worked out for supplying additional capacity during the peak period and energy at any time. Proper tariff structures incorporating such marginal costs would be designed. Some form of peak load pricing based on time-of-day metering should be introduced for large industrial consumers first and then others with high enough consumption. Due to seasonally changing hydro-power availability, systems with both thermal and hydro plants, could have seasonally varying tariff structures.

The relative prices between various fuels is important and changes should be made so that supply of various energy forms could match with the demands for these energy forms. Such prices should be fixed knowing the available energy resources of the country and import possibilities. Increasing energy prices will usually increase the cost of production, but only marginally except for energy-intensive industries such as Aluminium. Often energy prices are kept low with the argument that this will encourage industrial growth, but that is not so obvious. On the other hand charging the true price of energy based on marginal cost of production will avoid distorsions in the energy market and will lead to better energy conservation.

4. ROLE OF NON-CONVENTIONAL SOURCES OF ENERGY

As discussed earlier, almost half of the total energy consumption in India comes from non-commercial sources of energy and in the rural areas these sources including firewood and animal wastes cover almost 90% of the Energy used. The ecological consequences of increaded use of firewood, the burning of cowdung involving a loss in its value as fertilizer, and in general, the extremely low efficiency of energy use in the rural areas, makes it necessary that alternative sources of energy supply should be seriously considered for the rural areas. With the increase in the price of non-renewable sources of energy, specially oil, the focus has shifted in searching for new and non-conventional, and preferably renewable, sources of Energy. Solar, geo-thermal, tidal, wind and biogas energy are considered the main contenders as non-conventional sources of energy though all of them (except geothermal energy) essentially receive their energy from direct solar radiation or through some process of conversion. Research and development in exploring the possibilities of using these non-conventional sources of energy has started almost 15-20 years ago in India especially for bio-gas, geo-thermal and solar energy. Limited application has also been successful specially for bio-gas and there are about fifteen thousand bio-gas plants working in the country in several states. The Government policy thus favours the use of bio-gas and its introduction in the rural areas in a large way and it is planned that by the end of the Fifth Five Year Plan in 1979, 100,000 bio-gas plants will be in operation. Similarly, research and development activities and pilot plant studies are continuing in the areas of solar, wind, tidal and geothermal energy sources.

From an investigation of the experience in the implementation of bio-gas plants and research and development activities in the other sources of Energy, some important conclusions could be reached. The scope of non-conventional sources of Energy in supplying the Energy needs in the rural and urban areas of India by the end of the century is still going to be quite limited due to various technical, economic, social and organisational problems related with the utilisation of the sources on a wide scale. Perhaps bio-gas plants could supply a considerable portion of the rural energy needs by this time if the social and technical problems related with the organisation and setting up of community-type bio-gas plants are solved and the investment cost is brought down through research and development and the use of low-cost local materials. Still, the percentage of total energy needs supplied by these sources would be very small and unless major technological and economic breakthroughs are possible within the next 10-15 years, the role that these conventional sources will play in supplying the energy needs for development is going to be quite limited.

Solar Energy is at present competitive with other sources of power only for heating and cooling of buildings or of water and these are not large sources of aggregate demand in a tropical country like India. The use of solar Energy in residential and commercial establishments is expected to be quite limited. Water heating and refrigeration application in large buildings such as hostels, Government offices and large shopping centres might be possible in Urban areas. In the rural areas, the scope of solar Energy would be mainly limited to crop drying, refrigeration for large scale cold storage plants and water pumping, if commercial types of solar pumps could be developed. Now only solar drying is the most promissing use. Conversion of solar energy into electricity by solar cells or by direct application of heat are still highly expensive process and could be useful only in remote rural areas. Pilot scale plants for these should be built for experimentation.

Electricity generation from wind has not been very promising for developing countries in general due to the large initial investments and high cost of generation and storage, except at locations with very favourable wind conditions and poor transportation systems. In India, the average wind velocities are much lower than in other countries and it is highly seasonal, thus the scope for wind power in India appears to be quite limited except in isolated areas for seasonal activities like water pumping.

Bio-gas and fertilizer generation from animal wastes and agricultural wastes, mainly cow dung, human wastes and crop residues has been subject to large experimentation and techno-economic analysis. There are still some apprehensions regarding the economic profitability of bio-gas plants[1] but considering the various socio-economic advantages associated with successful introduction of bio-gas plants in the rural areas and the impetus to development that this will create, bio-gas appears to be the most important of the non-conventional energy sources and it is receiving increasing priority in India.

The concept of Energy plantations using quick-growing species does not appear to be a very promising solution in India mainly due to non-availability of land required for such plantations. But as the traditional use of fire-wood for cooking in the rural areas would continue indefinitely in the future, the social forestry concept has to be emphasized in whatever land that could be made available in the villages so that it could at least continue to be a partial solution to rural energy problem for the next few decades. Important gains could however be obtained by introducing some kind of well-designed low-cost stoves to increase the efficiency of burning fire wood which by itself could reduce the firewood consumption by significant amounts.

Whereas biogas appears to be the most promising source of non-conventional energy, several technical and economic problems related to its wide application in the rural areas have be solved within a very short time. The major advantage of bio-gas is that it is "two for one" technology where cowdung which is normally used either for fertiliser or for fuel can be used to produce both fertiliser and fuel. The efficiency of burning bio-gas in burners is usually higher by several factors to that of burning dung cakes, and the use of slurry from the bio-gas plants as a fertiliser appears also much more effective than the use of cow-dung directly. It could also become a completely decentralised technology using local skill and materials that could provide a convenient energy source in the rural areas, perhaps replacing the use of fire wood and electricity in villages which are too remote for rural electrification. Community bio-gas plant properly implemented through cooperatives or other village organisations could help the poor in obtaining a low-cost energy source because, a family size bio-gas plant does not appear to be within the reach of the poor villager both due to the high capital cost and also due to the requirement of 3 to 5 cows. Thus a wide scale contribution by bio-gas plants towards solving the energy problem in the rural areas could only be made if the community type bio-gas plants could be implemented in villages specially where the population lives in closely knit communities. Various problems related to the financing, construction, collection of dung, distribution of gas and pricing would have to be solved both at the technical and at the organisational level before community type bio-gas plants would be successful.

A note of caution must be made here so that bio-gas plants do not become another source for worsening the distribution of income in the rural areas, similar to the effect of the green revolution mainly associated with the high yielding varieties of grains and modern inputs like irrigation and fertilisers. Bio-gas plants could become a basic source of energy not only for domestic consumption but also for rural industry and agricultural activity, perhaps replacing rural electrification from transmission lines in remore areas. It is critical that the cost of constructing bio-gas plants should be brought down substantially so that there no doubts left regarding economic viability of these plants and scarcity of investment funds do not become a major bottleneck. A family size bio-gas plant producing about 100 c.ft. per day of gas approximately costs around 2,500-3,000 rupees (US $ 285-340) in India. Unconfirmed reports say that in China, where a cheaper and simplified form of construction is used, similar plants are available at a cost of US$20. The present Government policy in India is to provide a 25% subsidy for the construction of bio-gas plants and the banks are ready to supply such loans so as to encourage village industries schemes. Perhaps higher amount of finances could be made available for community-type bio-gas plants, thus removing a major bottleneck in their wide scale acceptance.

The role of non-conventional sources of Energy for domestic consumption in the urban areas appears to be quite limited. Bio-gas generation is possible from municipal wastes if the social problems related to the acceptability of such gas for domestic cooking could be removed. As suggested earlier, the role of solar energy would also be limited mainly to large buildings for heating or refrigeration none of which are high priority uses. Thus alternative sources of energy either in the form of liquified petroleum Gas (LPG), coal gas or solid smokeless fuel produced from coal would have to be made available in the urban areas for domestic and commercial use if the growth of consumption of kerosene for domestic cooking is to be curbed.

Research and development, pilot project preparation and field application for the utilization of various non-conventional source of energy are being pursued in India by a large number of institutions and with much enthusiasm,[2] under the sponsorship of the Ministry of Energy, Department of Science and Technology (DST), the National Committee for Science & Technology (NCST) and the Council of Scientific and Industrial Research (CSIR). Such activities in the field of geothermal energy, tidal power, solar energy, wind energy and biogas are encouraging but it is unlikely that by 2000 A.D., these non-conventional sources of energy will contribute a significant proportion towards meeting the national energy needs.

5. ENERGY DEMAND FORECASTING: AN APPROACH

A research project on Energy Planning Methodology for developing countries has been started in 1977 at the Indian Institute of Management. The first phase of the project will be completed in one year, but subsequent phases are expected to continue for an additional year or more. The basic objective of the research project is to suggest suitable methodologies for energy demand forecasting and energy-economic planning in the developing countries. The research project is not oriented in the current phase towards developing a specific plan for the energy sectors of India, but energy consumption and economic data for India and (if available) other developing countries will be used to test various methodologies that are considered relevant for these countries.

Energy use has always been linked to economic growth and prosperity of a country. But the energy crisis of late 1973 caused by the steep increase in the price of oil has made it necessary that energy sector planning and its relationship to economic growth is given increased attention by planners, specifically in the developing. The traditional approach to energy planning planning consists of (a) energy demand forecasting, (b) energy supply analysis and (c) energy supply-demand balancing, usually carried out in that sequences by individual energy-supplying sectors. This approach could not satisfactorily deal with the effects of interfuel substitution and relative price changes on the consumption of individual energy forms. The demand for energy and consequently the investment and foreign exchange needs for the energy sector are influenced by the rate of economic growth. But these in turn will influence and might constrain the rate of growth of the economy. In the traditional approach, this dual relationship was rarely considered, while planning for the energy sectors. But in the post-OPEC era, the economic growth prospects of any country and specifically the developing countries are very intimately linked with the developments in the energy sector and an integrated framework for energy-economic planning is needed. The objective of the current research project is to develop such a framework applicable for developing countries. The basic problems related to the consumption and supply of energy in the developing countries are different from those found in the developed countries. Many of the sophisticated econometric and other modelling approaches used in the developed countries may not be suitable for the developing countries. Thus there is a need for developing suitable methodologies for energy planning directed towards the problems and prospects of the developing countries themselves.

Investigations are being carried out in this research project mainly in to two aspects of energy planning methodology - (a) energy demand forecasting and (b) integrated framework for energy-economic planning. It is felt that most of the developing countries, including India, lack proper methodologies for energy demand forecasting. This is usually carried out by simple extrapolation of past trends of energy consumption and sometimes using simple regression models relating energy consumption to some economic parameters.

Usually such methodology do not take consideration of the price elasticity of energy consumption and are not usually based on any structural methods specifically for the industrial sectors. As the suitable time series data on energy consumption, prices and other economic variables are not always available in developing countries in a reliable form and there are structural changes in the economy brought about by the process of development itself, it was felt that the usual econometric approaches for energy demand forecasting may not be highly suitable in their case, specially for the industrial sector. It was then decided to attempt ddveloping some structural methods for energy demand forecasting for the industrial and related sectors.

To develop suitable methodology for energy demand forecasting, two specific approaches and techniques are being investigated (a) simple econometric methods and (b) input-output analysis and specific industry studies. Econometric models are being developed relating the consumption of total energy and individual energy forms i,e, coal, oil and electricity with their prices and other indicators such as GNP, population, national income and index of industrial production. A separate investigation will be carried out to determine suitable indicators for rural energy consumption both in the agricultural and domestic sectors. The alternative approach for demand forecasting is based on using an upto-date input-output table expressed in monetory terms to develop an energy input-output table in physical terms. An energy input-output table, in which the energy sectors are separated from the other sectors of the economy, expresses in physical terms, the energy input required for the production of an additional unit of output in any other sector. If recent input-output tables are available, the exercise of constructing energy input output tables should not be very difficult. It would be instructive as various issues related to fuel efficiencies, interfuel substitution and technological changes would have to be faced in this process. Again price elasticity might not affect industrial demand much but relative price changes will have the effect of changing the shares of different fuels in industries, where the fuel used is not completely determined by the technology. To take account of these cases, a series of energy input-output tables may have to be prepared to reflect different relative energy price scenarios in the future. The adjustment process to the higher prices of oil could be represented in this approach by gradually changing the energy coefficients for different energy forms and for various end-use sectors.

The energy coefficients for various industrial sectors developed through the use of in put-output analysis will be compared with such coefficients developed by the Planning Commission while carrying out material balances. Similar coefficients are also being computed from the data available on the energy consumption by various industries in the report of the annual survey of industries to check the consistency of these energy coefficients. For industrial sectors which are large consumers of energy such as steel, cement, fertiliser, chemical industry etc. individual industry studies will be carried out to determine the coefficients of energy consumption based on technical and process requirements, as well as, the scope of substitution between alternative energy forms.

Based on the data available, an attempt will be made to develop analytical models for forecasting energy demand in the domestic, agricultural, industrial and transportation sectors of the economy. It is possible that different methodologies may be suitable for different sectors of the economy. Whereas input-output analysis is being used for forecasting industrial energy demand, regression analysis or econometric models could be a better tool for forecasting domestic demand. Energy demand forecasting should be theoratically carried out simultaneously with energy supply analysis, so that inter linkages between them through the mechanism of price and resources availability could be investigated.

In the current research project, the energy demand forecasting models will be linked with various models of the energy supply sectors within the integrated framework for energy-economic planning shown in figure 2. As expected, the demand forecasting and supply models are linked with a macro-economic model of the general economy, so that the linkages between the energy sectors and the other sectors could be established. At this point we visualise that a aggregate version of the current input-output table being developed by the Planning Commission will be used as the macro-economic model. Various models are already available for the energy supply sectors, following the work of the fuel policy committee, the earlier work at the Institute and oil sector models developed by the oil industries. As far as possible existing supply sector models would be utilized in the integrated framework after suitable modification rather than develop new models for the supply sectors. It is expected that during the first phase of the research project, a suitable methodology for energy demand forecasting and an integrated framework for energy-economic planning will be developed which then could be applied to various developing countries including India during the subsequent phase of the energy research project.

The use of general econometric models is not recommended unless they are based on well-defined structural models of the end-use activity, except for forecasting consumptive use of energy in the residential and commercial sectors. Similarly, market-induced demand-supply equilibrium models are not expected to be very useful in the developing countries. The main reasons why input-output analysis is preferred over econometric models is that (i) the input-output framework would be also useful for developing planning models of the energy supplying sectors, and (ii) the effects of changing energy picture on the general economy could be analysed much better under the input-output, inter-industry or process-analysis framework. A dynamic input-output planning model similar to the one used by Carter[1] for U.S. could be developed to study the effects of changing energy picture on the growth prospects of the economy. The Pilot Energy Model[2] based on an input-output model of the economy and detailed description could also be adapted for use in the developing countries. In India, during the course of the energy planning study by the Fuel Policy Committee, a linear programming model[3] of the energy supply sectors was developed which included fuel extraction/import, processing and transport to meet demands from the various sectors. The model also included investment choices in different fuel industries related to location, choice of technique and capacity. An integration of such energy supply model with an input-output model appears feasible and is being developed under the current research project, "Energy Planning Methodology for Developing Countries[4]. In such an integrated energy-economic model, the linkages between the general economy and the energy sectors could be properly analyzed and any constraints on the economic growth arising out of the energy sectors could be identified and acted upon by the policy makers. Energy demand forecasting in the developing countries cannot be effectively separated from the issues of energy supply planning. The policy decisions the government has to make on energy and energy-related issues, often in other sectors of the economy, have far-reaching impact on the economic growth potential of the country through their effects on the energy sectors and their investment and import needs.

Important among these policy issues are (i) increased mechanisation and increased use of irrigation and fertiliser in agriculture, (ii) use of firewood, cowdung and agricultural wastes for rural domestic fuel, (iii) rural electrification for domestic and industrial use, (iv) use of kerosene and liquified petroleum gas (LPG) as domestic fuel in urban areas, (v) freight movement by road transport vis-a-vis by railways, (vi) dieselization visa-vis electrification of the railways, (vii) use of diesel buses vi-a-vis electric trolly buses, street cars or subways for urban mass transportation, (viii) pollution abatement policies, (ix) industrial strategy of basic heavy industries producing capital goods vis-a-vis light consumer good-producing industries and (x) provision of apparent luxuries such as the use of air conditioning, refrigerators or private automobiles for an affluent minority of the population vis-a-vis providing the basic needs for the masses on a priority basis.

These policy issues are highly important for the developing countries and they affect the energy sector and also the economic growth potential of these countries. One of the objectives of energy planning should be to focus on these issues and determine their impact on the economy through on analysis of the interdependent structure of the economy and dynamic input-output analysis would be highly useful in this area specially for some of the developing countries which have constructed reliable input-output tables for their economies. However, in using dynamic input-output analysis we have to be careful that the input-output matrix is periodically updated to reflect structural changes in the economy taking place by the very process of economic development. The input-output framework should be also modified to include fuel substitution possibilities in the production of the certain energy-related sectors (e.g. nitrogenous fertilizers, petroleum refining and petro chemicals, steel production from ore and scrap, or sponge iron, aluminium, industrial and domestic gas, etc.) through a linear programming framework. It is also possible to carry out sensitivity analysis in this model ing framework to analyse the effects of relative price changes for various energy forms and absolute increase in the cost of energy. There is a need for organizing research in this highly promising field of 'input-output modeling for energy planning' with special emphasis for the developing countries as much of the present work in this area is more relevant to developed economies with a more or less stable economic structure.

One of the most important areas, which is of special concern in developing countries is energy demand forecasting for agriculture and rural sectors where non-commercial fuels such as firewood, animal and vegetable waste play a major role. Some of the useful problems and results in this area have been discussed by Makhijani, Parikh, Reddy and others[5] but more work is needed in this area to develop reliable norms of energy consumption in rural areas for domestic cooking, lighting and for agriculture. The same is true for urban domestic demands for cooking, lighting, refrigeration and airconditioning and also for urban transportation. The use of input-output tables or end-use approach for industrial demand projection in developing countries appears to be a promising approach but field studies are needed to determine the best ways to prepare energy-input tables or develop output norms of industrial energy consumption by various industries and agriculture.

In most of the developed countries such as U.S.A., Canada, U.K. and other European countries the current approach seems to be the development of comprehensive models of energy supply and demand sectors and obtaining an equilibrium solution. Often such models are integrated with a description of the general economy through an input output or an econometric model. For various reasons discussed earlier, such comprehensive models will be very difficult, if at all possible, to construct in the case of the developing countries. There is the basic difficulty in getting adequate amount of reliable data for model estimation and also the need to update such models quite frequently with changes in the structure of the economy. A start could be made with simple regression models for demand forecasting and other models for supply analysis in most of the developing countries. However, for larger countries with better data availability, input-output analysis and construction of energy input-output tables hold a better promise specially if some way is found to study the effects of relative price changes on fuel substitution possibilities within the framework of input-output analysis. A closer concentration on supply modeling through the use of optimization techniques will possibly benefit the developing countries more in the long run than building sophisticated econometric models for demand estimation. But continued shortage of electricity and often coal in India and many other developing countries suggests that long-term demand forecasting based on economic growth targets, long-term planning of investment needs in the energy sector, and close monitoring of the capacity creation and capacity utilization of energy facilities is a basic necessity. This cannot be done only through the five-year planning frame-work being practised in India and many other developing countries but long-term investment, analysis for 15-20 years must be undertaken which could be reviewed periodically following the 'rolling plan' concept recently introduced in India.

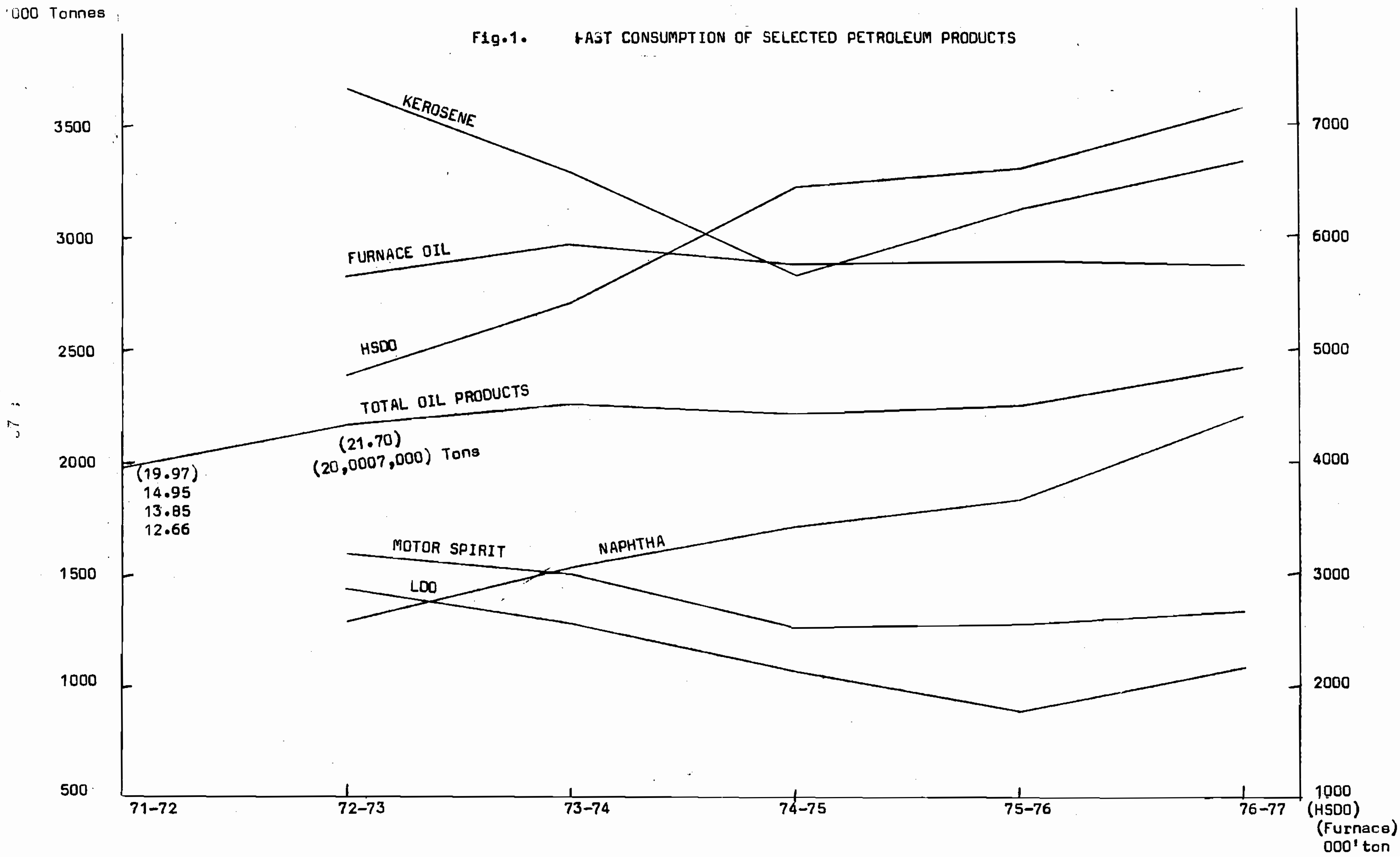
'000 Tonnes
Fig.1. PAST CONSUMPTION OF SELECTED PETROLEUM PRODUCTS
KEROSENE
FURNACE OIL
HSDO
TOTAL OIL PRODUCTS
(21.70)
(20,0007,000) Tons
(19.97)
14.95
13.85
12.66
MOTOR SPIRIT
NAPHTHA
LDO
3500
3000
2500
2000
1500
1000
500
7000
6000
5000
4000
3000
2000
1000
71-72
72-73
73-74
74-75
75-76
76-77
(HSDO)
(Furnace)
000'ton

FIGURE 2

INTEGRATED FRAMEWORK FOR ENERGY - ECONOMIC PLANNING

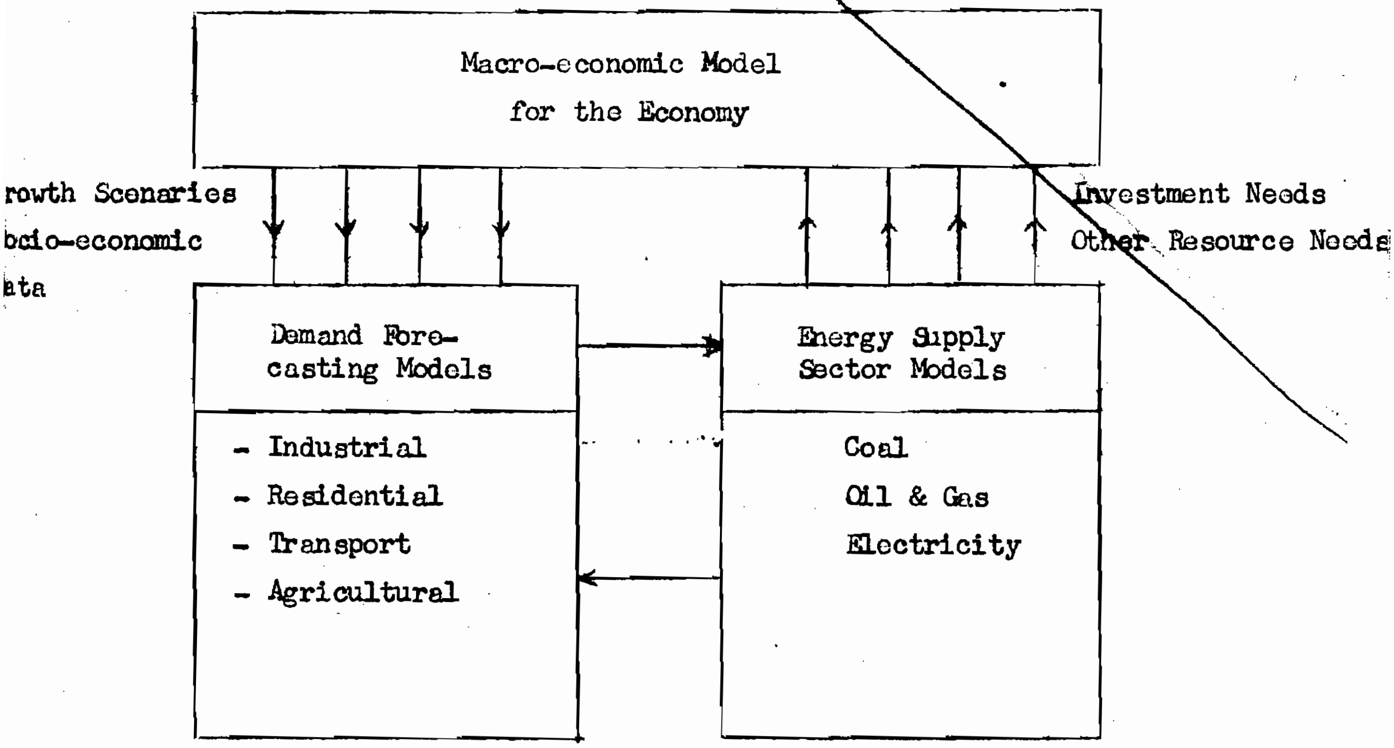

TABLE 1

TOTAL CONSUMPTION OF COMMERCIAL ENERGY FUEL WISE IN ORIGINAL UNITS

Year	Coal in M.Tons	Oil in Million Tons	Electricity in B. Kwh.
1953-54	28.70	3.66	7.60
1954-55	28.50	3.96	8.40
1955-56	28.00	4.66	9.40
1956-57	30.70	4.67	10.20
1957-58	34.60	5.22	11.80
1958-59	36.10	5.55	13.20
1959-60	35.70	6.18	15.40
1960-61	40.40	6.74	16.90
1961-62	44.10	7.46	19.37
1962-63	49.10	8.39	22.57
1963-64	48.60	8.65	25.21
1964-65	48.30	9.29	27.76
1965-66	51.80	9.94	30.56
1966-67	52.30	10.62	33.21
1967-68	54.50	11.28	36.76
1968-69	53.00	12.66	41.46
1969-70	56.66	13.85	45.02
1970-71	55.70	14.95	48.58
1971-72	55.91	19.97	52.52
1972-73	60.03	21.75	55.05
1973-74	59.91	22.35	56.35
1974-75	65.86	22.04	59.12
1975-76	69.92	22.45	66.94
1976-77	n.a.	24.10	n.a.

TABLE 2

Total Consumption of Commercial Energy Fuel-wise in million Tonnes of Coal Replacement

Year	Coal	Oil	Electricity	Total
1953-54	28.70	23.81	7.60	60.1
1954-55	28.50	25.77	8.40	62.7
1955-56	28.80	30.30	9.40	68.5
1956-57	30.70	31.16	10.20	72.2
1957-58	34.60	33.93	11.80	80.3
1958-59	36.10	36.15	13.20	85.4
1959-60	35.70	40.07	15.40	91.2
1960-61	40.40	43.86	16.90	101.2
1961-62	44.10	48.51	19.37	108.1
1962-63	49.10	54.53	22.57	126.2
1963-64	48.30	56.21	25.21	130.0
1964-65	48.20	60.41	27.76	136.4
1965-66	51.80	64.61	30.56	147.0
1966-67	52.30	69.07	33.21	154.5
1967-68	54.50	73.35	36.76	164.6
1968-69	53.00	82.27	41.46	176.8
1969-70	56.66	90.06	45.02	191.7
1970-71	55.70	97.19	48.58	197.0
1971-72	55.91		52.39	
1972-73	60.03	113.724	55.05	228.8
1973-74	59.91	116.147	56.24	232.3
1974-75	65.86	117.270	58.98	242.1
1975-76	69.92	120.333	66.82	257.1
1976-77	n.a.	129.246	n.a.	

Note: 1. Figures of consumption of coal do not include coal used for power generation.

2. Oil consumption does not include refinery losses and refinery boiler fuel.

3. The figures of consumption of oil do not include non energy products, such as Lubes & Greaves, Bitnmen, Naptha, Petroleum, coke etc.

TABLE 3

PAST CONSUMPTION OF COAL (UNITS: MILLION TONNES)

Year	1970-71	1971-72	1972-73	1973-74	1975-75	1975-76
1. Steel Plants (Coaking Coal)	17.30	17.00	19.00	18.66	18.51	20.96
2. Cement	3.24	3.38	3.70	3.65	4.38	4.44
3. Railways	15.56	15.84	15.28	13.92	14.14	14.30
4. Power Generation	14.46	16.02	18.52	17.74	20.30	23.04
5. Brickmaking	3.11	2.52	2.50	2.71	1.72	3.34
6. Soft Coke (for domestic use)	3.84	3.75	3.44	4.39	3.72	3.64
7. Export	0.46	0.40	0.55	0.62	0.54	0.44
8. Others including colliery consumption	12.19	18.08	16.56	16.02	22.06	22.70
9. <u>Total</u>	70.16	71.93	78.55	77.65	86.16	92.96

TABLE 4

PAST CONSUMPTION OF PETROLEUM, OIL & LUBES ('000 tonnes)

	1972-73	1973-74	1974-75	1975-76	1976-77
LIGHT ENDS					
1. LPG	244	269	288	336	368
2. Motor spirit	1592	1507	1257	1277	1316
3. Naptha	1297	1534	1713	1836	2196
4. Avgas/SBP/Others	168	174	157	150	162
5. Sub-total	3301	3484	3415	3599	4042
MIDDLE DISTILLATES					
6. Kerosene	3516	3294	2809	3104	3322
7. Aviation turbine fuel	816	778	831	897	956
8. HSDO	4770	5404	6431	6597	7106
9. LDO	1446	1290	1071	891	1094
10. MTO/JBO/Others	198	200	161	166	178
11. Sub-total	10746	10966	11303	11655	12656
FURNACE OIL					
12. FO (fertilizer)					
13. FO (non-fertilizer)					
14. Sub Total	5672	5912	5729	5780	5733
OTHER PRODUCTS					
15. Bitumen	1109	1066	897	690	882
16. Lubes/Greases/Others	917	917	700	727	787
17. Sub-total	7698	7895	7326	7197	7402
18. GRAND TOTAL	21745	22345	22044	22451	24100

TABLE 5

ELECTRICITY CONSUMPTION IN SELECTED MANUFACTURING INDUSTRIES (UNITS - M. Kwh.)

	1960-61	65-66	70-71	71-72	72-73	73-74	74-75	75-76	Rate of Growth over last 10 years. ie., 75-76/65-66
Aluminium	448	1,566	3,375	3,555	5,575	2,826		3,696	8.97%
Iron & Steel	1,613	2,545	3,195	3,178	3,715	3,796	3,825	4,120	4.93%
Cotton Textiles	2,088	2,763	3,138	3,128	3,965	4,056	4,393	4,780	5.56%
Fertilizers	477	1,828	2,531	2,791	2,918	3,115	3,048	4,473	9.35%
Chemicals	404	642	1,614	1,810	1,760	1,545	2,028	2,338	13.79%
Cement	936	1,059	1,371	1,448	1,318	1,284	1,509	1,754	5.18%
Paper	508	666	899	1,096	1,112	1,059	1,188	1,272	6.68%
Engineering		298	839	989	836	942		1,216	15.1%
Total listed above		11,387	16,962	17,995	19,137	18,623		23,649	7.58%
Total consumption by Industries	12,659	22698	34,866	37,053	38176	38549	39,142	44218	6.9%

Source: 1960-61, to 73-74 from P.D. Henderson: Energy Sector Report; Table 36 (updates), 74-75, 75-76, - C.E.A. Report

TABLE 6

INDIA

POWER TRANSMISSION PROJECT IV

Number of Villages Electrified and Irrigation Pumpsets/Tubewells Energized

March 31	Number of Villages Electrified	Proportion of Total Villages (Percentages)	Number of Irrigation pumpsets/Tubewells Energized (Thousands)
1950/51	3,100	0.5	21
1955/56	7,300	1.3	56
1960/61	21,700	3.8	198
1965/66	45,100	8.0	509
1968/69	73,700	13.0	1,081
1970/71	104,900	18.7	1,619
1971/72	122,100	21.6	1,890
1972/73	139,200	24.5	2,168
1973/74	156,000	27.5	2,440
1974/75	165,500	29.2	2,633
1975/76	184,714	32.26	2,786

Source: C.E.A. report

TABLE 7

Annual rate of growth of Petroleum Products Consumption since 1972 to 77

	1973-74 Over 1972-73	1974-75 Over 1973-74	1975-76 Over 1974-75	1976-77 Over 1975-76
Products				
Light distillates	5.54%	(<2%)	5.39%	12.31%
Middle distillates	2.50%	3.07%	3.11%	8.59%
Furnace Oil	4.23%	(< 2%)	< 2%	(<2%)
Other products	2.56%	(< 2%)	(<2%)	2.85%
All products	2.76%	(<2%)	<2%	7.34%
Selected Products				
Motor spirit	(<2%)	(<2%)	< 2%	3.05%
Kerosene	(<2%)	(<2%)	10.5%	7.02%
H S D O	13.29%	19.00%	2.58%	7.72%
L.D.O.	(<2%)	(<2%)	(<2%)	22.78%
Naphtha	18.27%	11.67%	7.18%	19.60%
L P G	10.25%	7.06%	16.67%	9.52%

TABLE 8

Relative share in net electricity consumption by different sectors

	60-61	65-66	70-71	71-72	72-73	73-74	74-75	75-76
Agricultural & Irrigation	4.9%	6.3%	9.2%	9,6%	12.1%	12.6%	14.7%	14.5%
Railway Traction	2.7%	3.5%	2.8%	3.1%	3.6%	3.1%	2.9%	3.1%
Industry	73.7%	72.8%	70.0%	69.5%	65.7%	64.6%	62.1%	62.4%
Commercial	5.0%	5.5%	5.3%	5.7%	5.8%	6.0%	5.8%	5.8%
Public Lighting	1.0%	0.9%	1.0%	0.9%	1.1%	1.0%	1.1%	1.0%
Domestic	8.8%	7.8%	7.9%	7.9%	8.7%	9.2%	9.8%	9.7%
Public Water Works and Miscellaneous	3.8%	3.2%	3.8%	3.3%	3.0%	3.5%	3.4%	3.6%
Total	100	100	100	100	100	100	100	100

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2. Government of India, "Fuel Policy for the Seventies", Interim Report of the Fuel Policy Committee (unpublished), New Delhi, India, May 1972.

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Section 4

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Section 5

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