COMMERCIAL ENERGY CONSUMPTION IN INDIAN INDUSTRY : PATTERNS AND PROSPECTS

Dissertation submitted to the Jawaharlal Nehru University
in partial fulfilment of the requirements for the
award of the Degree of
MASTER OF PHILOSOPHY

KULWANT SINGH

CENTRE FOR THE STUDY OF REGIONAL DEVELOPMENT
SCHOOL OF SOCIAL SCIENCES
JAWAHARLAL NEHRU UNIVERSITY
NEW DELHI-110067, INDIA

1984

JAWAHAR LAL NEHRU UNIVERSITY
SCHOOL OF SOCIAL SCIENCES
(CENTRE OF STUDIES FOR REGIONAL DEVELOPMENT)

Certified that the dissertation entitled 'Commercial Energy Consumption in Indian Industry: Patterns and Prospects' is submitted by Kulwant Singh in partial fulfilment of six credits out of a total requirement of twenty four credits for the degree of Master of Philosophy of the Jawaharlal Nehru University The dissertation is a bonafide work to the best of my knowledge and may be placed before the examiners for their consideration.

G.S. Bhalla

Dated: January 2, 1985 (Professor G.S. Bhalla)
Supervisor

Dated: January 5, 1985 (Professor Aijaz Ahmed)
Chairman

C O N T E N T S

A B B R E V I A T I O N S

mt	:	Million metric tonne
mtoe	:	Million metric tonnes of oil equivalent
tce	:	Metric tonne of Coal equivalent
mtce	:	Million metric tonne of Coal equivalent
tcr	:	Metric tonne of Coal replacement
mtcr	:	Million metric tonne of Coal replacement
kcal	:	Kilocalorie (1,000 calories)
kW	:	Kilowatt (1,000 watts)
mW	:	Megawatt (1,000 kW)
gW	:	Gigawatt (1,000 mW)
tW	:	Terawatt (1,000 gW)
kWh	:	Kilowatt hour
bkWh	:	Billion kilowatt hour
gWh	:	Gigawatt hour
TWH	:	Terra watt hour
I-O	:	Input Output ratio
GDP	:	Gross Domestic product
ABE	:	Advisory Board on Energy
WGEP	:	Working Group on Energy policy
LEC	:	Large Energy Consuming Industries
NLEC	:	Non-Large Energy Consuming Industries
HGDP	:	High rate of growth of GDP
LGDP	:	Low rate of growth of GDP

* * * * *

LIST OF TABLES

A C K N O W L E D G E M E N T

'Energy Crunch' is real in the Indian Economy. In view of this the present study on 'Commercial Energy Consumption in Indian Industry: Patterns and Prospects' was undertaken. It has been a stimulating assignment. Throughout this research work I have benefitted from the steadfast encouragement of professor G.S. Bhalla under whose guidance and supervision the work has been completed. I have also received valuable help in the form of statistical data, advice and comments from many friends and colleagues in various government departments. I am especially indebted to Shri J.N. Maggo, Deputy Adviser, Advisory Board on Energy and Shri S.K. Das, Deputy Statistician, Ministry of Industry for their knowledgable advice. Assistance received from Shri K.S. Ahuja and Shri G.P. Banerjee is gratefully acknowledged. Sanjay Sood and Rekha Punhani who have typed these pages with great accuracy and alacrity deserve my personal thanks.

All errors, omissions and deficiencies are my responsibility.

KULWANT SINGH

DECEMBER 1984

Chapter - I

Commercial Energy Consumption in Indian Industry: Patterns & Prospects

INTRODUCTION

1.1 Energy is crucial to all production. Whereas its abundant supply can create favourable conditions for growth, energy shortages can adversely affect both production and productivity. It is in the context of the planned objective of rapid growth that in India, energy sector has received large plan allocations. Total expenditure on Energy sector for the Sixth plan is expected to exceed 30 per cent of total plan outlay.

1.2 Commercial Energy Consumption in India has increased six-fold during the last thirty years. Between 1953-54 and 1980-81, the annual growth rate of commercial energy consumption was 6.7 per cent. Industrial sector is a major user of commercial energy in India. It accounts for 40 per cent of total commercial energy consumption whereas it produces only 18 per cent of GNp. High level of commercial energy consumption is due to our more energy-intensive industrial product mix such as steel, cement, ammonia, aluminium, pulp and paper, fertilizers, chemicals and refined petroleum products. Energy intensities have also increased in the economy in general and industrial sector in particular. High levels of energy intensities compared to many developed countries

and newly industrializing developing countries reflect differences between manufacturing process, the product mix, the type of energy source, the scale of plant and the general efficiency of energy use.

1.3 Another important determinant of the share of energy in total product cost is the price of energy. The differential prices of different types of energy effect their respective consumption in various sectors. It is essential to be aware of the impact of changing energy pricing structure for formulating appropriate energy policies.

Purpose of the Study

1.4 The specific purpose of this study is to describe and explain trends in commercial energy consumption and analyze the factors affecting energy consumption. As the energy is consumed in the process of production of goods and services, its close relationship with the overall growth of the economy and the sectoral growth of mining and manufacturing has been examined.

1.5 Use of energy in the industrial sector is the result of two inter-related factors - structure of the sector and intensity of energy use. Both structural and intensity characteristics are themselves manifestations of a variety of factors. An attempt has been made to study the impact of changing industrial structure on the demand for commercial

energy in general and that on various commercial fuels in particular. Trends in fuel-wise energy consumption in manufacturing in the first three decades of planning have been analyzed and a basis established for projecting future demand. A detailed examination of the heaviest energy-using industries has been carried out with the principal focus on production processes, technoligies and other significant factors. A key element of the approach is the calculation of ratios of energy use per unit of value added at constant prices.

1.6 Energy substitution is an integral part of energy management. To identify inter-fuel substitution possibilities, trends in fuel substitution have been studied. The endeavour has been to analyze, inter alia, the effect of increase in energy prices and other economic factors on the form of energy consumed. An examination of the changing consumption pattern of commercial energy in the Sixth plan illuminates the dynamics of demand changes and the use of commercial energy in the industrial sector as envisaged by our planners. Energy efficiency of our industries is another important issue which has been probed in detail. Forecast of commercial energy demand for the industry sector is a difficult task. Efforts have been made to project commercial energy requirements for the Seventh plan and beyond.

Approach and Method:

1.7 Basic Data: Energy Survey of India Committee Report, 1965 and Fuel Policy Committee Report 1974 provide fuel-wise commercial energy consumption both global as well as sectoral upto 1970-71. This has been supplemented with the data on Electricity, Petroleum, and Coal statistics from the annual publications. National Accounts Statistics furnish GDP statistics for the economy and its sectors. These have been made use of to correlate energy consumption and national and sectoral growth.

1.8 The best set of data on energy consumption in terms of comprehensiveness of coverage, comparability across industries and over time, and availability of data over a large number of years is prowided by C.S.O. The basic historical data for the major industries has been derived from the Census of Manufacturing from 1946 to 1958 and from Annual Survey of Industries (Census Sector) from 1959 to 1973. Energy consumption is reported both in the census as well as survey in terms of specific physical quantities and in value terms. The census was confined to 28 industries but the coverage was widened to 63 industry groups with the introduction of ASI in 1959. This classification has, however, undergone a change since 1973-74. The detailed results (census sector) published in 10 volumes are available upto 1973-74 only.

1.9 Historical energy consumption data on the census and Survey basis has been tabulated for analysing the changing energy utilisation patterns and energy intensities of large energy consuming industries which include textiles, fertilizers, cement, iron & steel, non-ferrous basic metals, refractories, inorganic heavy chemicals, pulp and paper, etc. have been worked out to study the changing trend of energy consumption under the influence of changing product-mix, technology and other economic and non-economic factors.

1.10 A close appraisal of the pattern of energy use in the seventies has been done on the basis of disaggregated consumption data available in the annual publications as well as the input-output table estimated for 1979-80 and projected I-O table for 1984-85 in the technical note on the Sixth plan.

Methodology

1.11 Trends in commercial energy consumption have been analyzed for the years 1953-1980 computing rates of growth of commercial energy fuel-wise as well as for the total energy both for the short-term and for the long-term. Energy-GDP elasticities for the various periods and their comparison with the developed countries help to examine fuel utilization efficiency in the economy as a whole and the industry sector in particular.

1.12 Regression models (both linear and exponential) relating energy consumption with activity levels have been studied to examine the degree nature of relationship and the of causation.

1.13 ASI data has also helped to study the changing consumption norms (Energy/Output) and the inter-fuel substitution. The question of inter-fuel substitution has been looked into by reviewing a variety of published information on the subject. The question of energy efficiency in Mining and Manufacturing has been addressed in a separate chapter and the factors responsible for low efficiencies analyzed. The impact of energy prices on the energy consumption pattern has been assessed through available estimates of price elasticities and cross-elasticities from some recent studies.

1.14 Two methods have been used for projecting the commercial energy demand for 1989-90 and 1994-95. These are (i) Macro - method using the simple relationship between value added and energy intensities; and (ii) End-use method which uses the energy consumption norms and the production targets for working out the energy requirement.

Data Limitations

1.15 A major handicap to our analysis and projections of energy use in industry has been the non-availability of recent ASI data. Other sources do not provide disaggregated data for the consumption of

different forms of commercial energy particularly for the less energy intensive industries. Working Group on Energy Policy, 1979 studied the energy perspective and projected the energy demand upto the year 2000-01. The energy consumption level during Sixth plan has proved many of WGEP assumptions untrue. This was clearly because WGEP projections were made in the absence of appropriate and comprehensive end-use consumption data on different energy fuels for the seventies. The data position has not substantially changed since then.

1.16 A second and most important limitation is that the industry sector in India consists of two distinct parts - one referred to as the registered sector consisting of factories registered under the Factories Act and the other unregistered sector. While ASI covers the total factory sector, its census sector does not cover more than 80-85 per cent of the factory sector. The magnitude of the unregistered sector is very important in so far as the unregistered sector is a significant contributor to the total industrial production and contributes over one-third of the total value-added. While this sub-sector of industry consumes non-commercial energy heavily, its commercial energy consumption pattern has also changed with greater consumption of electricity and coal.

However, there is a complete lack of commercial energy information on their consumption pattern. It is, therefore, difficult rather impossible to hazard a guess on the efficiency of commercial energy use in this important segment of industry.

1.17 A caveat may be entered in the beginning itself that the study has concentrated on the consumption pattern and not on energy demand. There is, undoubtedely, a substantial level of suppressed demand for coal and power in many industries and with the available data base, it is not possible to identify this gap in consumption and real demand. The question of energy shortages has also not been taken up.

Conceptual Questions of Energy Use

1.18 The conceptual problems relating to the conversion factors, efficiency criteria, price deflators for deflating value-added series have been resolved on the basis of economic and technical conventions adopted in this country.

Chapter 2

Trends in Commercial Energy Consumption

2.1 Commercial Energy provides the bulk of requirements for modern industrial society. The conventional* sources of energy, sold in the course of commerce or provided by a public utility, are coal (including lignite); petroleum (including fuel oil, gasoline, kerosine, diesel fuel, natural gas and liquified petroleum gas); and electricity generated by burning one or other of these fuels, or from hydro or nuclear power.

2.2 The share of commercial energy in the total energy consumption has been increasing over the past three decades. A statistical review of the consumption of commercial energy in India during the last three decades would provide a good basis for forecasting the energy requirements of the future commensurate with our development objectives and immediate and longer term needs. An analysis of the trends of energy consumption would also help in understanding the causes and consequences of such consumption particularly in the industrial sector so that measures are taken to rationalize the energy consumption through, inter alia, conservation and improved energy management. The analysis covers the three principal forms of energy, viz. coal, oil and electricity.

---

* Wood is not included in this category although it was extensively used in the past, and still is to some extent, for industrial purposes. Conventional and commercial energy is thus virtually synonymous.

Primary and Secondary forms of Energy

2.3 Commercial energy is divided into two forms, primary and secondary. The primary forms of energy are a gift of nature in which there has been no chemical transformation before use like coal, oil, solar, falling water, etc. Secondary forms of energy are produced by transformation of the primary forms. Hydropower is regarded as primary energy and thermal-generated power as secondary** energy. Similarly refined oil products are secondary forms.

Unit of Measurement

2.4 For purposes of aggregating the quantities of energy obtained from different energy sources, it is necessary to adopt a common unit of measurement. United Nations uses coal equivalent tonne as the unit of measure. In India, however, the Energy Survey Committee 1965 which first studied the trends in energy consumption adopted the 'coal replacement tonne' as the common measure. Since then the concept of million tonnes of coal replacement (mtcr) has been used by other Committees and groups. This measure takes note of not only the quantity of heat value available in the different fuels used but also of the varying efficiency in the appliances employed. mtcr gives the amount of coal that would

---

** Nuclear power is commonly referred to as primary energy although this does not accord with a strict interpretation of the definition.

have been needed in the economy if no other source of energy were available. The concept is of particular relevance in India where the major energy source is coal and the major policy question is how much coal is required to replace a particular fuel. The mtcr for a fuel is computed as under:

$$\text{mtcr fuel} = \frac{(\text{efficiency in use})_{\text{fuel}}}{(\text{efficiency in use})_{\text{Coal}}} \times \frac{\text{Calorific Value of fuel}}{\text{Calorific Value of Coal}}$$

It is assumed that calorific value of coal in India is equal to 5000 K cal/kg. The rates of conversion of different measures of energy in their original units to coal replacement and coal equivalent are set out in Table 2.1.

2.5 In the present study of pattern of commercial energy use we have made use of mtcr conversions. It is, however, felt that mtcrs should be computed and periodically updated for each individual fuel, keeping in view the prevailing efficiencies in use.

TABLE 2.1

Coal Replacement and Equivalents of Different Fuels

Fuels	Original Unit	Coal equivalent in m. tonnes mtce	Coal replacement in m. tonnes mtcr
Coal	1 mt	1.0	1.0
Hard Coke	1 mt	1.3	1.0
Soft-Coke	1 mt	1.5	1.5
Firewood (4750 K Cal/kg)	1 mt	0.95	0.95
Charcoal (6900 K Cal/kg)	1 mt	1.0	1.0
Oil products (10,000 K Cal/kg)			
Black products (i.e. FO/RBF/LSHS/HHS)	1 mt	2.0	2.0
Kerosene & LpG	1 mt	2.0	8.3
HSDO & LDO	1 mt.	2.0	9.0
Motor Spirit & Jet Fuel	1 mt	2.0	7.5
Natural Gas (9000 K Cal/kg)	$10^9 m^3$	1.8	3.6
Electricity	10^9KWH	1.0	1.0

Notes: Coking Coal 6640 K Cal/kg; Non-Coking Coal used in steam generation 5000 K Cal/kg)

Source: Report of the Fuel Policy Committee, 1974

Total Commercial energy Consumption

2.6 The consumption of commercial energy during the period 1953-54 to 1980-81 is shown fuelwise in original units in Table 2.2, in million tonnes of coal replacement units in Table 2.3 and the percentage share of different fuels in commercial energy consumption in Table 2.4.

2.7 Table 2.4 shows that the share of coal steadily decreased while the share of electricity have increased between 1953-54 and 1970-71. The share of oil which also increased consistently until 1972-73 started declining in 1973-74. The trend was reversed in 1976-77 and the share of oil in total energy consumption went up to 49.47 percent in 1980-81.

2.8 An analysis of the trends, fuel-wise indicates that over the period 1953-54 to 1970-71 the growth in the consumption of oil products and electricity was relatively more rapid than consumption of coal. In the period 1970-71 to 1975-76, there was a spurt in the coal consumption and a decline in the growth of oil and electricity. There was a reversal of this trend and the growth of oil and electricity consumption again picked up in the next five years. The details of the rates of growth during the different sub-periods of the three principal sources of energy are given in Table 2.5.

TABLE 2.2

Total Consumption of Commercial Energy Fuel-Wise

(in original units)

Year	Coal million tonnes	Oil million tonnes	Electricity TWH
1953-54	28.70	3.66	7.60
1954-55	28.50	3.96	8.40
1955-56	28.80	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	6.16	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	51.35	14.95	48.65
1971-72	54.14	15.92	51.25
1972-73	53.14	17.05	54.15
1973-74	59.91	17.56	55.52
1974-75	67.10	17.30	58.17
1975-76	70.96	17.79	65.97
1976-77	71.40	18.83	73.03
1977-78	75.86	20.06	76.00
1978-79	68.80	21.70	84.20
1979-80	71.90	22.87	86.37
1980-81	77.40	25.10	89.79

Note: Coal consumption excludes use of coal for colliery consumption and power generation; consumption of oil excludes oil used for power generation and non-energy purposes and refinery losses; consumption of electricity is at the consumer end.

Sources: Thro' 1978-79 Fuel Policy Committee Report 1974 and Working Group on Energy Policy 1979. Figures for the years 1979-80 and 1980-81 have been obtained from various annual publications viz. All India Coal Statistics; Indian Petroleum and Petro-chemicals Statistics; and General Review of public Electricity Supply.

....

TABLE 2.3

Total Consumption of Commercial Energy Fuel-Wise
(Million Tonnes of Coal Replacement)

Year	Coal	Oil	Electricity	Total
1953-54	20.70	23.00	7.60	60.11
1954-55	20.50	25.73	8.40	62.67
1955-56	20.00	30.30	9.40	60.50
1956-57	30.70	31.16	10.20	72.06
1957-50	34.60	33.93	11.80	80.33
1950-59	36.10	36.13	13.20	85.43
1959-60	35.70	40.07	15.40	91.17
1960-61	40.40	43.86	16.90	101.16
1961-62	44.10	48.51	19.37	111.90
1962-63	49.10	54.53	22.57	126.20
1963-64	48.60	56.21	25.21	130.02
1964-65	48.30	60.41	27.76	136.47
1965-66	51.00	64.61	30.56	146.97
1966-67	52.30	69.07	33.21	154.58
1967-68	54.50	73.35	36.76	164.61
1960-69	53.00	82.27	41.46	176.73
1969-70	56.66	90.06	45.02	191-74
1970-71	51.35	97.19	48.65	197.19
1971-72	54.14	103.48	51.25	208.07
1972-73	53.14	110.83	54.15	218.12
1973-74	59.91	114.14	55.52	229.57
1974-75	67.10	112.45	58.17	237.72
1975-76	70.96	115.64	65.97	252.57
1976-77	71.40	122.40	73.03	266.83
1977-78	75.86	130.39	76.00	282.25
1978-79	68.00	141.05	84.20	294.05
1979-80	71.90	140.66	86.37	307.01
1980-81	77.40	163.67	89.79	330.86

TABLE 2.4

Trends in Share of Different Energy Forms in Total Commercial Energy Consumption

Year	Percentage share in total commercial energy consumption		
	Coal	Oil	Electricity
1953-54	47.75	39.61	12.64
1954-55	45.48	41.12	13.40
1955-56	42.04	44.23	13.73
1956-57	42.60	43.24	14.16
1957-58	43.07	42.24	14.69
1958-59	42.26	42.29	15.45
1959-60	39.16	43.95	16.89
1960-61	39.94	43.36	16.70
1961-62	39.38	43.32	17.30
1962-63	38.91	43.21	17.88
1963-64	37.38	43.23	19.39
1964-65	35.39	44.27	20.34
1965-66	35.25	43.96	20.79
1966-67	33.83	44.68	21.49
1967-68	33.11	44.56	22.33
1968-69	29.99	46.55	23.46
1969-70	29.55	46.97	23.48
1970-71	26.04	49.29	24.67
1971-72	25.92	49.54	24.54
1972-73	24.36	52.25	24.03
1973-74	26.10	49.72	24.18
1974-75	28.23	47.30	24.47
1975-76	28.10	45.79	26.12
1976-77	26.76	45.87	27.37
1977-78	26.88	46.20	26.92
1978-79	23.40	47.97	28.63
1979-80	23.45	48.42	28.13
1980-81	23.39	49.47	27.14

2.9 The analysis of the trends in energy consumption for the five year sub-periods between 1953-54 to 1970-71 shows that there has been no dramatic change in the pattern of energy consumption. The period between 1970-75, however, shows a significant change in the oil consumption trend due to very large increase in the price of oil products. In 1972 coal industry was nationalised and this was also expected to have made an impact on the coal consumption in the coming years. Table 2.6 gives the year-wise consumption of coal, oil and electricity for the period 1970-71 to 1980-81 which reveals that the pattern of energy consumption has been undergoing a process of difficult adjustments in response to changes in the relative prices, scarcities and levels of activity in the consuming sectors.

Factors Affecting Energy Consumption

2.10 The increase or decrease of total commercial energy consumption or the consumption of specific energy forms is the result of a complex set of factors like the level of activity in the energy consuming sectors, the availability of different fuels, their relative prices, technological changes in the sectors, changes in the composition and quality of output in the sector, population growth, the degree of urbanisation and changing life - styles. In addition to these factors which are common to all developed countries, in developing countries like

TABLE 2.6

Consumption of Commercial Energy 1970-71 to 1980-81

Year	Coal (million tonnes)	% change over consumption of previous year	Oil (Million tonnes)	% change over consumption of previous year	Electricity (TWH)	% change over consumption of previous year
1970-71	51.35		14.95		48.65	
1971-72	54.14	5.4	15.92	6.5	51.25	5.3
1972-73	53.14	- 1.5	17.05	7.1	54.15	5.7
1973-74	59.91	12.2	17.56	3.0	55.52	2.5
1974-75	67.10	12.0	17.30	- 3.5	58.17	4.8
1975-76	70.96	5.8	17.79	2.8	65.97	13.4
1976-77	71.40	0.6	18.83	5.8	73.03	10.7
1977-78	75.86	6.2	20.06	6.5	76.00	4.0
1978-79	68.80	- 9.3	21.70	8.2	84.20	11.1
1979-80	71.98	4.6	22.87	5.4	86.37	2.6
1980-81	77.40	7.5	25.18	10.10	89.79	4.0

India, the rate of substitution of non-commercial fuel by commercial energy also affects the quantity of commercial energy consumed.

2.11 Energy is consumed in the process of production of goods and services. The consumption of energy, therefore, has a close relationship with the overall growth of the economy or the national income. In India a major portion of the commercial energy is consumed by the Mining and Manufacturing and Transport sectors. The level of activity in the Transport sector in turn is greatly dependent upon production in the mining and manufacturing sector. A close relationship betwen the total energy consumption and the income generated in the industrial sector also exist. However, variations in industrial energy consumption may be due to three very separate factors: absolute output changes, structural changes or energy intensity changes. Due to indivisibilities in energy-using equipment such as boilers, reduction in outputs may result in higher energy coefficients per unit of output. While increasing energy consumption has a clear linkage with economic progress, an examination of this relationship more closely in the context of economic development is useful for evaluating energy resources development strategies for various energy producing sectors. A rough idea of this relationship can be had from the rates of growth of commercial energy and the rates of growth of GDP and Value added in industry. Table 2.7 gives these rates of growth in the different sub-periods from 1953-54 to 1980-81.

TABLE 2.7

Rates of Growth of Commercial Energy, GDP and Value Added in Industry 1953-54 to 1980-81

(Average Annual Compound

Period	Rates of growth of consumption of				Rates of Growth	
	Total Commercial Energy	Coal	Oil	Electricity	GDP *	Value Added in Industry
Short-term						
1953-54 to 60-61	7.71	5.0 6.10	9.12	12.09	3.9	6.8
1960-61 to 65-66	7.76		8.05	12.60	2.7	7.3
1965-66 to 70-71	6.05	-0.20	8.31	9.70	4.9	3.2
1970-71 to 75-76	5.21	6.20	3.50	6.30	3.1	3.4
1975-76 to 80-81	5.6	1.0	7.3	6.4	3.4	4.9
Long-term						
1953-54 to 70-71	7.23	3.40	8.62	11.51	3.8	5.8
1953-54 to 75-76	6.78	4.20	7.50	10.33	3.6	5.3
1953-54 to 80-81	6.5	3.8	7.4	9.6	3.6	5.2
1960-61 to 70-71	6.09	2.43	8.28	11.10	3.7	5.2
1960-61 to 75-76	6.35	3.03	6.61	9.51	3.5	4.6
1960-61 to 80-81	6.1	3.3	6.8	8.7	3.5	4.7

* (at 1970-71 prices)

2.12 The rates of increase of total commercial energy over the long run follows the same trend as that of GDP as well as of Value added in industry. Such similarities are, however, not noticed in the different sub-periods. This is due to the sharp variations in the Energy-GDP elasticity in the different periods as would be seen from Table 2.8. However, the long-term energy-GDP elasticity coefficients show a remarkable stability varying marginally around 1.8 and a very low reduction over time is discernible.

2.13 The energy-GDP elasticity coefficient in India is high compared to developed countries where it is lower than unity (Table 2.8 1) due to gradual increase in fuel utilisation efficiency. In India, a part of the apparent increase in energy consumption is due to the substitution of commercial energy for non-commercial fuels, whose utilisation is not taken into account in the computation of the energy-GDP elasticity coefficients. Significantly, however, a very small decreasing trend in the elasticity coefficient is noteworthy.

The International Institute of Applied Systems Analysis (IIASA) at Vienna has computed commercial energy: GDP elasticities for the period 1950-1975 for various regions of the world as shown below. India's estimate is also included in the table for the purpose of comparison.

Region	Commercial Energy GDP Elasticity
North America	0.04
CONECON	0.68
West Europe	
Japan, Australia & New Zealand	0.64
Latin America	1.21
Africa, S.E. Asia and South Asia	1.42
Middle East, North Africa	1.17
China, Mongolia	1.53
World	0.87
India (1953-78)	1.35

TABLE 2.8

Energy-GDP Elasticity Coefficients in India

Period	Energy/GDP Elasticity Coefficients
1953-54 to 1960-61	1.98
1960-61 to 1965-66	2.07
1965-66 to 1970-71	1.23
1970-71 to 1975-76	1.71
1975-76 to 1980-81	1.65
1953-54 to 1970-71	1.90
1953-54 to 1975-76	1.80
1953-54 to 1980-81	1.81
1960-61 to 1970-71	1.86
1960-61 to 1975-76	1.81
1960-61 to 1980-81	1.74

TABLE 2.8.1

Energy-GDP Elasticities in Selected Countries

Country	Energy-GDP Elasticity Coefficient 1953 to 1970
1. France	0.76
2. Germany (FRG)	0.73
3. U.K.	0.42
4. U.S.A.	0.81
5. U.S.S.R.	0.84

Source: Working Group on Energy policy 1979

Energy Consumption and Gross Domestic product:

2.14 There is an accepted link between increasing energy consumption and growing national output. With the expansion of the industrial base, growing energy consumption is a natural corollary. Some of the recent studies have examined the relationship between energy consumption and national income. The basic conclusion of these studies is that 'the higher a nation's income or output on the current international scale, the higher, in general, its level of energy consumption; as its GNp rises over time, so does its energy consumption - in close, even if not proportionate, conformity'.

2.15 The relationship between energy supply and economic development of a country may be more or less self-evident but the findings of the recent research studies are not able to establish the chain of causation between these two factors. Energy is required to support a growing industrial sector. Conversely, progress in energy intensive industrial development will lead to increased energy production and consumption per capita. Increasing living standards lead to increasing energy consumption because of comfort needs that must be satisfied by energy intensive devices such as automobiles, appliances, air conditioning etc.

TABLE 2.9

Gross Domestic product at Factor Cost of 1970-71 prices

(Rs. crores)

Year	Value Added in			Total GDP
	Manufacturing Total (Registered and unregistered sectors)	Mining & Quarrying	Manufacturing and Mining Total	
(0)	(1)	(2)	(3)	(4)
1950-51	1750	132	1882	17536
1951-52	1700	150	1950	17883
1952-53	1850	155	2005	18517
1953-54	1901	157	2130	19688
1954-55	2136	164	2300	20233
1955-56	2309	167	2476	20870
1956-57	2493	177	2670	22013
1957-58	2585	190	2775	21631
1958-59	2697	195	2892	23465
1959-60	2883	207	3090	23894
1960-61	3135	238	3373	25534
1961-62	3435	251	3686	26440
1962-63	3771	286	4057	27003
1963-64	4080	292	4372	28380
1964-65	4402	297	4699	30617
1965-66	4456	337	4793	29023
1966-67	4398	347	4745	29307
1967-68	4477	358	4835	31068
1968-69	4678	358	5036	32725
1969-70	5179	375	5554	34802
1970-71	5223	378	5601	36736
1971-72	5367	385	5752	37313
1972-73	5590	406	5996	36910
1973-74	5861	412	6273	38646
1974-75	6004	439	6443	38916
1975-76	6128	480	6608	42662
1976-77	6660	498	7166	42986
1977-78	7100	512	7612	46773
1978-79	7881	523	8404	49463
1979-80	7735	527	8262	46854
1980-81	7866	546	8412	50526

Source: National Accounts Statistics
195051 to 1969-70 Jan'79
1970-71 to 1980-81 Feb'80

2.16 It may be difficult to establish causal relationship but it may be useful to determine the existence of statistical relationship between GDP and energy consumption.

2.17 In order to investigate this hypothesis, data on Gross Domestic product (at 1970-71 prices) and total commercial energy consumption from 1953-54 to 1980-81 has been used. The data for this analysis are contained in Tables 2.2 and 2.9. As the direction of causation is not established, the following relationships were attempted.

(a) GDP as a function of energy consumption.
(b) Energy consumption as a function of GDP

Both the log-log and linear forms were computed and the following equations obtained.

Regression relationship - Linear

1. E = - 112.58 + .0087 Y
(.00018) Standard error
T= 47.427
R = 0.99 R Bar Square = 0.988
F = 2249 DWS = 1.96

2. $Y = 13205.8 + 113.99\,E$

(2.40) Standard error

T = 47.43

R = 0.99 R Bar Square = 0.988

F = 2249 DWS = 1.98

Regression relationship - Log-log

3. $\ln E = -13.640 + 1.802 \ln Y$

(.040) Standard error

T= 37.60

R = 0.99 R Bar Square = 0.98

F = 1414 DWS = 1.047

4. $\ln Y = 7.620 + 0.545 \ln E$

(.014) Standard error

T = 37.6

R = 0.99 R Bar Square = 0.98

F = 1414 DWS = 0.98

In the above regression equations E is total energy consumption in million tonnes of coal replacement and Y is Gross Domestic product (at 1970-71 prices) in crores of Rupees.

2.18 It is interesting to find that both the log-log and linear forms have given very good fits. /statistical This is a/ identity in two variable case. Thus clearly there was a very close correspondence between GDP and energy consumption during the time period represented by the data. The correspondence of this relationship in the developed countries indicates its continuance through advanced stages of development.

2.19 While equations (2) and (4) indicate that increasing economic activity stimulates greater energy consumption, the other two equations imply that in the Indian context, energy does matter, that inadequate supplies of energy can inhibit development, and that assurance of an adequate supply and mix of energy inputs can stimulate growth. From time to time, power shortages have affected economic activity in both the industrial and agricultural sectors. Coal shortages have caused low utilization of installed capacities in major coal consuming industries including steel and thermal power plants. Fertilizer production has been adversely affected many times by inadequate energy supplies. The contention, therefore, is that inadequate energy supplies can result in lower industrial production and reduce the rate of economic growth.

2.20 In his recent study of 'Energy resources and economic development in India', Wallace Tyner states that 'uncertainty regarding future adequacy of energy supply could be a deterrent to both private and public sector investment in activities which are highly dependent on energy inputs. Expectations of energy shortages could certainly lead to reduction in investment levels. Similarly, expectations of abundant energy supplies at reasonable costs could provide a stimulus to investment.' Therefore, both current production levels and investment levels which reflect future production potential are dependent on reliable energy supplies. Adequate supplies of energy are an important component, if not pre-requisite, of sustained economic growth.

2.21 The unbalanced growth framework developed by A.O. Hirschman is quite relevant to explain the energy-GDP relationship. Power and other forms of energy fall into the catogory of Hirschman's Social Overhead Capital (SOC). Provision of an adequate supply of power at reasonable prices can induce investment in power intensive Directly Production Activity (DPA) through what Hirschman calls 'permissive sequence'. But shortages of power would cause production problems and higher costs in the DPA sector which will lead to more investment in

in energy sectors through 'Compulsive sequence' because DPA investments will 'compel' further investments in the energy sector. Hirschman, however, argues that 'there is no doubt that neglect of public utilities can become a more serious drag on economic progress .... that there is a minimum SOC/DPA output ratio, i.e. a point where DPA output can only be increased if SOC (i.e. energy) is expanded'. Hirschman's argument has special relevance to India where expansion of energy resource development can increase the rate of economic growth through maintaining and increasing the productive capacity of the Indian economy.

Energy Consumption and Sectoral GDP:

2.22 The statistical regression of energy consumption (global as well as sectoral) on the activity levels of the economy as a whole and on the sectoral level was attempted. Some results of global regression analysis are indicated above. Other results of regression analysis of energy consumption and sectoral activity in the mining and manufacturing sector are set out in Annexure-I and Annexure-II.

Chapter - 3

Commercial Energy Consumption in the Industry Sector

Trends and Pattern in the Energy Consumption

3.1 The manufacturing sector is the single largest user of commercial energy in India. Over the last thirty years, consumption of electricity in manufacturing and mining has grown around 9.3 per cent per annum and that of oil and coal by 4.1 per cent and 6.0 per cent respectively. Overall energy consumption grew at an annual growth rate of 6.8 per cent during 1953-80 as compared to 5.2 per cent increase in value-added in manufacturing and mining sector. However, the growth in energy consumption appears to have slowed down during the last one and a half decade. Table 3.5 gives the rates of growth of consumption both short-term and long-term of commercial energy in the industry sector. As against 12 per cent and 6.6 per cent growth registered respectively by electricity and oil during 1953-70, the growth rate of electricity during 1970-80 was around 5 per cent and that of oil nearly zero per cent. However, the consumption of coal recorded a growth of 10.3 per cent during 1970-75 and 5.6 per cent in the next quinquennium. The relative contribution of the different sources of energy to the development of manufacturing sector can be gauged from the trends and pattern of their consumption depicted in Tables 3.1 to 3.4.

TABLE 3.1

Commercial Energy Consumption by Mining & Manufacturing
(Million Tonnes of Coal Replacement)

Year	Coal	Oil	Electricity	Total
1953-54	13.80	3.65	5.00	22.45
1954-55	13.80	4.24	5.60	23.64
1955-56	13.30	4.70	6.30	24.30
1956-57	13.40	5.05	6.90	25.35
1957-58	16.60	5.54	7.70	29.84
1958-59	17.60	5.95	8.80	32.35
1959-60	16.80	6.44	10.30	33.54
1960-61	20.90	7.23	11.60	39.73
1961-62	24.20	7.69	14.46	46.35
1962-63	28.00	9.33	16.50	53.83
1963-64	27.00	6.56	19.13	52.69
1964-65	27.20	7.15	20.92	55.27
1965-66	30.10	8.09	22.62	60.81
1966-67	30.40	9.06	24.38	63.84
1967-68	33.00	9.85	26.79	69.64
1968-69	31.90	10.39	29.93	72.22
1969-70	35.34	9.36	32.34	77.04
1970-71	31.07	10.90	34.35	76.32
1971-72	37.06	8.50	41.49	87.05
1972-73	43.05	9.64	37.58	90.27
1973-74	42.47	9.93	37.92	90.32
1974-75	42.73	9.61	38.49	90.83
1975-76	50.66	9.63	43.35	103.64
1976-77	55.81	10.00	48.12	113.93
1977-78	61.27	9.78	49.39	120.44
1978-79	60.55	10.00	53.90	124.45
1979-80	60.81	10.71	53.26	124.78
1980-81	66.39	10.81	55.58	132.78

Sources: Fuel policy Committee Report 1965 (Thro' 1970-71) Working Group on Energy Policy 1979; and various issues of General Review of public Electricity Supply; All India Annual Coal Stastics; and Indian Petroleum and petro-chemicals Statistics.

Note: Coal consumption in mining and manufacturing includes consumption of steel plants, cement, cotton, jute, paper, brick industries.

2. Figures for oil are estimated consumption of Furnace Oil, LSHS/HHS, LpG and small quantity of HSD used in manufacturing process.

TABLE 3.2

Trends in Share of Different Forms in Total Commercial Energy Consumption by Mining and Manufacturing Sector

(percentage share in total energy consumed)

Year	Coal	Oil	Electricity
1953-54	61.47	16.26	22.27
1954-55	58.38	17.94	23.68
1955-56	54.73	19.34	25.93
1956-57	52.86	19.92	27.22
1957-58	55.63	18.57	25.80
1958-59	54.40	18.40	27.20
1959-60	50.09	19.20	30.71
1960-61	52.61	18.20	29.20
1961-62	52.21	16.59	31.20
1962-63	52.02	17.33	30.65
1963-64	51.24	12.45	36.31
1964-65	49.21	12.94	37.85
1965-66	49.50	13.30	37.20
1966-67	48.00	14.00	38.00
1967-68	47.39	14.14	38.47
1968-69	44.17	14.39	41.44
1969-70	45.87	12.15	41.98
1970-71	40.71	14.28	45.01
1971-72	42.57	9.76	47.66
1972-73	47.69	10.68	41.63
1973-74	47.02	10.99	41.98
1974-75	47.04	10.58	42.38
1975-76	48.88	9.29	41.83
1976-77	48.99	8.78	42.24
1977-78	50.87	8.12	41.01
1978-79	48.62	8.04	43.31
1979-80	48.78	8.58	42.68
1980-81	50.00	8.14	41.86

TABLE 3.3

Consumption of Commercial Energy in Manufacturing & Mining (Mtcr)

Percentage change over consumption of previous year

Year	Coal	Oil	Electricity	Total
1953-54	..	..	..	..
1954-55	..	16.16	12.00	5.30
1955-56	3.62	10.65	12.50	2.79
1956-57	0.75	7.45	9.52	4.32
1957-58	23.88	9.70	11.59	17.71
1958-59	6.02	7.40	14.29	8.41
1959-60	- 4.55	8.24	17.05	3.68
1960-61	24.40	12.27	12.62	18.46
1961-62	15.79	6.36	24.66	16.66
1962-63	15.70	21.33	14.11	16.14
1963-64	- 3.57	-29.69	15.94	- 2.12
1964-65	0.74	8.99	9.36	4.90
1965-66	10.66	13.15	8.13	10.02
1966-67	1.00	11.99	7.78	4.98
1967-68	8.55	8.72	9.89	9.09
1968-69	- 3.33	5.48	11.72	3.70
1969-70	10.78	- 9.91	8.05	6.67
1970-71	-12.08	16.45	6.22	99.07
1971-72	19.20	-22.02	20.79	14.06
1972-73	16.16	13.41	- 9.42	3.70
1973-74	- 1.35	3.01	0.90	0.06
1974-75	0.61	- 3.22	1.50	0.56
1975-76	18.56	0.21	12.63	14.10
1976-77	10.17	3.84	11.00	9.93
1977-78	9.78	2.20	2.64	5.71
1978-79	- 1.18	2.25	9.13	3.33
1979-80	0.43	7.10	- 1.19	0.27
1980-81	9.10	0.93	4.36	11.04

TABLE 3.4

Energy Consumption in Mining & Manufacturing as a percentage of Total Consumption in the Economy

Year	Coal	Oil	Electricity	Total
1953-54	48.00	15.33	65.79	37.35
1954-55	49.42	16.48	66.67	37.72
1955-56	46.18	15.51	67.02	35.47
1956-57	43.65	16.21	67.65	35.18
1957-58	47.98	16.33	65.25	37.15
1958-59	48.75	16.47	66.67	37.87
1959-60	47.06	16.07	66.86	36.79
1960-61	51.73	16.48	68.64	39.27
1961-62	54.86	15.85	74.65	41.39
1962-63	57.03	17.11	73.11	42.65
1963-64	55.55	11.67	75.88	40.52
1964-65	56.31	11.84	75.36	40.50
1965-66	58.11	12.52	74.02	41.38
1966-67	58.13	13.12	73.41	41.30
1967-68	60.55	13.43	72.88	42.31
1968-69	60.19	12.63	72.19	40.86
1969-70	62.37	10.39	71.83	40.18
1970-71	60.51	11.22	70.61	38.70
1971-72	68.45	8.21	80.96	41.68
1972-73	81.01	8.70	60.40	41.39
1973-74	70.89	8.70	68.30	39.34
1974-75	63.68	8.55	66.17	38.21
1975-76	71.39	8.33	65.71	41.03
1976-77	78.17	8.17	65.89	42.70
1977-78	80.77	7.50	64.99	42.67
1978-79	88.01	7.09	64.01	42.32
1979-80	84.48	7.20	61.66	40.64
1980-81	85.78	6.60	61.90	40.13

Note: Coal consumption in the economy excludes use of coal for colliery consumption and power generation.

Total consumption of oil in the economy excludes oil used for power generation and non-energy purposes and refinery losses; and

Total consumption of electricity is at the consumer and for the economy as a whole.

3.2 It is difficult to analyse the consumption pattern of industrial sector and establish the basis for projection 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. Manufacturing sector consists of two distinct parts one referred to as the registered sector consisting of factories registered under the Factories Act and the other the unregistered sector. The unregistered sector includes not only unregistered industrial establishments but also a very large number of household industries whose total number has been reported as 2.2 millions in the 1971-census. The unregistered sector is a very important contributor to the total industrial production and contributes over one-third of the total value-added in industries. Though a major portion of the commercial energy appears to be consumed in the registered units, the unregistered sector also consumes significant quantities of commercial energy. However, the unregistered sector is relatively less energy intensive as it depends on large quantities of non-commercial fuels, animal power and human labour for performing task which in the registered sector might involve the use of commercial fuels.

Table 3.5: Rates of Growth of Consumption of Commercial Energy in Industries Sector

(Average annual Compound %)

period	Rate of Growth of Value added in industries sector (at 1970-71 prices)	Rate of growth per year consumption			
		Commercial Energy	Coal	Oil	Electricity
Short-term					
1953-60	6.8	8.5	6.1	10.2	12.8
1960-65	7.3	8.9	7.6	2.3	14.3
1965-70	3.2	4.8	0.5	6.2	8.7
1970-75	3.4	6.4	10.3	- 2.5	4.8
1975-80	4.9	5.0	5.6	2.3	5.1
Long-term					
1953-70	5.8	7.5	4.9	6.6	12.0
1953-75	5.3	7.2	6.1	4.5	10.3
1953-80	5.2	6.8	6.0	4.1	9.3
1960-70	5.2	6.7	4.1	4.2	11.5
1960-75	4.6	6.6	6.1	1.9	9.2
1960-80	4.7	6.2	6.0	2.0	8.1

Energy: GDP Elasticity Coefficients for the Industrial Sector

3.3 Energy: GDP Co-efficients are estimated to indicate how much energy would be required for effecting a 1 per cent change in GDP. Lower the co-efficients, more efficient the energy use in the sector.

Table below gives fuel-wise energy: GDP elasticity coefficient with reference to commercial energy consumption in the industries sector and the sectoral GDP.

Table: 3.6.1: GDP Elasticity Coefficients* for the Industrial Sector (w.r.t. sectoral energy consumption and GDP)

	Coal	Oil	Electricity	Gross Energy
1953-54 to 1960-61	0.927	1.40	1.93	1.29
1953-54 to 1970-71	1.092	0.95	2.03	1.37
1953-54 to 1980-81	1.212	0.60	1.85	1.36
1961-62 to 1970-71	0.734	0.71	2.16	1.26
1961-62 to 1980-81	1.273	0.36	1.62	1.30
1971-72 to 1980-81	1.343	0.37	1.00	1.09
1973-74 to 1980-81	1.290	0.27	1.19	1.15

*derived from log-log regression relationship between fuel and value-added.

3.4 From the table it appears that the long-run total commercial energy: GDP coefficient has relatively remained stable. However, the commercial energy: GDP elasticity coefficient which was 1.26 for the period 1961-62 to 1970-71 went up to 1.30 in the next decade. Elasticity coefficients of individual fuels have shown wide variations. Coal coefficient, however, has generally gone up. Of particular interest are the coefficients for the period 1973-74 to 1980-81 after the international oil price increase. The coefficient has gone down in the case of oil in particular.

Intensity of Energy Use:

3.5 The intensity of energy use, defined as the ratio of the quantity of total commercial energy used per unit of value-added in the industry sector has been steadily increasing over time. The total commercial energy consumed in mtcr per Rs. 100 crores of value-added (1970-71 prices) in manufacturing and mining was as given below:

1953-54	1.05
1960-61	1.10
1970-71	1.36
1980-81	1.58

3.6 An examination of fuel-wise energy intensities, carried out in detail in Chapter 5 (Table 5.1) indicates that the increase in electricity consumption is the main reason for the rise in the intensity of energy consumption although the rate of growth of intensity of electricity consumption has been steadily declining (Table 3.6.2). On the other hand the combined intensity of coal and oil have shown greater stability. Coal is is used for providing heat and to raise steam in the industries sector and can be substituted by fuel oil of roughly half the weight of coal used. The Working Group on energy policy analysed the reasons for the stability of oil and coal intensities. It stated:

> "Except in the case of sugar, the other industries seem to be gradually switching to the use of commercial fuels. Such shifts would increase the intensity of coal and oil use. On the other hand, there is a gradual replacement of the old boilers of low efficiency by more energy efficient equipment and this would decrease the intensity of energy use. These two factors seem to have led to an apparent stability".

Table 3.6.2: Intensity of Electricity Consumption in Industries

	1960-61	1965-66	1970-71	1975-76	1980-81
1) Value added in industry (Rs. 100 crores at 1970-71 prices)	33.73	47.93	56.01	66.00	84.12
2) Electricity consumed (TWH)	11.60	22.62	34.35	43.35	55.50
3) Intensity of Electricity Consumption (kWH/Rs.V.A)	0.34	0.47	0.61	0.66	0.66
4) Rate of increase in intensity per year		6.6	5.4	1.6	nil

Industrial Structure and Energy Consumption

3.7 Industrial structure here refers not only to the product mix of total industrial output, but also to the mix of fuel consumed. Industrial energy consumption is a function, inter alia, of the structure of output. Here we look at our structure of industrial output and its implications for industrial energy demand. A comparison is also made with three other developing countries namely Brazil, Korea and Kenya. Table 3.6.3 presents structure of their economies.

Table 3.6.3: Structure of Economies of Four Developing Countries

	1977 GDP per capita (1977 US $)	percent of 1977 GDP by industry (%)	1977 industrial GDP in millions (1977 US $)	Rate of industrial Growth (1976-77)
Brazil	1,410	26	42,609	11
India	160	10*	16,000*	5
Kenya	290	13	560	0
Korea	900	30	10,546	23

* Data for 1976

Source: World Bank, Atlas; World Bank data services and U.N. Statistical Year Book

Table 3.6.4: Rate of Growth of Industrial Energy Demand

	percentage of total energy consumed by the industrial sector. (%)	Rate of growth of industrial energy demand (1967-76)	Industrial Energy Consumption/ Industrial Output Ratio (t oe $ million 1977 output	
			1967	1976
Brazil	24	10	804	612
India	34	7	2,367	2,568
Kenya	10*	16	391	871
Korea@	36	20	701	693

Source: International Energy Agency (Paris, OECD, 1979); U.N. Year Book of Industrial Statistics

* Manufacturing Sector only
@ Data for 1966-74

3.8 A comparison of the structural trends reveals that India's industial output has grown only slowly but its requisite energy inputs were much higher compared to Brazil, Kenya and Korea. The industrial structure of India is characterized by a wide range of activities. The basic pattern of structural change, starting in the 1950s and continuing into the 1970s and 1980s, was an increasing role for capital goods industries. The share of [illegible] energy intensive industries is quite high and some of the energy intensive industries like basic industrial chemicals, pharmacenticals, paper and paper products have been more dynamic.

3.9 As noted earlier, India's industrial energy consumption is extremely large, especially considering the relatively small role of industry in overall economic activity. Also, the Indian industries energy requirements per dollar of output are far larger than those of the other three countries. One important explanation for this high industrial energy demand would appear to centre on the fuel composition of industrial energy demand. Since India has abundant coal resources most industries developed by utilizing coal as their energy source. However, coal is generally used in less efficient industrial boilers. Secondly enormous amounts of energy used in industry are discarded as waste heat and the efficiency of energy use in the technical sense has been of limited concern to the industries.

3.10 Two other factors might also have resulted in the apparently high industrial energy output ratios in India. First, heavy energy-intensive industries comprise the bulk of industrial output. Second, some degree of diseconomics of scale in energy usage in large number of small and old establishments. The question of efficiency in energy utilization has, however, been examined in detail in chapter 5. Here it may be suffice to say that the important role of coal and the development of heavy industries explain most of India's high industrial energy consumption.

Energy Intensities - Historical Trends

3.11 Some of the industries consume large quantities of energy per unit of value added. For example consumption of coal per unit of value added contributed by steel industry is very high compared to the ratio for other industries. An attempt has been made to study the long-term historical trends in commercial energy consumption and value-added by selected large Energy Consuming (LEC) industries. These include textiles, fertilizers, inorganic heavy chemicals, non-ferrous basic metals, Iron and Steel, refractories, paper and paper board and cement. The analysis is based upon the energy consumption data reported in the census of Manufacturing Industries (CMI) from 1946 to 1958 and from Annual Survey of Industries (census sector) from 1959 onwards. The ASI series is available upto 1973-74.

It may be stated here that a detailed classification change was made when the A.S.I. series was started in 1959 and again in 1973-74 when NIC classification was introduced. Due to several classification changes in the available CMI and ASI series it has been possible to construct comparable energy consumption series for only selected few LEC Industries. Under each industry, the total coal, petroleum, fuels, electricity consumed by that industry is shown separately. However, under petroleum-fuels, the consumption of furnance oil, HSDO, LDO etc., is given collectively under one head as 'petroleum fuels', further, the C.M.I., A.S.I. does not differentiate between consumption in industry-owned transport or power generation units and that in the manufacturing process except that the consumption of motor-spirit is given separately in the latest ASI series. Results of the industry-wise consumption series thus will have to be interpreted with these limitations in view.

3.12 Textile Industry : The consumption of all the forms of commercial energy have increased during the period 1946-1973 (Table 3.7). However, electricity consumption increased five-fold by 1973 as compared to 1946. Textiles are not by themselves highly energy intensive. The energy consumed by Textiles is high due to the high volume of production. Energy intensities have, however, remained fairly stable in the textile industry particularly after 1956. Tables 3.0.1 to 3.0.6 indicate the recent trends in consumption of refined petroleum products, coal and electricity.

TABLE: 3.7

Trends in Energy Consumption in Selected Large Energy Consuming Industries (ASI-(CENSUS SECTOR)

I. TEXTILE INDUSTRY	1946	1951	1956	1973
Coal (million tonnes)	1.84	1.83	2.00	2.38
Oil (mtcr)	0.32	0.40	0.42	1.02
Electricity (billion Kwh)	0.93	1.27	1.98	4.65
Gross Energy Use (mtcr)	3.09	3.50	4.40	8.05
Value Added (million Rs.) (at 1970-71 prices)	3566	3433	3965	7289
Gross Energy use per thousand Rs. Value added (Tonne/thousand Rupees)	0.87	1.02	1.11	1.10

II. FERTILIZER INDUSTRY	1961	1965	1973
Coal (million tonnes)	0.38	0.42	0.73
Oil (mtcr)	.03	0.026	0.40
Electricity (billion kwh)	0.59	1.76	2.07
Gross Energy Use (mtcr)	1.08	2.21	3.20
Value Added (million Rs.) (at 1970-71 prices)	98	132	459
Gross Energy Use per thousand Rs. Value Added (Tonne/thousand Rupees)	10.20	16.74	6.97

III. INORGANIC HEAVY CHEMICALS	1961	1965	1973-7
Coal (million tonnes)	0.29	0.29	0.30
Oil (mtcr)	0.10	0.22	0.40
Electricity (billion kwh)	0.36	0.68	0.89
Gross Energy Use (mtcr)	0.75	1.19	1.59
Value Added (million Rs.) (at 1970-71 prices)	120	226	378
Gross Energy Use per thousand Rs. Value Added (tonne/thousand Rupees)	6.25	5.27	4.21

IV. PAPER & PAPER BOARD	1946	1951	1956	1961	1973
Coal (million tonnes)	0.35	0.45	0.67	1.15	1.47
Oil (mtcr)	0.004	0.006	0.012	0.04	0.28
Electricity (billion kwh)	0.04	0.05	0.12	0.34	0.88
Gross Energy Use (mtcr)	0.394	0.506	.802	1.53	2.63
Value Added (million Rs.) (at 1970-71 prices)	62	93	154	226	688
Gross Energy Use per thousand Rs. Value Added (tonne/ thousand Rupees)	6.35	5.44	5.21	6.77	3.82

V. NON-FERROUS BASIC METALS	1946	1951	1956	1961	1966
Coal (million tonnes)	0.12	0.13	0.14	0.16	0.29
Oil (mtcr)	0.018	0.042	0.040	0.04	0.14
Electricity (billion kwh)	0.008	0.02	0.14	0.41	1.96
Gross Energy Use (mtcr)	0.15	0.19	0.32	0.61	2.19
Value Added (million Rs.) (at 1970-71 prices)	306	145	307	355	548
Gross Energy use per thousand Rs. Value Added (tonne/ thousand Rupees)	0.49	1.31	1.04	1.72	4.00

VI. IRON & STEEL INDUSTRY

	1946	1951	1956	1961	1966	1973-74
Coal (million tonnes)	2.66	3.60	2.60	3.78	5.57	5.76
Oil (mtcr)	0.004	0.010	0.024	0.18	0.36	0.86
Electricity (billion kwh)	0.09	0.14	0.38	0.80	1.74	3.11
Gross Energy Use (mtcr)	2.75	3.75	3.00	4.76	7.67	9.73
Value Added (million Rs.) (at 1970-71 prices)	638	805	1954	883	1624	3086
Gross Energy Use per thousand Rs. Value Added (Tonne/ thousand Rupees)	4.31	4.66	2.85	5.39	4.72	3.15

VII. CEMENT INDUSTRY

	1946	1951	1956	1961	1966	1973
Coal (10^5mtcr)	0.35	1.02	1.67	2.64	2.99	3.86
Oil 10^6(mtcr)		..	0.02	0.04	0.50	0.38
Electricity 10^9(mtcr)	0.03	0.10	0.21	0.46	0.87	1.33
Gross Energy Use (,mtcr)	0.38	1.12	1.90	3.14	4.36	5.57
Value Added 10^6 Rs. (at 1970-71 prices)	46.44	157.55	223.82	234.38	383.15	274.27
Gross Energy Use per thousand Rs. Value Added (Tonne/thousands)	8.18	7.11	8.49	13.40	11.38	20.31

VIII. REFRACTORIES

	1961	1966	1973-74
Coal (million tonnes)	0.18	0.20	0.13
Oil (mtcr)	0.032	0.04	0.08
Electricity (billion kwh)	0.02	0.03	0.03
Gross Energy Use (mtcr)	0.214	0.27	0.24
Value Added (million Rs.) (at current prices)	44	42	108

3.13 Fertilizers Industry : Gross Energy use in the fertilizers industry has steadily increased since 1961. The ASI series indicate greater volatility in the energy intensity of fertilizers industry which could be due to several factors including variations in capacity utilisation, wasteful use of energy due to power-cuts and load shedding etc. Table 3.0.1, which gives the consumption of petroleum-energy by industries, indicates that the consumption of furnace oil has increased from 52 thousand tonnes in 1967 to 1306 thousand tonnes in 1981-82.

3.14 Inorganic Heavy Chemicals : Inorganic heavy chemicals which include caustic soda, soda-ash, calcium carbide, carbon black, titanium-dioxide and other chemicals like aluminium fluoride, calcium carbonate, phosphorous etc. are fairly energy intensive. Their gross energy use has doubled during 1961-1973. However, the energy intensity has declined due to improvements in energy efficiency. Energy constitutes an important segment of their operating cost and is an important determinant factor of the operational viability of the chemicals industry. Energy has thus become an important parameter for choosing

Consumption of petroleum Energy by Industries

Furnace oil including LSHS/HHS/TDO
(Thousand Tonnes)

Industry	1967	1970	1973	1974	1975	1976
Iron and Steel	267	311	439	440	324	402
Textiles	504	590	650	560	590	505
Cement	200	129	204	141	74	43
Ceramics & Glass	100	155	219	205	171	179
Chemicals	341	493	795	715	796	770
Aluminium	50	91	110	96	115	141
Sugar	19	39	59	52	46	52
Mining & Quarrying	75	45	35	125	101	201
Engineering	77	310	361	320	295	277
Fertilizers	52	90	266	285	356	436
Total Industry	1693	2261	3130	2949	2940	3174
Total consumption (all sectors)	3743	4651	5932	5705	5004	5661
% to Grabd Total.	45.23	40.61	52.90	51.69	50.79	56.09

	1977	1978-79	1979-80	1980-81	1981-82
Iron & Steel	471	618	431	417	591
Textiles	523	483	430	611	508
Cement	38	52	154	166	55
Ceramics & Glass	153	134	185	224	181
Chemicals	799	703	811	1040	998
Aluminium	122	121	122	113	98
Sugar	48	42	41	37	26
Mining & Quarrying	175	226	268	275	131
Engineering	229	179	250	195	218
Fertilizers	546	770	755	978	1386
Total Industry	3104	3328	3447	4056	4192
Total Consumption (all sectors)	5845	6668	7081	7474	7184
Industry % to total consumption	53.11	49.91	48.68	54.27	58.35

Note: Separate figures for LSHS/HHS are available since 1978-79

Source: Petroleum & Petro-chemicals Statistics. various issues.

Table 3.8.2: Trends in Consumption of Petroleum Energy by Industry Sector (LPG, HSDO and LDO)

(Thousand Tonnes)

	1967	1970	1980-81	1981-82
LPG	14.4	30.0	57	51
HSDO	106.0	119.0	618	651
LDO	78.0	87.0	202	208

Trends in Consumption of Petroleum Energy in the Economy

(Thousand Tonnes)

	1967	1970	1980-81	1981-82
LPG	74	166	405	492
HSDO	2785	3736	10345	10832
LDO	849	1047	1122	1036

Share of Industry in Total Consumption of Petroleum Energy (Percentages)

	1967	1970	1980-81	1981-82
LPG	19.46	18.07	14.07	10.37
HSDO	3.81	3.19	5.97	6.01
LDO	9.19	8.31	18.00	20.08

Source: Indian Petroleum & Petro-chemical Statistics - Various Issues

Note: Industry sector includes Iron & Steel, Textiles, Cement, Ceramics & Glass, Chemicals X& allied, Aluminium, Sugar, Mining & Quarrying, Enginerring and Fertilizers.

Table 3.0.3

Sectoral Consumption Pattern of Coal in India (1950-51 to 1982-83)

(million tonnes)

Major sector/industry	1950-51	1960-61	1970-71	1974-75	1975-76	1976-77
Railways	10.3	15.7	15.34	14.14	14.30	13.17
Power stations	2.3	6.2	10.80	20.30	23.04	26.85
Iron and Steel	3.9	9.8	13.53	15.92	18.80	20.34
Cement	1.2*	2.4	5.63*	4.36	4.44	4.97
Brick	1.3	1.3	. .	1.40	3.34	4.33
Cotton Textiles	1.5	1.8	- -	2.08	2.23	2.41
Jute	0.5	0.3	--	0.19	0.21	0.18
Paper	0.5	0.8	--	1.40	1.26	1.75
Domestic Soft Coke	1.4	2.6	3.24	4.02	3.63	4.02
Other Industries	5.88	13.09	19.99	19.75	17.52	18.54
Colliery Consumption	-	2.53	-	2.67	2.78	3.29

Major Sector/Industry	1977-78	1978-79	1979-80	1980-81	1981-82	1982-83
Railways	12.93	12.13	11.36	11.81	11.26	10.99
Power Stations	25.65	24.80	30.03	28.15	44.42	49.45
Iron & Steel	21.54	20.26	19.85	21.01	22.28	22.39
Cement	4.73	4.88	3.87	4.75	5.72	6.14
Brick	3.28	1.56@	0.54@	0.44@	0.66	-
Cotton Textiles	2.50	2.34	1.99	1.97	2.37	-
Jute	0.21	0.16	0.14	0.13	0.17	-
Paper	1.88	1.72	1.54	2.14	2.46	-
Domestic Soft Coke	3.54	2.68	3.38	3.05	3.09	-
Other Industries	23.81	26.23	29.31	32.10	24.51	35.83
Colliery Consumption	3.32	3.40	3.57	3.85	4.09	-

* includes consumption by brick industry

@ supply by rail only

Note 1: Separate figures for some of the industries for some years are not available.

2: Figures of coal consumption for power stations for 1981-82 & 1982-83 are provisional.

3. Figures of coal consumption for power stations excludes middlings (coal with high ash, content left after washing but usable for power and certain other purposes.)

4. Total availability of coal for industrial consumption, after adjustment of off take, is equal to production plus Imports minus exports plus changes in pithead and industrial stocks.

Data Sources: 1950-51 to 1970-71 Energy Policy for India by R.K. Pachauri
All India Coal Statistics, various issues.

Table 3.8.4: Consumption of Electricity in Selected Industries

Category	Consumption as % of total power consumption by industries	
	1969	1979-80
Aluminium (Primary)	9.35	10.13
Cement (Primary)	4.38	4.75
Chemicals	5.39	13.72
Fertilizers	10.47	11.66
Iron & Steel (Primary)	10.02	12.17
Paper	2.97	4.43
Textiles	10.94	15.73

Source: General Review

Table 3.8.5: Progress in Power Consumption

(MkWh)

	Total Energy Sold (Utilities)	Total Power Consumed (Utilities +Non-Utilities)	Electricity sales as industrial power by utilities	Non-Utilities generation	Total
1951	= 4793	6415			
1952	5006	6687			
1953	5597	8012			
1954	6251	8165			
1955	7111	9137			
1956-57	7959	10151			
1957-58	9345	11692			
1958-59	10718	13058			
1959-60	12407	14940			
1960-61	13840	16574			
1961-62	16448	19488			
1962-63	18670	22085			
1963-64	21794	25830			
1964-65	24219	27964			
1965-66	26735	30568			
1966-67	29128	33188			
1967-68	32737	36855			
1968-69	37352	41098			
1969-70	41062	45114			
1970-71	43724	48534	29558	5384	34942
1971-72	47063	52305	31626	..	
1972-73	49088	54398	32250	..	
1973-74	50246	56202	32459	6107	38566
1974-75	52632	58251	32684	6488	39172
1975-76	60246	66022	37569	6695	44264
1976-77	66609	73025	41610	7240	48850
1977-78	69255	76814	42365	7559	50194
1978-79	77293	84900	47728	7573	55301
1979-80	79084	87277	45955	8157	54112
1980-81	82367	90772	48069	8405	56474
1981-82	..	..	..	8600	..
1982-83	95917		53522		

1. Total power consumption = Power sold by utilities (excluding energy used in power station auxiliaries) plus total general by captive plants.

   Power consumption by Industrial Sector refers to total power sold as industrial power by utilities plus Non-utilities generation by industrial units (excluding railways) minus energy used in station auxiliaries = Net energy consumed.

Table 3.8.6: Coal Production in India (1950-1982)

Coking plus Non-coking coal (Excl. Lignite)
(million tonnes)

	Production	Year	Production
1950	32.8	1967-68	68.52
1951	34.43	1968-69	71.41
1952	36.30	1969-70	75.71
1953	35.98	1970-71	72.95
1954	36.88	1971-72	72.06
1955-56	39.00	1972-73	76.87
1956-57	40.94	1973-74	78.20
1957-58	44.81	1974-75	88.41
1958-59	46.68	1975-76	99.68
1959-60	48.59	1976-77	101.04
1960-61	53.80	1977-78	100.97
1961-62	55.18	1978-79	101.95
1962-63	63.45	1979-80	103.95
1963-64	65.13	1980-81	114.01
1964-65	62.78	1981-82(P)	124.23
1965-66	67.80	1982-83(P)	130.61
1966-67	68.56	1983-84(P)	131.89

Sources: S. Mohan Kumara mangalam :
Coal Industry in India (Through 1972-73)
and Economic Surveys 1980-81 and 1983-84
(P) = Provisional

technologies and making technological changes which result in maximising energy efficiency. Available data on power consumption norms for caustic soda suggest that the total power requirement for production of one metric tonne of caustic soda is approximately 3500 kwh with the present Mercury Cell plants which will go down to 2700 kwh in the newly installed Membrane Cell Plant*. The current price structure of energy and the consumption norms thus raise many questions regarding energy conservation, inter-fuel substitution and more energy efficient pollution free technologies particularly in the energy intensive chemicals and other industries.

3.15 Paper and Paper Board Industry: The installed capacity in the paper and paper board industry has increased from 0.14 million tonnes in 1951 to 1.54 million tonnes by the end of 1980 with a total investment of about Rs.1000 crores**. Most of the paper units have come up during what could be termed as, the low-cost energy era and while choosing the technology enough attention was perhaps not paid to the energy efficiency of the process.

Paper making is an energy intensive process. With the expansion of the capacity, requirement of gross energy has gone up from 3.94 lakh tonnes coal replacement in 1946 to 26.3 lakh tonnes coal replacement in 1973 as shown in Table 3.7. In 1980 the requirement of power of the industry was

---

* Report of the Seventh Plan Working Group on Inorganic Chemicals.

** Report of the Workshop on Energy sponsored by ICICI.

around 1.7 billion kWh which was expected to go upto 2.4 billion kWh by the year 1985. The estimated coal and power requirements of the paper industry in 1985 would account for approximately 6.1 per cent abd 2.7 per cent respectively of the total estimated industrial demand in that year of the respective sources. Tables 3.8.1 to 3.8.4 indicate the recent trends in the consumption of commercial energy in paper and other industries.

Energy intensities which have remained quite stable till 1961 had remarkably come down in 1973. A variety of factors such as (a) product mix, (b) raw material finish, (c) capacity utilisation, (d) type of fuel used, (e) extent of the plant integration, its size and age, (f) use of fuel saving technology, etc. influence energy consumption of different units in the industry.

In a background paper on the paper industry prepared for the workshop on Energy sponsored by ICICI in 1981 trends in energy prices and the cost of energy per tonne of paper output were reviewed for nine sample units for 1974-1980 and it was

observed as under:

Trends in Energy Prices 1974-1980

	Coal* Rs. per tonne	Furnace Oil Rs. per Kl	Electricity purchased (paise per Kwh)	Cost of Energy per tonne of output Rs.
1974	97.0	350	10	300
1978	141.3	1006	28	626
1979	148.2	1007	28	694
1980	209.7	1267	30	857

*Includes cost of transportation.

The background paper further observed that the cost of energy per tonne of output has increased more sharply than the unit consumption and that the cost of energy has increased more than per unit realisation. The implication and the lessons are clear that the recent trends in energy consumption and its costs should be reversed through short-term and long-term energy conservation measures. Short-term measures would include improvement in capacity utilisations, and other technical changes while long-run measures would include introduction of 'Total Energy' concept, wherever feasible for recovery of heat-waste, changeover from oil-fired to coal-fired boilers (i.e.) inter-fuel substitution and adoption of financially viable energy conservation schemes through appropriate energy efficient technologies.

3.16 Non-Ferrous Basic Metals:

Gross energy consumed by Aluminium, Copper, Lead and Zinc which was 0.15 mtcr in 1946 had gone up to 2.19 mtcr in 1966 although value added had just increased from Rs. 360 million to Rs. 548 million (at 1970-71 prices) during this period resulting in a steady increase in the energy intensities from 0.49 in 1946 to 4.0 in 1966. Aluminium, Copper and Zinc are highly power-intensive industries and their production has been considerably affected in the recent past on account of shortage of power. Aluminium alone consumed 10 per cent of total power consumption by industries in 1979-80. Aluminium production requires about 16,000 Kwh of power per tonne of metal from bauxite and electric power consumption accounts for nearly 30 per cent of the production cost of aluminium.

Aluminium today is the most important amongst all non-ferrous metals. Next only to steel, it is the most widely used metal in the world. India has a promising future for the aluminium industry in view of the recently discovered large bauxite deposits on the eastern coast. Presently the installed capacity of aluminium is 330,000 t/year. A conservative estimate of the future demand growth rate has been placed at 8 per cent per annum so that the country would need about 1.5 million tonne of metal by 2000 A.D. Production at this level would require 2400 to 2500 MW of power at the present level of consumption norms. The smelting of

aluminium requires uninterrupted and steady electrical energy and therefore aluminium smelters need to be located in a region of reliable power sources or else captive power generation may have to be considered for operating smelters at rated capacity. Aluminium, however, constitutes an energy bank. Recycling of aluminium calls for only 5.7 per cent of electrical energy required for its production. The energy need for recycling of various materials is shown below:

	Materials	kWh/kg.
1.	Steel	1.96
2.	Aluminium	0.8
3.	Copper	3.79
4.	Glass	5.13
5.	Plastics	19.8

Recycling is, therefore, the appropriate answer to economically utilize the energy bank, in aluminium production.

Aluminium metal is used in diverse applications, outstanding examples being electrical engineering, building and construction, packaging and transportation. The most impressive demonstration of energy-saving effect of aluminium is its application in transport sector. By reducing the dead weight of vehicles and increased payload, noteworthy fuel savings and a positive energy balance in favour of aluminium can be achieved.

Various processes are being developed to reduce the energy requirement which, however, are yet to be commercially established.

3.17 Iron and Steel Industry:

Iron and Steel Industry is a single large consumer of commercial energy. It consumed nearly 12 per cent of power and 35 per cent of coal consumed by industries in 1979-80. Historical trends of commercial energy consumption by Iron and Steel Industry are given in Table 3.7. Gross Energy Consumption has shown steady increase. However, energy intensity has declined since 1961. These trends based on CMI-ASI coverage do not seem to reflect the entire industry's consumption when we compare with the coal consumption data in Table 3.8.1.

A reference needs to be made here to the mini steel plants which have been installed in all regions of the country. In 1980 there were 146 mini steel plants located in various regions of the country. Steel making units in the mini steel plant consume maximum of the energy which amounts to about 63 per cent of the total energy required. About 89 per cent of this quantity is consumed in the form of electrical energy alone. This indicates the need for a major thrust in the conservation of energy in steel making directed towards saving the electrical energy.

Generally, however, the consumption of coal per unit of value added contributed by steel industry is very high compared to the ratio for other industries. Further more, the steel industry requires metallurgical grade coal (coking coal) and cannot use (except in a small proportion) non-coking coal.

3.18 Cement

The main fuels utilised by the industry are coal and power. The coal (non-coking) requirement of the industry is currently around eight to nine million tonnes per annum and with anticipated build up of additional capacity (based on dry process), the requirement is likely to exceed 12 million tonnes per annum by 1990. Some of the old cement plants have dual burning facilities (coal and furnace oil). The consumption of fuel oil which was 19 lakh tonnes in 1973 declined to insignificant levels and continued at low levels till 1982. On the other hand, power requirement of the industry is expected to increase to 1003 MW by 1989-90. The historical trends (Table 3.7) indicate that energy intensity has sharply gone up from 1951 to 1973. Inferior quality coal with lower lower calorific value, may be partly responsible for higher coal use; on the other hand price regulation may explain low value-added in the industry resulting in higher energy intensities till 1973.

Energy Consumption Norms for selected ASI Industries 1961-1969

3.19 An attempt has been made to study energy consumption norms for selected industries by taking fuel-wise commercial energy consumption from the Annual Survey of Industries 1961 and 1969. Energy consumption norms are defined as energy consumption per unit of output. With the introduction of better technology and process management, consumption norms are expected to decrease for some

of the industries. However, consumption norms (energy/output) will increase compared to the past due to:

(a) Improvements in quality of products;
(b) Substitution of human and animal energy;
(c) Substitution of non-commercial energy;
(d) Fall in capacity utilisation due to interruptions in production for a variety of resources; and
(e) decreasing quality of coal and increased use of coal instead of gas or oil.

If the value added per unit of output does not decrease, then energy intensity will decrease with the decrease in consumption norm. A comparison of consumption norms of 30 selected ASI industries for 1961 and 1969 (Table 3.9) shows the following:

1. Group I is a set of eight industries where energy consumption of all forms has increased. These, inter alia, include Jute, Textiles, Vegetable Oils, Cement, Iron & Steel, Castings and Refrigerators. As a result their gross energy use per unit of output has gone up and the consequent increase in energy consumption norm. There, however, seems to be an inexplicable rise in coal consumption for cement.

2. Group II is a set of eleven industries where energy consumption of oil and electricity have increased at the expense of coal. These include sugar, fire bricks and refractories, synthetic resins and plastic, iron and steel, iron pipes, basic metal industries and cotton Textiles. As a result of this inter-fuel substitution, gross energy consumption per unit of output has declined in the case of sugar, cigarette, fire bricks, refractories, sheets and plate glass, iron and steel iron pipes and in the case of others, energy consumption per unit of output increased.

3. Electricity consumption per unit of output increased in the case of hydrogenated oils, edible oils and structurals. Except in the case of structurals which experienced marginal increase in the gross energy use, other two industries consumption norms remained constant.

TABLE: 3.9

Energy Consumption Norms for Selected Industries
(Consumption of Coal, Oil and Electricity per unit Output)

Industry	Unit of Output	1961 Coal incl. Coke	1961 Fuel Oil	1961 Electricity	1961 Gross Energy Use	1969 Coal incl. Coke	1969 Fuel oil incl. Diesel Oil	1969 Electricity	1969 Gross Energy Use	% change in Gross Energy use 1969/1960
1	2	3 (Tonnes)	4 (Tonnes)	5 (Th. kwh)	6 (tcr)	7 (Tonnes)	8 (Tonnes)	9 (Th.kwh)	10 (tcr)	11
I										
Cocoa and Sugar Confedtionery	Hund. Tonnes	0.692	0.039	0.058	0.789	1.37	0.117	0.24	1.727	119
Breweries & Malt	Th. Litres	0.156	-	0.154	0.310	0.561	0.082	0.306	0.949	206
Jute Textiles	Hun. Tonne	25.55	0.047	45.08	70.677	26.38	0.074	58.11	84.564	20
Vegetable Oils	Th. Tonne	6.17	0.734	2.13	9.034	6.7	1.088	4.19	11.978	33
Cement	Tonne	0.332	0.003	0.058	0.393	1.64	0.016	0.522	2.178	454
Iron & Steel Castings	Hun. Tonne	42.05	0.39	10.91	53.35	49.89	12.18	57.80	119.87	125
Air Conditioner & Refrigerators	Hun. Nos.	1.426	0.67	14.03	16.126	0.38	2.58	19.20	22.16	37
Storage Batteries	Th. Nos.	3.03	0.84	5.19	9.06	4.71	1.45	14.29	20.45	126
II										
Sugar	Tonne	0.059	0.007	0.125	0.191	0.04	0.014	0.036	0.09	(-) 53
Cigarette	Million	0.504	0.032	0.244	0.78	0.199	0.075	0.364	0.638	(-) 18
Tannery	Th. Kg.	0.992	0.006	0.724	1.72	0.934	0.06	1.14	2.134	24
Synthetic Resins & Plastic	Tonne	0.985	0.006	0.06	1.051	0.171	0.15	2.27	2.591	147
Fire Bricks	Tonne	1.290	0.005	0.04	1.335	0.874	0.16	0.076	1.11	(-) 17
Refractories	Hun. Tonne	41.59	3.80	4.74	50.13	18.88	14.79	7.48	41.15	(-) 18

.....2/...

1	2	3	4	5	6	7	8	9	10	11
Sheets & plate Glass	Sq. Mts.	0.012	0.001	0.007	0.02	0.008	0.003	0.0013	0.0123	(-) 38
Iron & Steel	Hun. Tonnes	101.829	2.38	21.18	125.399	62.02	2.51	24.72	89.25	(-) 29
Iron pipes	Hun. Tonnes	22.18	0.77	16.96	39.85	11.46	2.25	17.95	31.66	(-) 21
Basic Metal Industries	Hun. Tonnes	117.39	16.75	297.6	431.74	72.16	22.58	562.04	656.78	52
Cotton Textiles	Hun. Tonnes	206.39	24.31	248.36	479.86	162.90	52.36	359.48	554.74	16
III										
Hydrogenated Oils	Hun. Tonnes	30.23	2.56	18.14	50.93	25.70	1.49	23.63	50.82	-
Edible Oils	-do-	7.76	1.48	5.75	14.99	5.88	1.38	7.37	14.63	-
Structurals	-do-	14.53	1.77	16.26	32.56	10.80	1.51	21.65	33.96	4
IV										
Bakery products	Hun. Tonnes	17.52	3.47	25.3	46.29	4.2	3.44	12.82	20.46	56
Manmade Fibres	Tonnes	2.42	0.57	2.93	5.92	0.82	0.01	0.692	1.522	(-)74
power Driven pumps	Numbers	0.05	0.014	0.034	0.098	0.001	0.005	0.026	0.032	(-)67
V										
Tea	Hun. Tonnes	36.49	3.09	21.89	61.47	38.277	33.17	13.17	84.667	38
Soaps	Th. Tonnes	10.59	11.33	12.78	34.7	4.59	14.26	12.55	31.40	(-)10
Insulators	Th. Nos.	0.865	.185	0.832	1.882	1.05	0.25	0.306	1.606	(-)15
Ferro-Alloys	Tonnes	0.168	-	4.52	4.688	0.067	0.06	3.72	3.847	(-)18
Writing Paper etc.	Tonnes	2.99	0.047	0.81	3.847	1.77	0.354	0.79	2.914	(-)24

4. Group IV is a set of industries which include bakery products, manmade fibres and power driven pumps. In their case energy consumption of all forms decreased.

5. The remaining five industries witnessed other type of variations in fuel consumption and as a result of which gross energy consumption per unit of output decreased in the case of soaps, insulators, ferro alloys and writing paper, etc. Only tea industry recorded an increase in the energy consumption norm.

Fuel-wise Consumption Pattern

Coal Consumption

3.20 Sectoral consumption statistics are compiled in a rudimentary form. Disaggregated consumption figures are available in terms of hardly 5-7 industries. Table 3.8.3 bring together such statistics as are available from a variety of sources. Consumption statistics are mainly based on railway shipments as for coal distribution controls are administered by railways. The consumption statistics of the four priority sectors namely, railways, power, steel and cement are fairly reliable as they do not buy coal from other traders. Other industrial buyers do some buying and selling and hence the detailed industrial break down of consumption is not very accurate. In the absence of accurate breakdown it is difficult to work-out reliable consumption norms for demand projections.

Refined Petroleum Products:

3.21 Refined petroleum products are used by the manufacturing sector for energy as well as non-energy purposes. Among non-energy uses, naphtha goes into fertilizers, plastics and artificial fibres although some

fertilizer plants are reported to have used naphtha as a fuel. In 1982-83, 2.89 million tonnes of naphtha was consumed out of which 2.2 million tonnes was consumed by fertilizer industry, 3.67 million tonnes by petro-chemicals and the negligible balance for other purposes. A little quantity of kerosene is also used in the manufacturing for cleaning machinery etc. Estimated consumption in 1971 was 30 thousand tonnes only. Industry sector basically uses diesel oil and furnace oil for captive power plants and other energy uses. Table 3.8.1 gives the fuel oil consumption by industries. Trends in consumption of LPG, HSDO and LDO by industry sector since 1967 are presented in Table 3.8.2. In a study of Consumption Pattern of Selected Petroleum Products undertaken by NCAER in 1971, it was observed that the industrial sector consumed furnace oil, HSDO and LDO in a ratio of 92.1, 1.53 and 3.2 respectively in the manufacturing process. As the products like furnace oil, hot heavy stock (HHS) and low-sulphur heavy stock (LSHS) are used as fuel for burning, the quality difference among them becomes unimportant. Hence the data on them is combined.

Electricity

3.22 Aluminium, Cement, Chemicals, Fertilizers, Iron & Steel, Paper & Textiles taken together consume bulk of power consumption by industries. Table 3.8.4 indicates their share in total power consumption by industries in 1969 and 1979-80. Progress in Power consumption since 1970-71 (Utilities as well as Non-Utilities) by the Industry sector may be seen in Table 3.8.5.

Trends in Fuel Substitution

3.23 Energy substitution is an integral part of energy development. The most important substitution problem at the macro level is concerning the replacement of non-commercial energy resources by commercial forms. Within the manufacturing sector, there is a need to minimize the use of oil by substituting coal to as large an extent as possible because coal is abundantly available in the country while the country is in deficit in all petroleum fuels. Table 3.8.6 gives the coal production since 1950-51. The demand of oil is met by importing both crude as well as finished products, resulting in large amounts of foreign exchange loss. But with the advancement of technology part of coal is rather replaced by oil. With the Naphtha injection in blast furnace, the molten metal output for the same furnace volume increases tremendously. Similarly other industries such as brick kiln, cement, glass, tank furnaces, etc. require much less therms per unit output when fuel oil is used in comparison when coal is used. Further it is reported that lot of fuel saving and higher production can be achieved through gasification of liquid fuels before being fired in the furnace.

3.24 Generally the following considerations are important in the choice of fuel:

1. Availability
2. Supply
3. Price
4. Specified Industrial Requirements
5. Efficiency of Utilisation

First consideration suggests that as the country is deficit in so far as availability of petroleum fuels in India are concerned, replacement of non-petroleum fuel with petroleum products in bulk quantity may not be encouraged unless it is in the national interest. But as regular supply of coal is difficult due to railway bottlenecks and interruptions in coal production due to uncertain labour conditions and low productivity of labour, it is difficult to replace petroleum fuels.

3.25 Cost of fuel is more important in cases where cost of heating in the finished product is quite considerable as compared to the total cost. Such industries are thermal power generation, steel, cement, etc. In other cases where fuel bill is insignificant or quality of product is more important thanany other factor, cost of fuel occupies a secondary place. In the former case fuel requiring simple burning arrangement and low capital cost and in the latter case, fuels that can produce desired finished product are preferred.

3.26 Recent trend is also not only to compare the prices of various fuels on the basis of calorific value only but also to consider various efficiencies of utilisation. It has been reported that in Britain, oil even at three times the price of coal per tonne was found to be cheaper per unit of output in the furnaces specially designed for oil firing. Actually petroleum fuels possess such qualities that they can rather replace other conventional fuels like coal in most of the applications. Even if liquid fuels are

available at higher costs, they may increase the output of the existing plant in such a proportion that it becomes overall economical. It is further reported that through R & D efforts, it is possible to bring down fuel consumption by suitably changing the design of the burner.

3.27 These factors have affected the process of substitution in India. There has hardly been any substitution of coal for oil in steam raising. The reason is that in terms of thermal efficiency, oil fired boilers have an edge over coal fired ones. Even if oil costs little higher than coal, it is still preferred for simplicity and more perfect temperature control. The bulk of the oil used for raising steam is in regions far away from sources of coal and till the problems associated with the transportation and distribution of coal of assumed quality on a sustained basis continue it would be unrealistic to expect any switch from oil to coal use, however, desirable that may be from the balance of payments angle. As the priority uses of both gas and oil appear to be different, any significant substitution of gas for oil as boiler fuel does not seem to be possible. In ceramic industry technically gaseous fuel is the best that can achieve temperature and atmosphere free from sulphur.

3.28 Substitution of 'non-commercial' fuels by commercial fuels is inevitable resulting in higher elasticity co-efficients. However, the extent of such substitution is difficult to be estimated. ASI data reveals that Bagasse constitutes 60 per cent of 'non-commercial' energy

consumption. As per the Indian Sugar Annual Number 1982, the production of wet whole sugarcane bagasse in 1980-81 was 155 lakh tonnes. Most of the bagasse produced at present is burnt in the sugarcane mills as fuel to generate steam required by them while technically it can be used as a valuable raw material for producing paper (on an average, 6 tonnes of wet whole bagasse can produce 1 tonne of paper). But this may perhaps not be substituted since the supply of bagasse is so very reliable for the industries that consume it. Factors like distant location of the paper mills, seasonal and fluctuating supplies of bagasse are some of the practical difficulties in bagasse pulping becoming a commercial proposition. Integrated plants of sugar and paper may perhaps be the only answer as proposed by some researchers.

3.29 A number of industries like brick making, mini paper mills etc. use firewood and agricultural residues. In the absence of latest ASI data, the direction of their substitution in the recent past is not known.

3.30 Advisory Board on Energy(ABE) has observed that a significant amount of energy used in the industrial sector is in the form of heat. Roughly 65 per cent of the energy consumed is for process heat. Industries like steel, cement, metal forming require heat at very high temperature. There are, however, a number of industries which use heat below 500^{o}C for which coal

oil and firewood are used. There is another large set of industries, the heat requirement of which is below 140°C. These include tea, tobacco, sugar, agricultural products, animal feed, wood seasoning, rice milling, paper, textiles, breweries, piggeries, distilleries and the like. Advisory Board on Energy(ABE) is inclined to the view that in such industries, the use of coal mainly and to a lesser extent wood and oil for meeting low-grade requirements in industry can be reduced through solar energy and other forms of energy like waste heat recovery. If this potential is realised it may be possible to substantially reduce the use of coal in industry.

3.31 In India, however, it is difficult to substitute present oil applications in Industry which are otherwise quite minimum due to various administrative controls. Secondly, fuel substitution requires plant modifications which may possibly require large investments. Lack of assured coal and power supply also hinder the normal process of substitution dictated by various economic forces.

CHAPTER - 4

THE CHANGING ENERGY CONSUMPTION PATTERN DURING SIXTH FIVE YEAR PLAN, 1980-85

4.1 The pricing structure of commercial energy during the last one decade has undergone a sea change. With this change in the pricing structure, the consumption pattern of coal, oil and electricity should change in principle so as to encourage substitution of oil if coal and electricity supply could be reliably provided. In 1977 coal, electricity and fuel oil were priced approximately at 90,250 and 450 per mtcr, respectively (i.e. after discounting for fuel efficiency). The prices of petroleum increased further in 1978-79 due to global rise in the price of petroleum products. This rise in prices out of line with the General Index further changed the pricing structure to effect distributional changes in response to price rises as well as the tempo of development in the sectors particularly using energy derived from petroleum products.

4.2 With the change in the backdrop, it is of great interest to analyse how the planners projected these changes in the consumption pattern for the Sixth Plan 1980-85 in the input-output block of the core model.

The year 1979-80 was adopted as the base year for the purpose of projections. The technical note on the Sixth Plan (1980-85) has constructed Input-Output Transaction Table showing intermediate use and final demands for Indian economy for the year 1979-80 and projections for 1984-85 in eighty nine sectors which, inter alia, reflects the pattern of use of electricity, coal and petroleum products for these two years (Tables 4.1 to 4.6).

CONSUMPTION PATTERN OF PETROLEUM PRODUCTS: 1979-80/1984-85

4.3 Table 4.1 presents the inter-industry use of petroleum products in the Indian Economy in 1979-80 and 1984-85. The Plan anticipated a marked change in the percentage share of consumption for the agriculture sector which consumes diesel oil for tractors, pumps, power tillers and power sprayers. On the other hand a marked decline in the share of transport sector and a somewhat smaller decline in manufacturing sector was expected. Table 2 indicates the ex-post and ex-ante availability and disposal of petroleum products. It was estimated that by 1984-85 the country would import 36 per cent of total oil requirements. While 76 per cent of the available petroleum products were expected to be consumed in the inter-industry use, the share of private consumption in the total disposal was expected to go down from 28 per cent in 1979-80 to 18 per cent in the total. However, the share of Government consumption was expected to go up from 3.98 per cent to 6.37 per cent. This consumption

pattern assumed that the domestic output will increase at a compound rate of growth of 6.3 per cent. However, the actual achievement of 5.2 per cent has been short of this target (Table 4.8). If the gap is not filled up by imports, the projected consumption pattern will be much different from the actual.

CONSUMPTION PATTERN OF COAL: 1979-80/1984-85

4.4 Secondary sector consumed 90 per cent of the total coal consumption in 1979-80 and this share was expected to remain unchanged by 1984-85. However, the share of manufacturing was expected to go down from 59.56 per cent to 51.92 per cent at the end of Sixth Plan. On the contrary, greater percentage of coal consumption by Electricity, Gas and Water supply was expected in 1984-85 with the share of thermal power generation going up. (It went up from 54 per cent in the total power generation in 1979-80 to a little over 61 per cent in 1982-83). Interestingly, rail transport will consume 30 per cent more coal in 1984-85 as compared to 1979-80. However, during these five years the share of coal consumption by railways will move down from 6.35 per cent to 4.84 per cent.

4.5 Cement Industry and man made fibres that are experiencing great expansion at this stage will be consuming nearly double the quantity of coal at the end of Sixth Plan compared to their consumption level in 1979-80. The share of consumption in the total will however go down in

the case of refractories, iron and steel and non-ferrous metals. While the inter-industry use of coal will relatively increase, both private and Government consumption was estimated to curtail their percentage share in the total, although their absolute consumption levels were projected higher than before (Table 4).

4.6 In 1979-80 coal consumption was less than the domestic output although country was importing better quality of coal for steel plants etc. But it was estimated that five years after, domestic output will be less than the required availability. Coal output was expected to grow at a rate of 9.7 per cent per annum during the Sixth Plan. However, the increase is expected to be around 7 per cent. Slower growth will affect the normal process of substitution besides affecting capacity utilization levels in many industries.

ELECTRICITY CONSUMPTION PATTERN: 1979-80 to 1984-85

4.7 Table 4.5 and Table 4.6 relate to electricity. The inter-industry use of electricity projected for the terminal year of 1984-85 was not expected to be markedly different from the prevailing use in 1979-80 although the level of intermediate consumption was to be higher by 62 per cent. Agriculture sector was expected to double its share in the electricity consumption from 2.5 per cent in 1979-80 to 4.9 per cent in 1984-85 while the share of secondary sectors consumption was to remain roughly constant. As electricity cannot be stored and its imports or exports from neighbouring

countries are negligible, the total domestic output (utilities + non-utilities) was expected to meet the demand for inter-industry use and private and Govt. consumption. This sector was expected to grow at 11 per cent per annum but the actual growth of electricity is estimated to be around 9 per cent during the Sixth Plan.

4.8 The implications are quite clear. The manufacturing sector which is the major consumer of electricity would not be able to operate at the desired levels of capacity utilisation. Secondly, inter-fuel substitution dictated by the pricing structure would not be possible due to the supply bottlenecks.

4.9 A striking departure from the plan projection is, however, seen in tables 4.7 and 4.8. As part of the energy strategy, in 1980's oil exploration was intensified to increase indigenous production. As a result of these efforts crude oil production growth rate of 19.31 has far exceeded the expected target of 13 per cent during the Sixth Plan which will ease the availability of petroleum products in the coming years.

TABLE 4.1: DETAILS OF INTER-INDUSTRY USE OF PETROLEUM PRODUCTS IN THE INDIAN ECONOMY 1979-80 & 1984-85

Sl. No.	Sector/Industry	1979-80 Rs/crores	1979-80 As percent of total	1984-85 Rs. crores	1984-85 As percent of total	1984-85 1979-80 % change
1.	primary	398.20	15.36	1169.29	26.91	194
	Of which:					
	(a) Agriculture	317.47	12.24	1040.20	23.94	228
	(b) Mining & Quarrying	..	..	..	..	.. NIL
2.	Secondary	929.52	35.84	1391.36	32.02	50
	Of which					
	(a) Manufacturing:	789.65	30.45	1153.00	26.53	46
	Of which:					
	Cotton Textiles	78.11	3.01	81.55	1.88	4.4
	Jute Textiles	24.80	0.96	27.83	0.64	12
	Wood products	85.70	3.30	111.09	2.56	29
	Chemical Fertilizers	40.60	1.57	76.14	1.75	85
	Other chemicals	13.72	0.53	24.30	0.56	77
	Cement	23.72	0.91	45.63	1.05	92
	Iron & Steel and Ferro Alloys	122.44	4.72	177.31	4.08	45
	Non-ferrour Metals	34.35	1.32	55.70	1.28	65
	Motor Vehicles	28.11	1.08	46.77	1.08	68
	Others	338.10	13.04	509.68	11.73	51
	(b) Gas, Electricity and Water Supply	139.87	5.39	238.36	5.49	70
3.	Tertiary	1265.64	48.80	1784.81	41.07	41
	Of which:					
	Transport services	1212.97	46.77	1717.45	39.53	42
	Railway Transport	111.85	4.31	158.69	3.65	42
	Other Transport	1101.12	42.46	1558.76	35.88	42
	Total Inter-Industry Use (1+2+3)	2593.36	100.00	4345.46	100.00	68

TABLE 4.2: AVAILABILITY AND DISPOSAL OF PETROLEUM PRODUCTS 1979-80 & 1984-85

(As obtained from the Input-Output Transactions Tables of Inter-Industry projected in the technical note for the Sixth plan for the relevant years)

Sl. No.	Item	1979-80 Rs. crores	1979-80 Per cent of total	1984-85 Rs. crores	1984-85 Percent of total
	Availability				
1.	Domestic Output (Total)	2831.21	73.90	3842.34	67.00
2.	Imports	1012.20	26.42	2037.00	35.52
3.	Exports (less)	0.0	..	0.0	..
4.	Change in Stocks Increase (-) Decrease (+)	-1230 ..	- 0.32 ..	-144.60 ..	- 2.52
	Total Availability (1+2-3+4)	3831.11	100.00	5734.74	100.00
	Disposal				
5.	Inter-Industry Use	2593.36	67.69	4345.46	75.77
6.	private Consumption Exp.	1085.24	28.33	1024.03	17.86
7.	Government Consumption Expenditure	152.51	3.98	365.25	6.37
	Total Disposal (5+6+7)	3831.11	100.00	5734.74	100.00

TABLE 4:3: Details of Estimated Inter-Industry Use of Coal & Lignite in the Indian Economy 1979-80 & 1984-85

Sl. No.	Sector/Industry	1979-80 Rs. Crores	1979-80 As percent of total	1984-85 Rs. Crores	1984-85 As percent of total	1984-85 / 1979-80 % change
1.	Primary Sector	19.01	1.71	70.81	3.73	272
	Of which:					
	(a) Agriculture	0.70	0.06	1.00	0.05	143
	(b) Mining & Quarrying	8.25	0.74	57.55	3.03	598
2.	Secondary Sector	1007.44	90.42	1715.52	90.33	70
	Of which:					
	(a) Manufacturing	663.54	59.56	985.86	51.92	49
	(b) Electricity, Gas & Water Supply	336.16	30.17	718.26	37.83	114
	of (a)					
	Paper & Paper Board	29.57	2.65	46.32	2.44	57
	Misc. Coal & petroleum products	180.09	16.16	280.55	14.78	56
	Chemical Fertilizers	28.15	2.53	52.79	2.78	88
	Manmade Fibres	13.17	1.18	28.37	1.49	115
	Refractories	89.43	8.03	125.96	6.63	41
	Iron & Steel	106.54	9.56	158.78	8.36	49
	Non-ferrious Metals	16.11	1.45	26.12	1.38	62
	Cement	45.06	4.04	86.67	4.56	92
3.	Tertiary Sector	87.67	7.87	112.81	5.94	29
	Of which:					
	Transport Services	70.79	6.35	91.85	4.84	30
	Railway Transport	69.41	6.23	89.95	4.74	30
	Other Transport	1.38	0.12	1.90	0.10	38
	Total Inter-Industry use (1+2+3)	1114.12	100.00	1899.14	100.00	70

TABLE 4.4 Availability and Disposal of Coal and Lignite 1979-80 and 1984-85 (as obtained from the I-O model projections for the Sixth plan)

Sl. No.	Item	1979-80 Rs. Crores	1979-80 percent of total	1984-85 Rs. Crores	1984-85 percent of Total
1.	AVAILABILITY				
1.	Domestic Output (Total)	1206.67	100.33	1915.22	95.02
2.	Imports	70.50	5.86	133.00	6.60
3.	Exports (Less)	- 12.80	- 1.06	- 21.30	- 1.06
4.	Change in Stocks Increase (-) Decrease (+)	- 61.70	- 5.13	- 11.40	- 0.57
	Total Availability (1+2-3+4)	1202.67	100.00	2015.52	100.00
	DISPOSAL				
5.	Inter-Industry Use	1114.12	92.64	1899.14	94.23
6.	private Consumption Exp.	73.36	6.10	94.09	4.67
7.	Government Consumption Expenditure	15.19	1.26	22.29	1.10
	Total Disposal (5+6+7)	1202.67	100.00	2015.52	100.00

TABLE: 4.5: Details of Inter-Industry Use of Electricity in the Indian Economy 1979-80 & 1984-85

(At Factor Cost at 1979-80 prices)

Sector/Industry	1979-80 Rs. Crores	1979-80 As percent of total	1984-85 Rs. Crores	1984-85 As percent of total	1984-85/1979-80 (% change)
1. primary	209.83	6.26	464.55	8.54	121
Of which:					
(a) Agriculture	84.50	2.52	265.24	4.87	214
(b) Mining & Quarrying	80.80	2.41	143.42	2.64	78
2. Secondary	2183.32	65.15	3588.49	65.93	64
Of which:					
(a) Manufacturing	1190.33	35.52	1928.59	35.43	62
Of which:					
Sugar	61.13	1.82	125.09	2.30	105
Cotton Textiles (excl. Handlooms & Khadi)	124.97	3.73	136.99	2.51	10
Wood Products	63.06	1.88	85.82	1.58	36
Paper & Paper Board	41.05	1.22	67.52	1.24	64
Chemical Fertilizers	187.30	5.59	368.80	6.77	97
Iron & Steel and Ferro-Alloys	87.85	2.62	[illegible]	2.57	59
Non-ferrous Metals	88.80	2.65	[illegible]	2.73	70
Motor Vehicles	22.55	0.67	39.53	0.73	76
(b) Construction	108.53	3.24	160.57	2.95	48
(c) Gas, Electricity & Water Supply	884.46	26.39	1499.33	27.55	70
3. Tertiary	958.11	28.59	1389.74	25.53	45
Of which:					
(a) Trade, Storage & Warehousing	340.54	10.16	490.82	9.01	44
(b) Education	80.48	2.40	121.03	2.22	50
(c) Transport Services:					
(i) Railway Transport	32.54	0.97	50.78	0.93	56
(ii) Other Transport	39.85	1.19	57.50	1.06	44
Total Inter-Industry Use (1+2+3)	3351.30	100.00	5442.78	100.00	62

TABLE:4.6 : Estimated Availability & Disposal of Electricity : 1979-80 & 1984-85 (Gas, Electricity and Water Supply)

(As obtained from the input-Output model projections for the Sixth plan) At factor cost at 1979-80 prices

Sl. No.	Item	1979-80 Rs. Crores	1979-80 percent of Total	1984-85 Rs. Crores	1984-85 percent of Total
	AVAILABILITY				
1.	Domestic Output (Total)	3830.67	100.0	6527.87	100.00
2.	Imports	-	-	-	-
3.	Exports	-	-	-	-
	Total Availability (1+2-3)	3830.67	100.0	6527.87	100.00
	DISPOSAL				
4.	Inter-Industry Use	3351.30	87.49	5442.78	83.38
5.	private Consumption Expenditure	418.00	10.91	921.99	14.12
6.	Government Consumption Expenditure	61.37	1.60	163.10	2.50
	Total Disposal	3830.67	100.00	6527.87	100.00

TABLE:4.7: Availability and Disposal of petroleum and Natural Gas: 1979-80 and 1984-85 (As obtained from the Input-Output Transactions Tables projected for the Sixth plan).

Sl. No.	Item	1979-80 Rs. Crores	1979-80 Percent of Total	1984-85 Rs. Crores	1984-85 Percent of Total
	AVAILABILITY				
1.	Domestic Output (Total)	457.50	16.71	839.50	24.39
2.	Imports	2294.60	83.82	2604.00	75.66
3.	Exports (Less)	..	..	..	..
4.	Change in Stocks	- 14.70	- 0.53	-1.60	- 0.05
	Increase (-) Decrease (+)				
	Total Availability (1+2-3+4)	2737.40	100.00	3441.90	100.00
	DISPOSAL				
5.	Inter-Industry Use	2737.40	100.00	3441.90	100.00
6.	private Consumption Exp.	0.0	---	---	---
7.	Government Consumption Expanditure	0.0	--	--	--
	Total Disposal (5+6+7)	2737.40	100.00	3441.90	100.00

TABLE 4.3 Production of Electricity, Coal and petroleum 1979-80 to 1984-85

	Electricity Bkwh	Coal incl. Lignite	petroleum Crude	petroleum products
		Million Tonnes		
Weight (1970=100)	9.2300	5.8430	1.5460	1.6200
1979-80	104.6	106.8	25.5	11.8
1980-81	110.8	118.8	24.1	10.5
1981-82	122.0	130.1	28.2	16.2
1982-83	130.1	137.1	30.8	21.1
1983-84	139.9	138.45	32.8	26.0
1984-85*	159.2	149.7	33.0	28.6
Growth rate 1979-80/ 1984-85				
Actual	8.8	6.9	5.2	19.3
Anticipated**	11.2	9.7	6.3	13.0

* Estimated on the basis of actual growth in Apr-Nov 198

** Based on Tables 4.2, 4.4, 4.5 and 4.7

Chapter 5

Energy Efficiency* in Manufacturing & Mining

5.1 Energy requirements per unit of value added are very high in India compared to developed and newly industrializing countries. Energy intensities are also increasing over the years. The industry sector is the largest consumer of commercial energy in India. In 1980-81, the industry sector consumed 40 per cent of total consumption of commercial energy while it contributed only 17 per cent to the Gross Domestic product. It consumed 62 per cent of the electricity and 61 per cent of the coal and 59 per cent of the fuel oil. Consumption of commercial energy in Mining & Manufacturing has increased at a compound rate of growth of 6.5 per cent between 1953-54 and 1980-81. On the other hand value added in mining and manufacturing has risen at 5 per cent per annum during this period.

---

* According to the laws of thermodynamics, energy efficiency refers to the minimum utilization of an available energy source through an energy converting device for a given task. Energy efficiency in physical terms takes into account both the quality and quantity of energy input as well as the efficiency of energy converting device for a particular task and is defined as under:

$$\text{Efficiency} = \frac{\text{Absolute minimum energy required for a given task}}{\text{energy inputs to a device or system from some source (i.e. total energy consumed)}}$$

However, it is not sufficient simply trying to approach the maximum of the above thermodynamic law and improve the thermal efficiency. It is necessary to apply economic criteria to the goal of maximizing energy efficiency. Technology/resource combination options which provide the greatest level of energy efficiency in the above sense may not be economically best. There is a point where the marginal cost of saving a unit of energy will be larger than the marginal benefit associated with such a saving. To determine this equilibrium one must consider the total cost of production and use of energy including the fuel availability of supply and substitution possibilities at the factory level. In this chapter, however, energy efficiency is generally taken in the technical sense.

5.2 Energy intensities are defined as energy consumption in physical units like kWh or tonne, per unit of value added. Table 5.1 gives the electricity coal and oil energy intensities in the industrial sector from 1953-54 to 1980-81.

Table 5.1 - Energy Intensities in the Industries Sector

	Electricity (kWh/Re.V.A.)	Coal* (Kg/V.A.)	Oil@ (Kg/Re.V.A)	Total Commercial Energy (tonne coal replacement/ thousand Rs.)
1953-54	0.234	0.645	0.105	1.05
1955-56	0.254	0.537	0.094	0.98
1960-61	0.344	0.620	0.107	1.18
1965-66	0.471	0.628	0.084	1.27
1970-71	0.613	0.555	0.097	1.36
1975-76	0.656	0.766	0.073	1.57
1980-81	0.661	0.709	0.064	1.58

* Excludes use in power stations.

@ includes FO/LSHS/HHS used as energy fuel and not as feed stock in the manufacturing sector FO/LSHS/HHS used as fuel in utility power stations is also excluded.

5.3 During 1970-71 and 1975-76 power shortages have been reported at a minimum. Between these two years electricity intensity has increased by 1.4% per annum reflecting a growing share of electricity consumption to total industrial energy consumption. Over the total period of 1953-54 to 1980-81, electricity intensity has increased at a rate of growth of 3.7% per annum while overall energy intensity has gone up by 1.5% per annum compound. As is evident the intensity of

electricity consumption has increased over a period. However, the rate of growth of intensity has declined. This is only to be expected since in the initial stages of industrialization, the share of industries which produce or process primary commodities or minerals is high and it is these industries that have a relatively higher electricity intensity. Further in the initial stages of the spread of electricity in a country, a large number of industries using other energy forms switch to the use of electricity. In view of these factors, the intensity of electricity use is bound to be high in the initial stages of development. Also when the product mix of an industry changes, electricity consumption per unit of production could increase specially due to improvements in quality of products. For example, an increase in the share of superior quality paper or textiles could lead to an increase in energy intensity of these industries.

5.4 Historical energy intensities in the case of coal and oil have fluctuated reflecting both their price and availability. However, the intensity of electricity use has registered a steady increase.

5.5 Total energy requirements per unit of value added in the industrial sector has also steadily increased due to the changing product-mix. To analyse the factors responsible for the increasing energy intensity in the manufacturing sector, it is essential to study the characteristics of the changing industrial-mix in India. It is equally important to examine energy intensities in some of the large energy consuming industries that include textiles, cement, chemicals, non-ferrous metals, aluminium, pulp and paper, fertilizer, Iron and steel, sugar, petro-chemicals, mining & quarrying, etc. The question of energy efficiency is also linked up with the changes in the energy prices due to several factors. In the following pages we analyse some of these questions to examine the reasons for the apparent high energy input to value added by the industrial sector.

Industrial Structure

5.6 Over the last thirty years, the industrial base of the country has been widened. The whole industrial structure has been diversified covering the entire range of consumer, intermediate and capital goods. Both qualitative and quantitative changes have taken place in various sub-sectors of the industry sector. Each industrial activity requires different level of

energy consumption per unit output. To answer the questions raised above, we may classify the industrial sector into registered sector and unregistered sector. Some of the industries in the registered sector do consume large quantities of energy. The share of such Large Energy Consuming (LEC) industries has declined as a percentage of the registered sector during the last thirty years. However, their share has remained more or less constant in the total industrial sector comprising of registered and unregistered industries. Table 5.2 gives the percentage share of types of industries in the total value added by Manufacturing Sector.

Table 5.2 - Industrial Structure

Year	Registered			Unregistered	LEC as percentage of the registered sector
	LEC	Non-LEC	Total		
1951-52	34.98	19.91	54.89	45.11	63.73
1961-62	32.97	25.33	58.30	41.70	56.55
1971-72	33.78	28.27	62.05	37.95	54.45
1980-81	35.12	27.98	63.10	36.90	55.66
1981-82	34.90	29.10	64.00	36.00	54.53

Source: National Accounts Statistics: 1984
Basic Statistics relating to the Indian Economy (1965, 1977)

It can be seen that over the last thirty years, the share of unregistered sector has declined from 45 per cent to 36 per cent in 1981-82. The percentage share of non-LEC in the registered sector has increased.

Table 5.3 presents the data on value added by the registered and unregistered sectors for 1970-71 and 1981-82 as well as the corresponding growth rates over these years at 1970-71 prices.

Table 5.3: Value Added and its growth rate by Registered & Unregistered Manufacturing Sectors (at 1970-71 prices) (Rs. lakhs)

Industry Group	Registered Sector			Unregistered sector		
	1970-71	1981-82	Growth Rate (percent)	1970-71	1981-82	Growth Rate (perce
1. Food products	26015	40741	3.9	10411	24976	2.9
2. Beverages, tobacco & Tobacco products	9911	13999	3.2	10409	16790	4.4
3. Textiles	59730	102610	5.1	44611	79320	5.4
4. Wood & Wood products	3094	2137	(-)3.3	22043	21939	-
5. Paper & Paper products	14959	18916	2.1	5106	11772	7.9
6. Leather & Leather & Fur products	2260	1096	(-)1.6	6907	8044	1.4
7. Rubber, plastic petroleum & Coal products	12890	18109	3.1	1820	3407	1.6
8. Chemicals and Chemical products	36707	68419	5.8	5837	11694	6.6
9. Non-Metallic Mineral products	11399	15361	2.8	9342	18092	6.2
10. Basic Metal and Alloys Industries	20451	48088	4.9	462	716	4.1
11. Metal products and Parts	9454	13049	3.0	11772	16227	3.0
12. Machinery, Machine Tools & parts	19306	39221	6.6	6375	11706	5.8
13. Electrical Machinery	18213	41899	7.9	3627	6560	5.6
14. Transport Equipment	24396	36404	3.7	5346	8824	4.3
15. Miscellaneous Manufacturing Industries	10652	19673	0.5	13258	17294	2.5
16. Repair Services	6397	8099	2.2	10603	17720	4.8
17. Net Value Added including Bank Charges	296317	488629	4.7	175929	274949	4.1
18. Bank Charges	8917	18148	6.7	1393	5245	13.9
19. Net Value Added	287400	470481	4.5	174536	269704	4.1

Source: National Accounts Statistics, 1984

5.7 As could be seen that during 1970-71 to [illegible] 1981-82, the registered sector moved faster than the unregistered sector. In 1971-72, the unregistered sector had a lower share of the total industries sector than the registered sector and the percentage share of the unregistered sector has declined further in 1981-82 because of lower growth rate compared to the registered sector. In other words, for the unregistered sector to have the same share in 1981-82 as in 1971-72 in total, it would have had to grow at [illegible] same rate compared to the registered sector. Table 5.3 further highlights that energy intensive industries have grown at faster rates than industries which are not energy intensive.

Changes in the Energy Consumption in the Industries

5.8 Survey of the recent research on changes in the energy consumption indicate that the coefficients of energy consumption per unit of value added or per unit of physical output undergo change due to the following:

(a) Consumption norms decrease with the introduction of better technology and process management. If consumption norm decreases, the energy intensity decreases even if value added per output does not decrease;

(b) Increase in wages lead to increase in value added per output resulting in decrease in energy intensities in some sectors;

(c) Increase in energy prices; and

(d) Increase in scale of production.

5.9 It has also been observed that energy intensity for electricity has gone up in some industries due to increased share of the quality of the products, such as fine paper, fine textiles; purer chemicals, etc. Lesser imports of high quality products, machinery, parts, etc. have also affected electricity consumption.

5.10 These considerations do suggest that base-level energy intensities for oil and electricity in the large energy consuming industries reduce gradually but modestly over time because of the possibilities of energy conservation by better management or by technological changes. As regards Non-LEC industries, energy intensities may increase due to lack of R & D efforts in the industries for energy conservation and due to lack of incentives as the energy consumed by individual unit may not be significant so as to encourage measures for energy conservation. However, the energy intensities computed by Advisory Board on Energy for 1970-71 and 1978-79 are as under:

	1970-71 Actual	1978-79 Actual
Electricity (kWh/Re)		
LEC	1.20	1.46
NLEC	0.3349	0.2640
Oil (kg/Re)		
LEC	0.1063	0.0840
NLEC	0.0906	0.0392
Coal (kg/Re)		
LEC	1.0100	1.324
NLEC	0.3396	0.2725

The decrease in energy intensities for oil in both LEC and Non-LEC indicate the impact of increase in oil prices on oil consumption.

5.11 It is quite possible that due to conservation, efficiency improvements and new processes, intensities in the case of LEC industries can be expected to decline. However, in the case of NLEC it is difficult to predict without proper study of improving production efficiencies and that of substitution of electricity and coal for presently used non-commercial sources.

Large Energy Consuming Industries:

5.12 Large Energy Consuming Industries need to be examined in a greater detail. Table 5.4 gives relevant data for our analysis. It may be seen that the highest energy consumption is by iron and steel, followed by textiles and fertilizers (excluding feed stock). Textiles consume the highest amount of electricity and oil, whereas iron and steel are the largest consumers of coal. Textiles are not by themselves highly energy intensive industries, the energy consumed by them is high due to the high volume of production.

5.13 Energy intensities of these industries have different order of ranking because of the differences in the volume of production and in value added by each of the sectors. Here Non-ferrous basic metals,

fertilizers and chemicals precede textiles. Energy intensities for some of the LEC industries is rather high by international comparisons. (It is to be noted that in India, the intensities are given in million metric tonnes of coal replacement, i.e. mtcr units whereby fuels such as electricity and oil get multiplied by higher efficiency factors that are not treated merely in calorie equivalent terms. Moreover, one metric tonne of coal in India is standardised to have 5000 kilo calories per kg. as compared to U.N. convention of 7000 k Cal/Kg).

5.14 The consumption norms - i.e. the energy consumed in mtcr per metric tonne of product - are the highest for non-ferrous basic metals. Here aluminium production is included which consumes approximately 16,000 (kWh)/kilo watt hour or units per tonne. Textiles comes next if we measure textiles by weight. However, if measured in metres, the norm is 1.856 per thousand metres.

Table 5.4: Consumption of Energy by Large Energy Consuming Industries & Norms of Consumption 1973-74

Industry	Coal & Coke (million tonne coal replacement)	Fuel Oils (million tonne coal replacement)	Electricity (million tonne coal replacement)	Total Energy@ (million tonne coal replacement)	Value Added (Rs 10^5)	Energy Intensities (Tonne per '000 Rs. Value Added	Consumption* Norms (per Tonne of product)
Textiles	2.38	1.02	4.65	8.05	9625	0.82	3.53
Fertilizers**	0.73	0.40	2.07	3.20	523	6.12	1.07
Inorganic Heavy Chemicals	0.30	0.40	0.89	1.59	482	3.30	1.42
pulp & paper	1.47	0.28	0.88	2.63	889	2.96	2.54
Non-ferrous Basic Metals	0.28	0.24	2.47	2.99	384	7.79	6.89
Iron & Steel	5.76	0.86	3.11	9.73	4400	2.21	1.91
Aluminium	0.21	0.20	2.27	2.68	163	15.83	N.A.

Notes: 1 mt of fuel oil = 2 mtcr; bkWh = mtcr;
1 kg of coal = 5000 K Cal.

* refers to 1970
** Excludes feed stock
@ includes Diesel Oil consumption also.

These data have been compiled from the available published data in Annual Survey of Industries, census sector, 10 Volumes, C.S.O.

Factors Affecting Energy Intensities/Energy Consumption Norms in Industry

5.15 As seen above (Table 5.1), energy intensities have increased in the industrial sector from 1.18 in 1960-61 to 1.58 in 1980-81, measured in tonne coal replacement per Rs. 1,000 of value added. There are also reports that in India, energy intensities (ratio of energy consumption to value added in industry) are large compared to other ...

developed and developing countries. This is rather surprising considering the labour-intensive technologies that are often used. Moreover, 36 per cent of the value added is in the unregistered sector. These aspects have been examined and the following points are considered relevant to explain, the increasing level of energy intensity in India.

5.16 The increasing intensities in the manufacturing sector over the last 20 years have increased. The large energy consuming industries have been increasing their share in the total value added. Even within the large energy consuming industries sector, growth rates of industries which consume more energy per unit value-added are higher than the growth rates of industries which consume lesser energy such as textiles. Table 5.5 elucidates this point quite clearly. Thus although large energy consuming industries have been contributing roughly 35 per cent of value added for the last 30 years, the composition of the LEC has been changing.

Table 5.5: Share of Individual Large Energy Consuming Industries in Total Value added by them

	Percentages				
	1950-51	1960-61	1970-71	1980-81	1981-82
Textiles	64.75	51.03	37.17	41.22	30.51
Paper and Paper Products & Allied Industries	6.90	8.30	9.31	6.74	7.10
Chemicals and Chemical products	10.19	13.75	22.04	23.74	25.60
Non-metallic Mineral products	4.74	7.22	7.09	5.72	5.77
Basic Metal Industries & Metal Products	13.45	19.85	23.58	22.58	22.95

Source: National Accounts Statistics 1984 and previous issues

5.17 Secondly the share of the Non-LEC (Table 5.2), which are more energy-intensive than the unregistered sector, is also increasing.

5.18 Jyoti Parikh has stated some more reasons for increase in the Energy/Value added ratios compared to the past which include (a) slow increase in wages; (b) controlled prices for some of the outputs; and (c) increase in consumption norms. The increase in consumption norms may be partially due to improvements in quality of products and partially due to substitution of non-commercial sources of energy.

5.19 The norms of energy consumption for producing a given product i.e. energy consumed per unit physical output are important indicators of the energy efficiency of a given technology. These consumption norms depend upon various factors like production technology and plant capacity, capacity utilization, quality of products and product mix. Slow improvements in the technology, small and uneconomic scale of production, fall in capacity utilization due to infrastructural or other constraints, increased use of coal instead of gas or oil and decreasing quality of coal are some of the factors that have affected adversely energy efficiency of Indian Industries. The existing technology in many of our industrial units e.g. textiles, cement, etc. is obsolete and also does not have economics of scale.

5.20 Table 5.6 shows a comparison of energy consumed per unit of production for various countries. It is true that the state of technologies in various countries may be varying substantially and there may be problems of measurement and comparison of energy use between countries. The fact is, however, obvious that India consumes more energy per unit production of crude steel, aluminium, pulp and paper and cement compared to most developed countries. This may be for want of energy-efficient technologies, advantages of economies of scale or due to greater fluctuations in capacity

utilization. 'Electricity consumption per dollar of value added is very high compared to the developed countries. It is specially 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. Moreover, industries based on natural gas or oil are much less in India compared to Western and Eastern Europe. Natural Gas and Oil are more efficient fuels compared to Coal ' Jyoti Parikh,(Planning Commission). However, in individual industries the norms of energy consumption are getting lower for new plants possibily due to better technology of production.

5.21 Energy efficiencies in the large energy consuming industries are thus higher by international comparisons but are improving over time. Bokaro Steel plant consumes 1.19 tonne of coal per tonne of product as compared to 1.64 tonne in IISCO and 1.42 tonne in Bhillai. The consumption of coal in cement plants using dry process is much lower as compared to the wet process plants. There are, however, a lot of fluctuations in energy efficiency from year to year due to changes in capacity utilisation in some of these industries.

Changes in Norms for Coal Consumption:

5.21 A brief review of the factors affecting Norms in important coal consuming industries is carried out.

Steel Industry: The norms for coking coal consumption per tonne of hot metal in the steel industry has not changed significantly over the past few years and has averaged 2.00. This could deteriorate if the ash content of coking coals decline.

Table 5.6: International comparison of Energy Efficiency in Industries

(10^4K Cal per tonne of product)

Country	Crude Steel	Paper & Pulp	Cement	Aluminium
Austria	450(i)	344	90	1346
Canada	555	673	(95(d) (140(w)	..
Denmark	236	353	164(w)	..
Germany	326	438	91	1481 & 1503
India	1161(i)	1130	170(w)	2295
Ireland	(140 (167(x)	..	153	..
Italy	334	340	96	..
Japan	513	512	121	1385
Laxemburg	701	..	..	..
Netherlands	470	..	131	1290
Newzealand	738	692	175	2165
Norway	189(e)	659	115	1591(e)
Spain	180(e)	220	138	2000
Sweden	398	489	140	1640
Switzerland	..	557	..	..
Taiwan	485	476	115	1464
Turkey	500	..	(93(d) (139(w)	..
United Kingdom	478	627	138	2107
United States	533	579	151	949

Notes: (e) Electricity only; (d) pig Iron;
(x) Scrap Iron; (w) Wet Process;
(d) Dry Process.

Source: Parikh and Chaitanya, EPW (Vol. 15, No II)

.... It is, however, possible to effect reduction in the norm through the following:

(a) Increased volume of blending of imported and indigenously produced coking coal;

(b) Operation at higher blast furnace temperature; and

(c) Optimal sizing of ore.

Cement

5,22 With an increasing proportion of cement production capacity being based on dry process plants, average coal consumption per tonne of cement should decline. However, the growing proportion of dry process capacity would mean that the average power consumption would increase. It is anticipated that dry-non-dry process mix is likely to prevail in the ratio of 90:10 by 1994-95. As a result of this change the modified consumption norms suggest a decline of coal consumption by 10 per cent and an increase of power consumption by 10 per cent.

Fertilizers

5.23 Any expansion in coal-based ammonia making capacity and new generation of fertilizer plants using coal for steam-raising can effect the consumption norms and the demand for coal by the fertilizer industry.

Paper Industry

5.24 Coal consumption in the paper industry can be reduced through the following:

(a) installation of Cogeneration Systems;

(b) installation of soda recovery boilers; and

(c) System efficiency.

The introduction of efficient cogeneration systems could lead to a reduction in demand for grid electricity. The same would be true of the POL industry and the textile industry.

Brick-Industry

5.25 With coal of high volatile matter, low ash and calorific value of around 4500 K Cal/kg the norm is about 17 tonnes per 1 lakh bricks. But this

norm, according to the National Building Organisation (NBO) is inflated by the brick industry to ensure that it gets the coal. However, the poor quality and calorific value of coal currently being supplied to the kilns averages less than 3000 K Cal/kg. This has resulted in a higher norm over the past three years of about 22 tonnes of coal per 1 lakh bricks.

Coal consumption can be reduced in the brick industry by the following:

(a) Available new brick kiln designs which reduce specific coal consumption by 8 to 10 per cent. These are, however, based on the use of Grade I Coal.

(b) promoting the use of fly ash bricks.

The dispersed nature of the industry makes it difficult for innovations to be commercialized on any significant scale.

Energy Prices and Industries:

5.26 Pricing of Energy has a direct impact on the energy consumed by the industries. It can lead to inter-fuel substitution, energy conservation or change in the product mix. Some of the industries can introduce conservation measures merely by appropriate process management, full capacity utilisation, etc. Such industries can bring down energy consumption without any additional hardware. The industries can as well switch over to less expensive energy forms such that energy costs are minimised. Thirdly over the longer period, the industrial-mix may change towards less energy consuming activities.

Table 5.7: Price Indices in the Energy Sector

(1970-71=100)

Year	All Commodities (WPI) (1000.00)	Manufacturing (490.74)	Coal (11.47)	Electricity (24.00)	petroleum (6.02)	Furnace Oil (4.00)
1961-62	55.2	60.2	59.6	66.6	71.8	
1962-63	57.3	62.8	62.5	72.6	73.3	
1963-64	60.9	66.4	66.8	76.6	80.9	
1964-65	67.5	70.0	69.3	79.7	81.2	
1965-66	72.7	74.4	72.5	83.2	83.5	
1966-67	82.8	83.4	76.5	91.4	88.6	
1967-68	92.4	92.7	88.1	92.2	91.7	
1968-69	91.3	92.8	103.2	95.4	93.8	
1969-70	94.8	93.1	98.9	95.8	97.1	
1970-71	100.0	100.0	100.0	100.0	100.0	100.0
1971-72	105.6	109.5	103.2	102.5	130.2	111.4
1972-73	116.2	121.9	112.8	105.7	142.0	113.3
1973-74	139.7	139.5	122.9	111.3	317.1	150.7
1974-75	174.9	160.8	146.6	137.2	606.5	308.4
1975-76	172.9	171.2	185.0	158.1	700.3	377.8
1976-77	176.6	175.2	197.8	171.1	740.3	429.7
1977-78	185.8	179.2	198.4	182.4	787.6	429.9
1978-79	185.8	179.5	211.3	209.1	802.9	432.6
1979-80	217.8	215.8	293.6	225.6	1304.0	529.9
1980-81	257.3	257.3	340.6	239.7	2041.8	880.1
1981-82	281.3	270.6	424.4	279.6	2130.7	1148.5
1982-83	288.3	271.7	485.7	328.2	1984.8	1185.6
1983-84	316.1	295.8	534.6	387.7	1739.5	1228.1
Growth Rates						
1961-62/ 1970-71	6.8	5.8	5.9	4.6	3.7	
Growth Rates						
1970-71/ 1983-84	9.3	8.7	14.7	11		

Source: Office of the Economic Adviser
Ministry of Industry

5.27 Price indices in Table 5.7 indicate that the prices of energy have risen more than the wholesale price index for manufacturing as well as for all commodities compared to 1961-62. However, prices of electricity have risen less than the other two fuels namely coal and oil. The present pricing structure should, in principle encourage substitution of oil if coal and electricity supply could be reliably provided.

5.28 The consumption of a particular fuel is affected by its own price as well as by the prices of other substitutable fuels. The impact of change in the relative prices of different fuels can be estimated through price elasticities and cross-price elasticities of different fuels. Given below are estimates of price elasticities of different fuels worked out in some of the recent studies.

1. N.D. Uri has estimated price elasticities and cross price elasticities of fuel demand on the basis of 1960-71 data. His estimates for the mining and manufacturing sector and for the economy

as a whole are as under:

	Manufacturing & Mining	Total
Ecc	- 0.15	- 0.20
Eoo	- 0.09	- 0.10
Eee	- 0.14	- 0.21
Eco	0.13	0.11
Eco	0.16	0.15
Eoc	0.15	0.24
Eoe	0.12	0.13
Eec	0.10	0.09
Eeo	0.09	0.04

Note: Eij refers to the amount by which consumption of 'i' fuel will change in response to a 1% change in price of 'j' fuel.

c = Coal; o = Oil; e= electricity

5.29 Above estimates indicate that a 10% increase in the price of coal would decrease coal consumption by 1.5% in the mining and manufacturing sector and 2% in the economy as a whole. This would, however, increase oil consumption by 1.5% and 2.4% and electricity consumption by 1% and 0.9% respectively in the mining and manufacturing sector and the economy as a whole.

2. Gopal K. Kadekodi has worked out own price elasticities from the data based on input-output Table for 1979-80. Kadekodi's estimates, which are generally higher than those of Uri's are as under:

	Fuel	Price Elasticity
(a)	Coal	- 0.2050
(b)	petroleum & Natural Gas	- 0.3002
(c)	Electricity	- 0.3906

3. Jyoti Parikh has estimated cross price elasticities of some petroleum products with respect to crude oil price.

	Fuel Consumption	Cross Price Elasticity
(a)	Kerosene	- 0.072
(b)	HSD (transport sector/ passenger kms)	- 0.06
(c)	HSD (agriculture/ lift irrigation)	- 0.01

4. Elasticity of electricity demand for final consumption in the Input-Output Table with respect to electricity price has been estimated at (-) 0.600 by M.N. Murthy. His estimate of elasticity of electricity demand for industrial consumption with respect to electricity price = - 0.469 which indicates that a 10% increase in electricity price results in a 4.69% fall in electricity consumption in the industrial sector. The impact of the price increase is, however, swamped by the impact of many other factors.

5.30 In the recent past, fuel oil has been substituted by coal although not in as big a way as possible, partly because of the impediments in coal movement and partly due to changes required to burn coal in equipment designed to utilise fuel oil. Since bulk purchases of electricity and coal are at concessional rates, therefore, the prices to industries are lower than indicated in Table 5.7. However, at constant prices, industries have now started

paying little more than in the past particularly for coal. This should encourage conservation.

5.31 The area of energy pricing has become quite important. The objective of energy planning and management is to provide reliable energy supply. Adequate pricing policies can help in taking appropriate decisions for conservation measures, appropriate choice for technologies as well as for industrial mix.

Policy Implications:

5.32 India is still in the initial stages of major industrialization programmes. Opportunities to utilize energy efficient technologies in India are greater than many developed countries which already have well established industrial bases. In this regard, the role and contribution of large energy consuming industries is quite significant. Nevertheless, the choice of suitable energy efficient industrial technologies in LEC sectors and greater emphasis on Non-LEC industries are necessary.

5.33 Secondly location policy should take into account various aspects so as to minimize transport of energy, raw materials and finished products. Western region is the most industrialized but is energy deficient.

5.34 If the decline in capacity utilisation can be arrested and the trend reversed energy use can be reduced in many industries.

5.35 Energy efficiency can be increased through development of energy-efficient industrial technologies, reduction of the energy-intensive product-mix. In order to increase energy efficiency, additional investment may be required. It may be worth giving industries incentives for these changes. Our energy efficiencies are gradually improving and it should be possible to further gain momentum through greater awareness and proper policies. Easy-to-implement housekeeping measures which have low or negligible costs can help to an extent in increasing industrial energy efficiency. Other contributing factors can be increased capacity utilization and capital investment in energy conserving technologies.

Chapter - 6

Projections of Commercial Energy Use in Industry Sector

6.1 Estimating energy requirements of the industry sector is a difficult proposition because of the diverse industrial activities requiring different levels of energy consumption per unit of output and because of qualitative and quantitative changes taking place in various sub-sectors of the industry sector. Secondly, it is also difficult to project long-term production levels. However, the perspective gained through examination of historical and current trends of the energy intensities of the heaviest energy-using industries should help project energy consumption by the industry sector as a whole. Two alternative methods have been used for this purpose viz. (a) Macro-Method and (b) End-Use Method. Forecast of demand has been restricted to 1989-90, the terminal year of the Seventh plan and 1994-95.

The Macro Method:

6.2 Total energy, fuel-wise, has been projected using the simple relationship between the sectoral GDP and the fuel-wise energy intensities (Energy-Value added ratio). That is, projected sectoral GDP for a given year has been multiplied by projected energy intensity for that year. This simplified projection does not take into account the possible changes in the composition of industries, the possible shift in technology and the rate of substitution of non-commercial energy by commercial energy.

Demand Projection for Electricity

6.3 In Table 3.6 we have examined trends in the intensity of electricity consumption in Industries. Based on the rate of growth of value added in industries for 1979-1982 sectoral GDP for the industrial sector has been estimated for the year 1984-85 and further projected for the years 1989-90 and 1994-95 assuming a rate of growth of 7 per cent as given in the plan perspective. It has also been assumed that the intensity of electricity consumption will remain constant at 1980-81 level. The forecast of electricity demand in industries sector based on these assumptions is given in the following table.

Electricity Demand in Industries 1980 - 1994

	1980-81	1984-85	1989-90	1994-95
1. Value Added in industries Rs. 100 crores (1970-71 prices)	84.12	101.03	141.7	198.74
2. Intensity of Electricity Consumption (kwh/Rupee Value Added)	0.661	0.661	0.661	0.661
3. Electricity demand in TWH	55.60	66.78	93.66	131.37

6.4 The assumptions behind constant Energy Intensity are that some of the Large Energy Consuming (LEC) industries would grow (through installation of new capacities) at a slower pace than in the past,

while some of the technology intensive industries like electronics, sophisticated machine tools etc. involving lower electricity input per unit of value added at a relatively faster rate. In any case the energy intensity for electricity has remained constant during 1975-1980. In this connection Working Group on Energy policy 1979 has observed,

> "Several industrialised countries have adopted as a goal the gradual reduction in the intensity of energy consumed per unit of national income. In our country also, it is necessary that at least in respect of electricity, which is a very high cost energy, there should be an attempt to reduce this intensity (or atleast maintain it) through better utilisation of capacity, more efficient use of electricity in the industries sector and by following a strategy of industrialisation in which LEC industries form a diminishing part."

The implications for new installation of capacities are also clear that appropriate technologies are selected with due regard to energy consumption. The present accent on increasing the rate of employment generation in all sectors would lead to a decrease in energy intensities. However, the policy of encouraging decentralised industrial growth may impede the fall in electricity intensities.

Demand projections for Coal and Oil:

6.5 Using the similar relationship between the value-added by the industry sector and the energy intensities for oil and coal, demand for oil and

coal for the industry sector has been projected as under:-

	Actual		Projected		
	1975-76	1980-81	1984-85	1989-90	1994-95
Value Added in Industries Rs. 100 Crores (1970-71 prices)	66.08	84.12	101.03	141.7	198.74
Energy Intensity (Oil)	.073	.064	.064	.064	.064
Energy Intensity (Coal)	0.766	0.789	0.813	0.837	0.862
Oil Demand (million tonnes)	4.82	5.38	6.47	9.07	12.7
Coal Demand (million tonnes)	50.62	66.37	82.14	118.6	171.3

6.6 It has been assumed that the energy intensity of Oil will remain constant inspite of the policy to restrict the use of furnace oil among new industries on technical reasons alone and to encourage the shift from oil to coal in selected industries. Faster growth of domestic crude production during Sixth plan and recent relaxation in policy for installation of DG Sets for captive power generation in selected industries for improving their capacity utilization are important considerations to assume that oil intensities may not decline as assumed by the Working Group in 1979 although oil consumption for captive power is not taken into account for computing oil intensities. On the other hand coal intensities will increase due to gradual switch from non-commercial to commercial energy and lesser availability

of high grade coal of high calorific value.

6.7 It may be mentioned that WGEp had examined the coal demand separately for the steel industry and rest of the industrial sector because steel industry today consumes around 20 per cent of the total coal production and that the consumption of coal per unit of value added by steel industry is very high. Secondly coal can be substituted by fuel oil of roughly half the weight of coal used. Therefore, WGEp preferred to estimate coal and oil demand for the industry sector excluding steel by taking the combined intensity of coal and oil.

6.8 It is difficult to predict how value added per unit of output would change in future. To overcome this Jyoti Parikh in his model on energy demand for the Industry sector estimated energy requirements through categorising industries into LECs and Non-LECs. Value Added and energy consumption for each set of industries were estimated on the basis of available data and energy intensities for each category worked out to project Energy requirements separately for LEC and Non-LEC industries. This method of energy demand forecast helps in assessing the impact of policies designed to alter the industrial mix. Data limitations are, however, quite apparent. CSO's data on value added in manufacturing is clubbed in large sectors.

6.9 Advisory Board on Energy (ABE) in their Perspective on Demand for Energy in India upto 2004-05 (November 1984) has forecast energy demand for the industry sector through this macro-method. ABE has derived value Added for LEC Industries from the ASI data and value added in NLEC industries has been arrived at by subtracting LEC value added from the total value added by the industry sector. Actual energy intensities (fuel-wise) for 1970-71 and 1978-79 have been worked out as under:

	1970-71	1978-79
Electricity (kwh/Re)		
L.E.C.	1.20	1.46
N.L.E.C.	0.3349	0.2640
Oil (kg/Re)		
L.E.C.	0.1063	0.0840
N.L.E.C.	0.0906	0.0392
Coal and Coke (kg/Re)		
L.E.C.	1.0100	1.324
N.L.E.C.	0.3396	0.2725

6.10 It has been assumed that the present level of intensities of energy use in LEC and NLEC will continue although it is possible that due to conservation, efficiency improvements and new processes, intensities in the LEC industries can be expected to decline. It is difficult to forecast growth trend of energy intensity of NLEC which will depend upon improvements in production efficiencies and on substitution of electricity and coal for presently used non-commercial sources.

It is however, felt that the energy intensities of Non-LEC industries may not decline as the actual 1970-71 and 1978-79 figures indicate due to lack of R & D effort for energy conservation and lack of incentives as the energy consumed by individual unit may not be significant. Non-LEC industries consume 37% of the electricity and their share is expected to increase in future.

6.11 Energy demand for 2004-05 has been projected by ABE for different scenarios envisaging the following growth rates for 1984-85 to 2004-05.

1. Low GDP= 4 per cent compound annual Growth for 1984-2004.
2. High GDP= 5 per cent compound growth per annum.
3. Low LEC growth rate so that the share of value Added by LEC industries in the total industrial growth comes down to 30% in 2004-05 i.e.
   LEC/YIND = 30% in 2004-05.
4. High LEC = LEC/YIND = 37% in 2004-05.

6.12 These assumptions assume two different strategies of industrial growth : (1) Strategy aimed at moderating growth in the energy intensive industries (2) Strategy to maintain high growth rate of LEC industries. As the difference between the strategies gets accentuated with time, the terminal

year i.e. 2004-05 energy consumption will be as under:-

	Low GDP Low LEC	LGDP HLEC	HGDP LLEC	HGDP HLEC
Electricity (bkwh)				
LEC	140	173	170	210
NLEC	59	53	72	65
Fuel Oil (mt)				
LEC	8	10	10	12
NLEC	9	8	11	10
Coal (mt)				
LEC	127	157	154	190
NLEC	61	55	74	67

6.13 The above results indicate that in a high GDP scenario the effect of following a strategy aimed at moderating growth in the energy-intensive industries will result in a saving of about 33 bkwh of electricity, 29 million tonnes of coal and 1 million tonne of oil. This is the effect of reducing the share of LEC industries in the Manufacturing Sector from 37% to 30%. The policy implications of these results are that either the share of LEC in the industries sector should be brought down to effect energy saving or else energy efficiencies of the LEC be increased through R & D efforts to reduce their consumption levels and their energy intensities.

End-Use Method:

6.14 With the help of the consumption norms and the production targets of individual industries, it is possible to derive the energy requirements for the individual industries. Unfortunately, detailed fuel oil consumption norms for various industries are not available and are highly susceptible to the pricing policies and availability of oil. The same holds for coal, for which disaggregation is available in terms of 5 to 7 industries. However, electricity consumption norms are available in the Technical Note on Sixth plan. The plan document also gives the targets of production for major individual industries in physical terms for 1984-85 and 1994-95. The targets of production for 1989-90 have been estimated using the annual growth rate of these industries for 1984-1994. Further it has been assumed that the electricity consumption norms do not change upto 1995 because of

(i) expected substitution of oil by electricity;
(ii) increase in the shares of the high quality products in the total output; and
(iii) expected improvements in the quality of products.

It is assumed that the effect of increase in electricity consumption due to these factors will be neutralised through electricity conservation efforts.

The Table below gives the electricity demand from the end use method for some of major industries only.

TABLE: Electricity Demand Forecast for Major Industries from End-Use Method for 1989-90 and 1994-95

Item	Unit	1989-90 (projection)		1994-95 (projection)	
		production Target	Electricity Consumed in Mkwh	production Target	Electricity Consumed in Mkwh
Coal	10^6t	231	3465	325	4875
Iron ore	"	64	960	75	1125
Petroleum products	"	46.6	1444	61.4	1903
Cement	"	46.3	5556	65	6670
Mild Steel	"	15.8	11850	22	16500
Cloth	10^6 mtrs.	16157	8744	20000	10824
Paper & Paper Board	10^3t	2123	2972	3000	4200
Newsprint	"	258.	542	370	777
Synthetic Fibres	"	317	1594	490	2959
Nitrogenous Fertilizers	"	6384	9001	9700	13678
phosphatic Fertilizers	"	2244	2581	3600	4140
Aluminium	"	459	9180	700	14000
Copper Refined	"	58	12	75	15
Zinc	"	116	467	160	672
Lead	"	35	18	50	25

Chapter - 7

principal findings and Conclusions

1. In the first two decades of planning, the share of coal in the gross commercial energy use in the economy steadily decreased while the share of electricity and oil consistently increased. The pattern of energy consumption has been undergoing a process of difficult adjustments in response to changes in the relative prices, scarcities and levels of activity in the consuming sectors. Electricity has been the preferred form of energy consumption and has consistently registered a high growth rate.

2. A close relationship exists between the consumption of energy and the overall growth of the economy. The rates of increase of total commercial energy over the long run follows the same trend as that of GDP as well as of value added in industry.

3. An important factor that emerges from the study is the relative intensity of energy consumption in the economy. The long-term energy: GDP elasticity coefficients show a remarkable stability. The energy-GDP elasticity coefficient in India is high compared to developed countries where it is lower than unity due to high fuel utilization efficiency. Our high elasticity coefficient may be due to a fairly steep 'S' curve during the early phases of industrialization. It could also be due to the fact that there is an element of substitution of non-commercial energy by commercial energy in the Indian economy.

4. From time to time power shortages in India have affected economic activity in both the industrial and agricultural sectors. Coal shortages have caused low utilization of installed capacities in major coal consuming industries.

5. The intensity of energy use in industry has been steadily increasing during 1953-54 to 1980-81. The increase in electricity consumption is the main reason for the rise in the intensity of energy consumption.

6. India's industrial output has grown slowly but its requisite energy inputs were much higher compared to Brazil, Kenya and Korea.

7. The important role of coal in our fuel-mix and the development of heavy industries mostly explain our high industrial energy consumption.

8. Historical trends of energy consumption of some large energy consumption industries reveal that energy intensities have remained fairly stable in the case of textiles, while in the case of inorganic heavy chemicals, paper and paper board, iron and steel, energy intensities have declined. There has been a steady increase in the energy intensity of Non-Ferrous Basic Metals and Cement. Greater volatility in the energy intensity of fertilizers industry has been observed.

9. Substitution of non-commercial fuels by commercial fuels have resulted in higher elasticity coefficients for commercial energy.

10. Actual growth rate in production of coal, electricity and petroleum products has been much short of target at the end of Sixth plan (1984-85) with the result that inter-fuel substitution dictated by the pricing structure would not be possible due to the supply bottlenecks.

11. The share of Large Energy Consuming (LEC) industries has declined as a percentage of the registered sector while their share has remained more or less constant in the total industrial sector comprising of registered and unregistered industries.

12. Growth rates of industries which consume more energy per unit value-added are higher than the growth rates of industries which consume lesser energy such as textiles.

13. Energy intensities for some of our LEC industries are high by international comparisons. This may be for want of energy efficient technologies, advantages of economies of scale or due to greater fluctuations in capacity utilization. Energy efficiencies in the LEC industries are lower by international comparisons but are improving overtime.

14. prices of electricity have risen less than the other two fuels namely coal and oil. The present pricing structure should, in principle encourage substitution of oil if coal and electricity supply could be reliably provided.

15. Adequate pricing policies can help in taking appropriate decisions for conservation measures, appropriate choice for technologies as well as for industrial mix.

16. Opportunities to utilize energy efficient technologies in India are enormous. Energy efficiency can be increased through development of energy-efficient industrial technologies reduction of the energy-intensive product-mix and improvements in capacity utilization.

17. Demand forcasts, based on different growth scenarios indicate that a strategy aimed at moderating growth in the energy intensive industries can result in an annual saving of about 33 bkWh of electricity, 29 million tonnes of coal and 1 million tonne of oil by the year 2004-05.

18. Past patterns of commercial energy consumption indicate that in the next two or three decades, patterns of energy consumption will change.

-.-.-.-.-.-.-

Annexure-I

Regression models both linear and log linear relating consumption of each energy fuel in the economy as dependent Variable to Gross Domestic Product (GDP) as explanatory Variable were studied and regressed for the year 1953-54 through 1980-81 and for various sub-periods. The results of the total period (1953-1980) are as under:

Sl. No.	Dependent Variable	Independent Variable	Regression Model
1.	Coal (Y_1)	GDP (X_1)	$\log Y_1 = -6.833+1.036 \log X_1$
			$Y_1 = 1.203+0.0015 X_1$
2.	Oil (Y_2)	X_1	$\log Y_2 = -16.32+1.904 \log X_1$
			$Y_2 = 6.32+0.004 X_1$
3.	Electricity (Y_3)	X_1	$\log Y_3 = -24.14+2.663 \log X_1$
			$Y_3 = -50.60+0.003 X_1$
4.	Total Energy (Y_4)(Commercial)	X_1	$\log Y_4 = -13.64+1.802 \log X_1$
			$Y_4 = -112.57+0.009 X_1$

Other related results are as Under:

Dependent Variable	r^2	Adjusted R^2	t-values	SE	DWS
log Y_1	0.93	0.9277	10.6	0.055	0.936
Y_1	0.92	0.92	17.8	0.000	0.948
Log Y_2	0.90	0.90	33.6	0.050	0.779
Y_2	0.98	0.98	35.98	0.000	1.241
log Y_3	0.98	0.98	32.5	0.002	0.825
Y_3	0.99	0.99	45.92	0.000	1.002
log Y_4	0.98	0.98	37.6	0.048	1.048
Y_4	0.99	0.99	47.4	0.000	1.957

r^2 = Square of Correlation Coefficient;
SE = Standard error;
DWS = Durbin Watson Statistic

Note: Y_1, Y_2, Y_3, Y_4 relate to consumption in the Economy as a whole.

Annexure-II

Regression models both linear and log-linear relating consumption of each energy fuel in the industrial sector as dependent variable to sectoral GDP for the industry sector (mining and manufacturing) as explanatory variable were also studied and regressed for the year 1953-54 through 1980-81 and for various sub-periods. The results of the total period (1953-1980) are as under:

Sl. No.	Dependent Variable	Independent Variable	Regression Model
1.	Coal (Y'_1)	GDP (X'_1)	$\log Y'_1 = -6.63 + 1.21 \log X'_1$
			$Y'_1 = -7.91 + 0.008 X'_1$
2.	OIL (Y'_2)	(X'_1)	$\log Y'_2 = -3.60 + 0.60 \log X'_1$
			$Y'_2 = 3.32 + 0.001 X'_1$
3.	Electricity (Y'_3)	(X'_1	$\log Y'_3 = -12.59 + 1.85 \log X'_1$
			$Y'_3 = -15.60 + 0.009 X'_1$
4.	Total Energy (Y'_4) (Commercial)	X'_1	$\log Y'_4 = -7.37 + 1.36 \log X'_1$
			$Y'_4 = -20.18 + 0.018 X'_1$

Other related results are as under:

Dependent Variable	r^2	Adjusted R^2	t-values	SE	DWS
$\log Y'_1$	0.97	0.97	31.48	0.038	1.20
Y'_1	0.97	0.97	27.67	0.000	1.06
$\log Y'_2$	0.83	0.82	11.17	0.06	0.93
Y'_2	0.74	0.73	8.7	0.000	0.86
$\log Y'_3$	0.98	0.98	38.89	0.04	4.28
Y'_3	0.98	0.98	35.83	0.000	0.83
$\log Y'_4$	0.99	0.99	51.28	0.026	1.19
Y'_4	0.99	0.99	46.74	0.0003	1.30

r^2 += Square of Correlation Coefficient;

SE = Standard Error;

DWS = Durbin Watson Statistic.

Note: Y'_1, Y'_2, Y'_3, Y'_4 and X'_1 relate to the industrial sector only.

R E F E R E N C E S

1. Advisory Board on Energy. A Prospective on Demand for Energy in India, 1984.

2. Ashok V. Desai: Energy Output and Consumption in India, Working Paper No. 97, CDS, Uloor, Trivandrum.

3. Bernard A. Gelb, Jeffrey pliskin. Energy Use in Mining: Patterns and Prospects.

4. Chandhok H.L. Wholesale price Index in India.

5. Centre for Monitoring Indian Economy, Current Energy Scene in India, May 1984.

6. Dileep M. Wagle and N.V. Rao. The Power Sector in India.

7. Henderson P.D. India: The Energy Sector, Oxford University Press.

8. Indian petroleum and Petro-chemicals Statistics 1982-83.

9. John G. Myers. Energy Consumption in Manufacturing Ballinger publishing Company (1974).

10. Jyoti K. Parikh: Modelling Energy Demand for Policy Analysis, planning Commission, 1981.

11. Jyoti K. Parikh and Chaitanya EPW-1980 Vol. XV No. 11

12. Kadekodi G.K. pricing of Energy Inputs: Cases of Coal, petroleum and Electricity, Institute of Economic Growth (IEG) monograph; December 1983.

13. Murthy M.N. Efficiency and Distributional Equity and Optimal Structure of prices for public Electricity Supply in India (IEG) monograph, January 1983.

14. NCAER 1971, Consumption pattern of Selected petroleum products.

15. National Productivity Council Total Energy and Energy Substitution 1976.

16. planning Commission, Sixth Five Year plan 1980-85.

17. planning Commission. A Technical Note on Sixth Five Year plan.

18. public Electricity Supply. All India Statistics, General Review; Central Electricity Authority.

19. Rajendra K. pachauri, Energy policy for India.

20. Report of the Energy Survey of India Committee 1965.

21. Report of the Fuel policy Committee, India, 1974.

22. Report of the Working Group on Energy policy, planning Commission, 1979.

23. Report of the Working Group on Cement Industry 1985-1990, Ministry of Industry.

24. Report of the Working Group on Paper and Paper Board Industry, Ministry of Industry.

25. Report of the Working Group on Inorganic Chemicals 1985-1990.

26. Structural Changes in Consumption of petroleum products: 1969-1979.

Quarterly Economic Report of the Indian Institute of public Opinion.

27. Uri N.D. Energy Demand and Inter-Fuel Substitution in India, European Economic Review, 1979.

28. Wallace E. Tyner. Energy Resources and Economic Development India.

29. Workshop on Energy; paper and Cement Industries, ICICI - 1981.

30. Workshop on Energy; Caustic Soda, Soda Ash, Aluminium, ICICI -1982.

31. Workshop on Energy Supply and Industrial Growth FICCI - 1983.

32. World Bank. Energy in the Developing Countries 1980.

33. Yojna. Vol. XXVI - 1 & 2 (Energy Special)

-.-.-.-.-.-.-