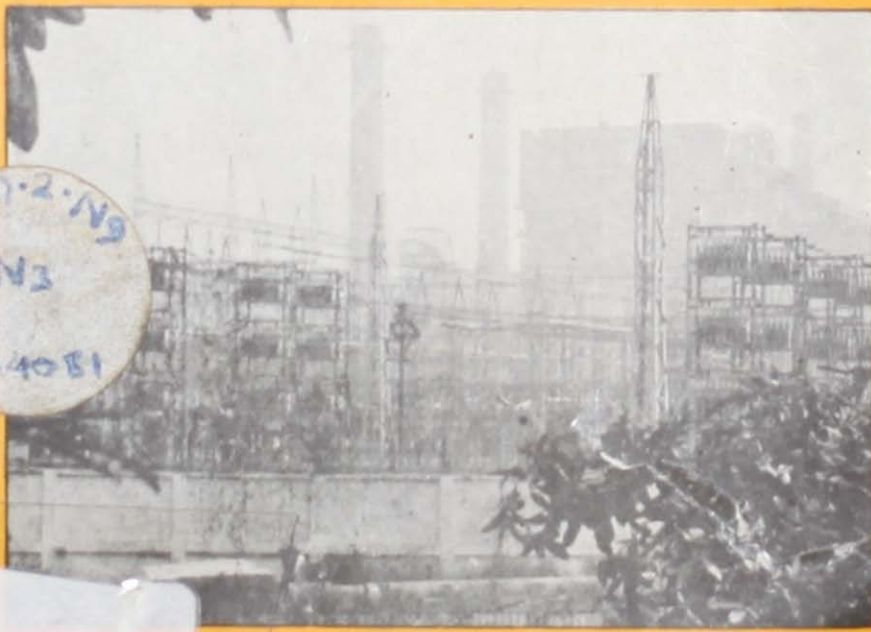
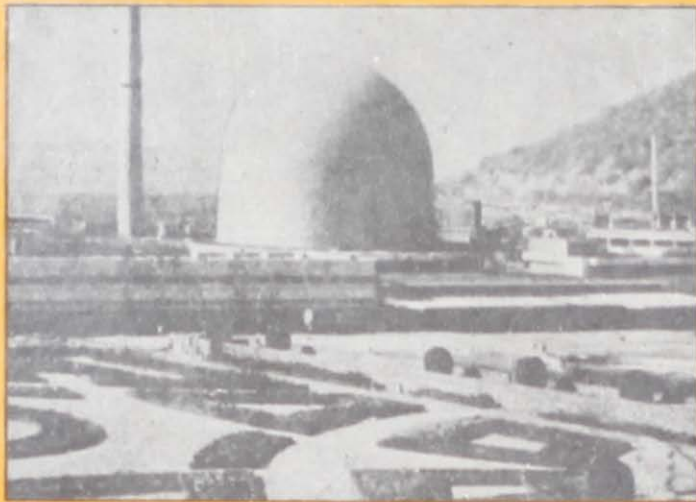


# ENERGY ECONOMICS



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BIRUNDHA VARADARAJAN

The horns of the dilemma, pertaining to energy are many. Growth of industrial societies, the changing pattern of consumption of large quantities of energy and fuel, modern technology and living styles have evolved with the expectation of uninterrupted supply of oil. Concern over environment depends on conservation and energy renewal technologies, posing challenges to generate and use energy in ecologically sound ways. The situation calls for the creation of an awareness of the emerging problems of energy production and consumption among the planners, policy makers, academicians and researchers.

Realising the importance of energy economics, universities have introduced a course for post-graduate students. They will find this book useful in pursuing their research. It can also serve as reference material. Its main purpose is to introduce students to the exciting subject of energy economics and to make them understand the difficulties facing the world on the energy front.

***ENERGY  
ECONOMICS***

# **ENERGY ECONOMICS**

**DHULASI BIRUNDHA VARADARAJAN**



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*Energy Economics*

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## INTRODUCTION

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Energy is the capacity to do work or to transfer heat. In ordinary speech we refer to physical work or mental work to describe a variety of activities that we think of as energetic.

Energy means physical ability to perform a work and a work is done when a body is moved by a force. Naturally, there is use of some form of energy in the work that is performed. To the physicist, however, work has a very specific meaning. Work is done on a body when a body is forced to move. Merely holding a heavy weight requires force but is not work because the weight is not being moved. Lifting a weight, however, is work. Climbing a mountain or a flight of stairs is work. So is stretching a spring, or compressing a gas in a cylinder or in a balloon, because all these activities move something.

Does an object lying on the ground have energy? If it can do work or transfer heat, the answer is yes. If it is a lump of coal, it could burn and be used to heat water or cook food and, therefore, it too has energy.

Energy has been a key factor in the supply of food and also physical comforts necessary for the existence of mankind. The energy within human beings is dependent on food that they consume. If it is an apple one could eat it and it would enable one to do work and to keep one's body warm. So, an apple has energy. But to get the food, man has to do some work which requires energy. Thus, the use of energy is an inseparable part of human existence.

### Evolution of Energy

The wheels of civilisation are kept turning by energy and all this energy, whether we draw it from a gallon of gasoline, a tonne of coal or a pound of butter, has come to us from the sun.

Energy is wealth and in the case of apprenticed sunlight, wealth of a particularly discernible kind, for it is freshly created and does not involve robbing the poor, taxing the rich, or despoiling the earth of materials which may be needed by our descendants as much as by ourselves. Yet this energy is free for him who can discover how to capture and control it. Science learns to capture a constantly growing fraction of the energy that is available and turn it more effectively to useful ends.

The most useful forms of energy for practical purposes are those we call heat, sound and light. Energy has also mechanical, electrical, magnetic, chemical and gravitational forms.

It is clear that technological man no longer lives within this ancient energy flow pattern. Before the advent of fire our ancestors needed only 2000 kcals of energy per day per person. People domesticated animals engaged in agriculture, and used fuel for cooking and heating. Per capita energy requirements rose by a factor at roughly 6 to 12,000 kcals per day. By 1860, small amounts of coal were being mined, heat engines had been invented, and a resident of London used about 70,000 kcals of energy per day.

In western Europe at this time, the total population and the per capita energy requirements were so high that man needed more energy than could be simultaneously replenished by the sun. He began to use reserves of energy stored as fossil fuels.

In the United States, in 1970, man's per capita utilisation was 230,000 kcals per day, a rate which greatly accelerates the exhaustion of fossil fuel. This prodigious rate is unique in the history of the world.

Since people are now more versatile in their activities the 230,000 kcals of energy are spread out in a variety of ways—a man heats his home, drives his car, bears responsibility for the fuel used by trains, trucks and tractors that serve him. He also burns lights and runs electric appliances. Indirectly, he uses the energy consumed by the industries that supply him with goods. This utilisation therefore seems less personal than the 2000 daily kilo-calories of food required for primitive people or even the 12,000 kcal rate for early agriculturists.

### **Two Fundamental Laws**

Where does energy go after it has been used? A lump of coal turns to ash but what becomes of its energy? This non-substance called



"the ability to do work" is hard to define and hard to keep track of. Two questions arise:

1. Could we not find used energy and reuse it?
2. If energy does not really matter could we find an alternative one?

These questions engaged the attention of scientists for a long time and the search for answers led to the development of the science of heat, motion or of thermodynamics.

Primitive man tried to finish his work through muscle power. Later, he cooperated with his fellowmen and groups of men working together were able to do the work. The situation improved further after people had learnt to domesticate large animals and use them as beasts of burden. But a more far-reaching development for doing work was the invention of machines. The lever, the wheel, the roller, the screw, the inclined plane and, later, the gear and the block and tackle were all devices that could increase the force that a man or his animals could exert.

These three techniques—cooperation among people, the use of animal power and the application of machines—enabled man to build (and sometimes to destroy) such wonders as the Pyramids of Egypt, the Great Wall of China and the cities of Athens, Rome and Carthage.

### The Laws of Thermodynamics

Thermodynamics—derived from the Greek *therme* (heat) and *dynamis* (power)—is an applied science that defines and interprets the relationships among energy heat and work. It is the science that makes possible an understanding not only of steam engines but also of the relationships of energy to society and the machines that serve as a technological foundation.

The first scientist to ascertain the relationships among heat, energy and work was Benjamin Thompson, founder in 1799 of the Royal Institution in London. Thompson studied the heat produced when a brass cannon was bored. Early theories of energy contended that heat was an invisible fluid called caloric fluid. Thompson discovered that the heat was at the same temperature in both the bored barrel and chips and furthermore concluded that the supply of heat must be endless. This led him to speculate that it was motion and not the mysterious caloric fluid.

Heat, then, was not a material substance as the caloric theory had held it to be. Later, a British scientist, James P. Joule,

established a mathematical measure of the exact relationship between heat and work, which led to the establishment of a principle which is called the First Law of Thermodynamics. "Energy and matter can neither be created nor destroyed." This law can also be expressed in terms of conservation of energy. There is no proof for the first law. It is simply a concise statement about man's experience with energy.

### **Second Law of Thermodynamics**

Modern technology demands far more energy than can be supplied by men and beasts. Instead, it makes use of engines, which consume fuel to produce heat and convert the heat into work. The idea that heat could be converted into work was far from obvious. In fact, heat engines have been used successfully only during the past 200 years or so (James Watt developed his steam engine in 1769). The first experimental proof that energy can be converted without gain or loss from one form into another was supplied by James Joule in 1849.

Heat and work are two forms of energy and it is therefore possible to convert heat into work or work into heat. Thus one can create heat by rubbing two sticks together and the heat produced is exactly equivalent in energy to the work required to rub the sticks. It was also discovered that fuels contain potential heat. A pound of coal contains stored energy which can be released by combustion. But heat is also stored in substances that are not fuels. For example, ordinary substances as water: water loses energy when it turns to ice, therefore water must have energy.

Likewise, only some of the energy from firewood could be used to produce work, the rest being lost in technological processes. This observation leads to the restatement of the second law: "Energy cannot be completely recycled."

### **Second Law of Thermodynamics**

This law was first formulated by a brilliant young French physicist, Sadi Carnot. His famous technical paper "Reflections on the motive power of heat" was written in 1819 when he was 23. His analysis led him to the conclusion that a heat engine operates on a certain cycle, that is, a fluid in the engine receives and rejects heat during a series of steps in it. The fluid would always return to its original state.

He outlined the cycle of operation of a steam engine. Water absorbs heat in the engine's boiler as water evaporates into steam.

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He outlined the cycle of operation of a steam engine. Water absorbs heat in the engine's boiler as water evaporates into steam.

The steam expands and performs mechanical work, then it is condensed back to water as the heat is removed from it in the condenser. Then the cycle is repeated as the water is pumped back into the boiler and converted into steam

Thus he said there would always be three conditions in a heat engine:

- a) Heat added,
- b) Work performed, and
- c) Heat rejected.

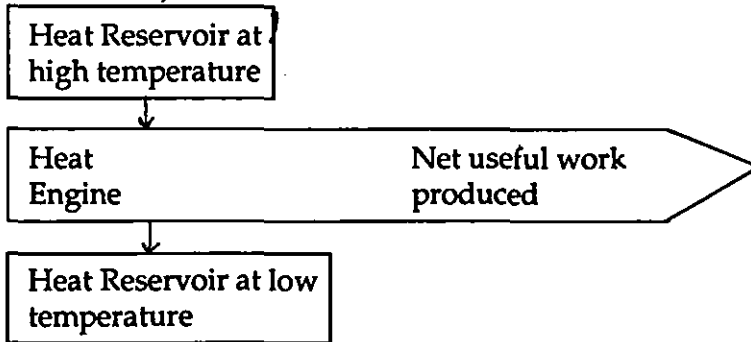


Fig. 1: Heat Engine Steam Cycle

Carnot additionally defined the efficiency of a heat engine which he said depended upon the temperature relationship of the heat received by the engine's boiler and the heat rejected by its condenser.

### Law of Entropy

Carnot's principle has come to be known as the Second Law of Thermodynamics which was stated more succinctly by the German physicist, Rudolf Clausius, in 1850. "It is impossible for a self-acting machine unaided by any external agency to convert heat from one body into another at a higher temperature."

In addition to stating the Second Law of Thermodynamics in a concise manner, Clausius contributed a term called entropy, which describes the relationship of energy to an engine or a process. Entropy is derived from a Greek word meaning transformation.

A heat engine will convert some of the original energy content of fuel into work in the engine and will dissipate the waste heat. So while no energy is destroyed, some—the waste heat—is transmitted to a useless form. Energy, then, is constantly moving from a higher to a lower state. He called his discovery

“the principle of the increase of Entropy”, a corollary of the Second Law of Thermodynamics. The energy of the universe is constant but its entropy increases towards a maximum. Today the Second Law of Thermodynamics is called the Entropy Law, and it is used to describe not only the processes of energy conversion in engines but also the circumstances of many other systems, including those of economics, physics, urban development, biology, ecology and the nature of the universe itself.

In a general sense, the laws of thermodynamics instruct us that on our planet—and in our universe—all activities of nature and its creatures are subject to two conditions:

1. Energy and matter can neither be created nor destroyed. In other words, there is no such thing as a free lunch, and you can't get something for nothing.
2. Since energy constantly changes from a higher to a lower form, it is not possible for us to break even. The entropy law describes the existence of a great natural law—a sort of energy gravity of the universe. Energy is constantly moving from a higher level to a lower level. In the same way that gravity influences water flow, energy can't be made to run uphill.
3. The Entropy Law teaches us that the rule of biological life and, in man's case, of its economic continuation is far harsher. In Entropy terms, the cost of any biological or economic enterprise is always greater than the product.
4. Another way of understanding the Entropy Law is to visualise the world's entropy process as constantly moving toward disorder. A deck of cards held in one's hand represents order; flung to the floor the deck scatters into fifty-two individual cards in a random fashion. The deck intact is a stock of potential energy that is in a state of low entropy; once the cards are scattered, a person will have to expend more energy in picking them up and arranging them into a deck than the energy originally required to scatter them. Scattered on the floor, the cards are high entropy.
5. The significance of the discovery of the laws of thermodynamics has not yet been fully appreciated by any human society. In our history of energy, the discovery of

these laws took place half way through the nineteenth century in the midst of the Industrial Revolution in Europe and America. At that point, the Western world had not yet entered the age of energy, which spawned the age of technology and the age of automation. With the application of the thermodynamics laws, the efficient harnessing of energy in engines made it possible for engineers and scientists to develop the mechanised arts of the coming age, with its skyscrapers, automobiles, airplanes, telephones, radio and television.

6. The real contribution of Carnot, Thompson, Clausius and other thermodynamics scientists was that energy could be understood for the first time in history. The Greek had ordered the universe around fire, earth, air and water with fire having the most prominent place, but they did not understand the nature of energy. James Watt built his steam engine without understanding the nature of the energy that allowed its operation.
7. More powerful and efficient machines could be built only through applying the science of thermodynamics whose laws have frequently been called the laws of the conservation of energy by avoiding wastage of energy.

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## SOURCES OF ENERGY I (CONVENTIONAL)

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Energy can be extracted from various sources, i.e., bioenergy, human energy, mechanical energy, kinetic energy and animal energy. Energy classification may be based on its nature, quality, marketability and storing capacity.

### **Commercial and Non-commercial Energy**

Some of the energy resources fetch a price and can be marketed while others are freely available, for example, solar energy, fuel wood and animal and agricultural wastes. But this classification is rather relative in character. What was available once freely cannot be available free of cost due to shortage of its supply, (e.g., firewood). Moreover, what is available freely in one place (rural) is sold in the market in other areas (urban). Solar energy may be available freely but its conversion involves certain costs such as solar cells.

### **Renewable and Non-renewable Energy Resources**

Energy resources like firewood, agricultural waste, solar energy, and wind energy are inexhaustible in character and can be renewed depending upon the changes in demand. But energy resources like coal, oil and other fossil fuels (resources that are stored beneath the earth) are limited in character and would be exhausted within a prescribed period of time. Greater usage of such fuels would result in an energy crisis and the supply cannot be adjusted according to the changing demand.

### **Conventional and Non-conventional Energy Resources**

Conventional energy is used conventionally and can be stored, for example, by coal and oil. The non-conventional energy

resources are rarely used. Moreover, these cannot be stored easily. Their storing as well as conversion involves heavy costs, e.g., solar, wind, biogas, etc.

### **Direct and Indirect Energy**

Some of the energy sources can be used directly, for examples, coal, oil, solar, fuelwood, etc. But these energy sources may be used to generate indirect energy, for example electricity. Electricity generated from various sources can be considered as indirect energy.

The generation of electricity is possible either through a centralised or a decentralised system.

In a centralised system there is an electricity generating centre whereby electricity is transmitted through grids and vast network transmission wires to the consumption points. There are three different sources, viz., thermal, hydel and nuclear. In a thermal power station coal or oil is used as fuel. Hydro power is generated when the stored water in dams is released with a force through rotating turbines. Nuclear power is generated by using thorium, uranium and plutonium as fuel. The centralised electricity generating system has its own environmental impacts.

The decentralised electricity system does not involve huge costs on the establishment of power stations, e.g., electricity generated through small hydel power stations (near the Himalayan ranges), solar energy, wind energy, bioenergy.

### **Different Energy Sources**

#### **Coal**

Coal is by far the largest known energy resource existing in the country. The resources of coal in India have been assessed by the Geological Survey of India. A lot of work was also done by the National Coal Development Corporation and some State Government in the country.

Reserves of all types of coal in seams exceeding 0.5 metres in thickness and occurring within a depth of 1,200 metres were of the order of 186 billion tonnes as of January 1, 1990. Of these, about 56 billion tonnes were proven reserves. As of January 1, 1989, gross reserves of coal were of the order of 176.3 billion tonnes. Thus, gross reserves registered an increase of 9.7 billion tonnes during 1989. Proven reserves increased from 52 billion tonnes to 56 billion tonnes in the same period.



A statewise break-up of the gross reserves indicates the predominant position of Bihar. With more than 61 billion tonnes of coal the state accounts for almost a third of the total coal reserves in the country. Between January 1, 1986 and January 1, 1990, coal reserves increased by nearly 13 billion tonnes in Orissa. This represents 43 per cent of the total increase in coal reserves during the period. The increase in Madhya Pradesh was 8.3 billion tonnes and in Bihar 3.3 billion tonnes during the same period. However, the new finds in coal reserves, particularly in Orissa, are mostly of a very poor quality (in terms of calorific content). According to a report of September 1989, the Geological Survey of India has formulated a seven-point strategy for coal exploration during the Eighth Plan period. The strategy envisages identification of coking coal-bearing sectors in the Sonapur coalfield in Madhya Pradesh and the East Bokaro and South Karanpura fields in Bihar, besides establishing reserves of superior quality coal in the virgin areas of Ranigunj, South Karanpura, Talcher and Tat Pani-Ramkola coalfields. The strategy also emphasises exploration in the potential areas of north-eastern regions. The entire operation envisages a total budgetary outlay of Rs. 90.4 crores involving 3.04 lakh metres of drilling.

#### *Lignite Deposits*

Lignite reserves are estimated to be of the order of 6,200 million tonnes as of 1989. Of these 4,450 million tonnes are known to be located in the South Arcot district of Tamil Nadu, Rajasthan, Pondicherry, Gujarat and Jammu and Kashmir and, recently, Kerala is the other state with lignite deposits. Significant increases were recorded in the known lignite reserves. In Rajasthan these increased from 47 million tonnes in 1985 to 770 million tonnes in 1990. Lignite is found in the Bikaner district of Rajasthan. In Jammu and Kashmir, lignite deposits are concentrated mostly in the Nichahom area of Baramulla district. Known reserves increased from 8 million tonnes to 90 million tonnes between 1985 and 1990 in the state. Lignite deposits are mined at Panandhro in Kutch district of Gujarat. In 1989, Kerala was added to the list of states with lignite deposits with the discovery of 100 million tonnes of lignite.

*Production Trends*

All coking coalmines were nationalised in October 1971 and non-coking coalmines in January 1973. The pre-nationalisation period was characterised by unscientific and unsafe mining methods in highly fragmented mines. The post-nationalisation period witnessed a decline in the number of mines and an increase in the growth of coal production. Total coal production increased at the rate of 4 per cent per annum between 1960-61 and the time of nationalisation. In the post-nationalisation seventies, the rate of growth of production increased to more than 5 per cent. Most of this increase originated in the spurt in coking coal production in 1974-75 and 1975-76. In the case of non-coking coal, while the growth rate between 1960-61 and 1973-74 was 5.61 per cent per annum, the growth rate in the post-nationalisation seventies was only 4.87 per cent per annum.

The eighties were generally a period of steady and healthy growth rates of coal production. While coking coal production fluctuated in different years these fluctuations were offset by a steady growth in the production of non-coking coal. Total coal production increased during the Sixth Plan period (1980-81 to 1984-85) at the rate of 6.66 per cent per annum; this increased to nearly 7 per cent per annum in the Seventh Plan period. A good part of the impressive increase in industrial production during the eighties can be traced to the steady improvement in coal production during this period.

**Table 1.1: Coal Production Growth Rates in India**

<i>Period</i>	<i>% increase per annum</i>		
	<i>Total Coal</i>	<i>Coking Coal</i>	<i>Non-coking Coal</i>
1960-61 to 1971-72	4.08	0.43	5.56
1960-61 to 1973-74	4.05	-0.10	5.61
1971-72 to 1980-81	5.16	5.38	5.09
1973-74 to 1980-81	5.53	7.90	4.87
1980-81 to 1984-85	6.66	7.98	6.24
1985-86 to 1989-90	6.96	5.40	7.41

*Source:* Energy sector as a whole, centre for monitoring Indian Economy, Bombay.

*Features of Coal Industry*

The average size of coalmines in India is small, though as a consequence of the nationalisation measures and the accompanying reorganisation of collieries it has increased considerably. In 1971 there were nearly 800 collieries in operation. As a result of nationalisation a large number of small units have been closed or merged, most of them in the Raniganj and Jharia coalfields. Thus the 300 or so private mines have been taken over by the coalmines authority in the Raniganj and Jharia coalfields. These have been reconstituted into 86 mining concerns while the 388 mines acquired earlier by Bharat Coking Coal were similarly reorganised into 87 units. The total number of operating units in production in the public sector is now over 300, so that the average output is of the order of 240,000 tons per year.

About 20 per cent of coal production in India comes at present from open cast mines and 80 per cent from underground mines which are for the most part very deep. Working methods for extraction vary greatly from the most primitive one of mining through solid blasting or cutting and blasting to tightly mechanised ones. For 1969, 36 per cent of the output was recorded as having been obtained by coal cultures, which were then used in 226 mines. Mechanical loaders were in operation in 22 units covering less than 3 per cent of the output and conveyors in 39 mines with less than 10 per cent of it.

*Problems of Coal Production and Coal Transport*

The problem of making more coal available has two main aspects: production and transport. It is convenient to consider them separately though transport facilities are one of the possible constraints on production.

*1. Capacity Utilisation:* According to a report of June 1990, Coal India Limited had an idle capacity of 28 million tonnes in 1989-90. The unutilised capacity was 7.78 million tonnes in underground mines accounting for 29 per cent of the total underground mining capacity of 20 million tonnes in the case of open-cast mining accounting for 39 per cent of the total capacity. Reportedly, investment in underground capacity is about Rs. 1000 per tonne and in open-cast mining about Rs. 700 per tonne. Based on these figures, investments lying idle works out at Rs. 2,178 crores. Part of the reason for this waste of capacity is lack of adequate

development of panels and working faces in underground mines and lack of a reporting system in general.

The assessed system capacity in 1989-90 of all mines together was 196.67 million tonnes against which there was a production of 178.59 million tonnes, i.e., a gap of 18.08 million tonnes between the assessed capacity and the actual production. The gap between actual production (178.59 million tonnes) and the system capacity (196.67 million tonnes) is accounted for by a number of factors such as:

1. power interruption;
2. industrial relations problems;
3. rains;
4. land constraints;
5. despatch constraints;
6. law and order problems, and
7. non-availability of machinery, etc.

Many of these factors work in conjunction and it is not possible to isolate the impact of any single factor. On the basis of analysis of factors adversely affecting production about 4 million tonnes of loss of production can be attributed to non-availability of machinery.

*Technology:* The development of the coal industry in the country has been hampered to a large extent by the direct import of technologies from Western countries, which had abundant access to supplies of petroleum and thus did not stimulate demand for coal, which may have led to modernisation of the coal industry. This feature is part of a worldwide trend that has been observed even in such countries as the United Kingdom and West Germany, where the existence of large deposits of coal did not appreciably affect the increasing dependence on oil as a source of energy in industrial and agricultural activities. The result has been that most of the coalmines in the country until recently suffered from the use of outdated equipment, the existence of hazardous working conditions, and poor financial health.

*Transport:* Transport of coal in India is a critical issue both in the immediate present and in the longer term. Distribution of coal is made on the basis of assessed demand of various coal consumers. Distribution of coking coal required for metallurgical purposes is controlled under the Colliery Control order, 1945, and is made by the coal controller. In the case of non-coking coal there is no

statutory control on distribution. The long-term standing linkage committees functioning in the Department of Coal establishes linkages to power stations and cement plants.

Linkages to the industries in the non-core sector and fertiliser plants are established by the non-core sector linkage committee of CIL. These committees meet every quarter and allocate coal to each powerhouse as well as cement plants.

Despite the planned production process and the elaborate arrangements made for its distribution and, quite ironically, despite the mounting stocks of coal in early 1990, the Railways and CIL are at the centre of the problem with each blaming the other for this sorry state of shortage amidst plenty. Against a total order of 14,886 wagons in January 1990 and 15,599 wagons in February 1990, placed by CIL, actual supply was of 13,717 wagons in January 1990, and 13,613 in February 1990. However, CIL was able to load only 13,613 wagons in January 1990 and 13,430 in February 1990. Thus, CIL blames the Railways for not supplying enough wagons and the railways blame CIL for its failure to supply adequate coal for loading.

To overcome this problem over a longer term a good deal of research and planning need to be undertaken on alternative systems for treating and transporting coal. The possibilities will have to be explored of coastal shipping, large transport in the Ganga and Yamuna river system, pipeline for conveying coal in slurry form, and construction of railway lines exclusively for coal traffic. One such possibility, which is already being developed, is the construction of major stations in coalfields rather than at load centres so that energy is transported by high voltage transmission lines rather than in the form of coal by surface transmission. Another way to reduce coal movement would be by greater refining of coal, for example, through washing or gasification, at or near the points of production. Whether the benefits of this would exceed the costs involved is however debatable. The balance of advance as between different methods and processes for handling coal will change in course of time with changes in technical knowledge and input costs.

*Low-grade Coal:* Another feature of Indian coal is its unusually high ash content. Of good quality coal, which is classified as containing not more than 19 per cent of ash plus moisture, there exist only 460 million metric tonnes. A large component of the

costs of using coal is due to the high ash content of Indian coal. These take the form of extensive ash removal facilities at coal burning plants and the additional cost of transporting coal containing a large percentage of ash which cannot be used to provide energy. As a national policy it was decided to set up coal washeries to reduce the ash content of Indian coal. In the past most of these were established by steel plants to reduce the intake of ash in blast furnaces. Only about 4 million metric tons per year of the total capacity established for washeries was intended to be used for non-coking coal, and even this has been poorly utilised. The actual utilisation of washeries as a whole is about 60 per cent of their rated capacity, and only very recent efforts have improved upon this poor performance.

*The Price of Coal Products:* In the case of coal the difference between different grades and qualities under the former pricing arrangements was rather small. As a result, there was a natural tendency for consumers to favour higher grades of coal than were technically necessary. Shortages of these would develop in relation to lower quality coal.

The Fuel Policy Committee has recommended in its final report that in future coal prices should be separately determined in relation to each producing area. Within an area the general level of prices should be such as to enable the mines taken together to cover their costs and earn a 10 per cent return on their investment. The committee has suggested that the structure of prices should adequately reflect the value of the specific qualities to the consumer as well as the relative scarcity of coal of different qualities.

#### *Current Status of CIL*

Pithead prices of coal are fixed by the Central Government under the Colliery Control Order, 1949. Prices were last increased for CIL coal on January 1, 1989, from Rs. 219 to Rs. 249 per tonne. This was done with a view to compensating the CIL to some extent to meet its increased cost of production. Subsequent to the increase in prices the gap between the cost of production and the selling prices did decrease in the year ended 1989-90. The gap between the two was Rs. 3.63 per tonne in 1985-86 which increased to Rs. 11.54 per tonne in 1986-87.

In 1989-90 wages accounted for 45 per cent of the total production costs, of CIL (44 per cent in 1988-89), stores for 15 per

cent, depreciation 10 per cent, interest 8 per cent, power 8 per cent and the rest 14 per cent. In 1988-89 CIL made a loss of Rs. 23.26 crores compared to a loss of Rs. 225 crores in 1987-88. In 1989-90 the company hoped to make a modest profit of Rs. 60 crores.

### **Eighth Five-Year Plan (1990-95)**

#### *Investment Proposals*

On a number of matters affecting the coal industry there may be a need for concerted action to formulate an industry-wide policy and to extend the interests and responsibilities of the industry further than they have normally been accepted in India up to the present. A second related subject which may need more consideration is marketing. A strong marketing organisation is lacking in the industry. A third subject in which the industry may need to take a more active interest is research and development.

A working group on coal and lignite was constituted by the Planning Commission under the chairmanship of the Secretary, Coal, to study and recommend investment proposals for the Eighth Plan (1994-95) at 320.89 million tonnes, including 8.59 million tonnes of washery middlings for the power plants. To meet this demand, a production target of 304.45 million tonnes has been suggested for Coal India Ltd. and SCCL Mines, Singhereni Collieries Co. Ltd. and 5.86 million tonnes for Tata Iron and Steel Ltd., Indian Iron and Steel Co. Ltd. and Damodar Valley Corporation Ltd. The balance requirement is to be met by drawing down pithead stocks.

The working group has also proposed a total investment of Rs. 20,399.61 crores for the Eighth Plan period. Of this Rs. 16,569.31 crores are meant for the coal sector and Rs. 3830.3 crores for Neyveli Lignite Corporation Ltd. An alternative scenario of investment and production was also worked out by the working group according to which a total investment of Rs. 16,552.44 crores would be needed to yield 295.46 million tonnes of coal by 1994-95 from the CIL and SCCL mines.

### **Oil Production in India**

#### *Introduction*

In day-to-day life oil has a very important role to play in every country. Though oil was discovered in India long ago, it could cross the production mark of one million tonnes per annum only around 1962-63. In 1951, the annual oil production was about 0.25 million tonnes, while in 1963 it rose to about 1.6 million tonnes

and in 1971 to about 7 million tonnes. For 1976 the estimates were about 8.9 million tonnes and for 1978 about 13 million tonnes.

### *Oil Wells*

When a possible source of oil has been located drilling is undertaken. If the oil flows out of the ground of its own accord, the well is described as a 'gusher'. This results from the great pressure exerted upon the oil underground. Often, however, pumps have to be installed to raise the oil to the surface.

The life of an oil well is mostly unpredictable. Some will continue to yield oil for many years, while others may dry up in a relatively short time, sometimes within a matter of weeks.

### *Refining*

The petroleum which comes out of the ground cannot be used in its crude forms. It must be refined and factories where it is refined are known as refineries. Refining operations have become progressively more complex as the range of employment of oil products has expanded; a modern refinery may produce as many as 80 distinct products.

Refining is an operation in which there are considerable economies of scale, at least up to an output of 100,000 barrels per day, but the life of certain sections of a refinery plant is short, and rapid technical change can bring about obsolescence before its expected working life has been realised. The refineries are also influenced by the type of crude used, but technological progress has given the refiner a considerable degree of flexibility, and market influences are even more important.

### *Refining Process*

The increasing demand for gasoline has necessitated an improvement in its yield in refining operations which has been made possible by the development of the cracking process. In cracking, the excess behaviour fractions are converted into lighter ones by the application of heat and pressure. The process was developed shortly after World War I. It received a great impetus after 1930 through the employment of catalysts.

### *Products*

The main products of refineries are gasoline, kerosene oil, gas oil, diesel oil, residual or fuel oil, lubricating oil, and bitumen and other solid or semi-solid residues. Large quantities of gas are also produced, some of which are used in the refineries themselves.



Other products of increasing importance include liquified petroleum gases, fuel and feedstock for the petrochemical industry. In Tamil Nadu, the Madras Refineries Ltd. (MRL) is one of the refineries in India.

### *Petroleum*

Petroleum supplies more than half the world's energy requirements. It provides fuel for heat and lighting, lubricants for machinery and raw materials for a number of industries. The word 'petroleum' is derived from the Latin word 'petra', meaning rock, and 'oleum', meaning oil. It is so called because it is derived from the rocks. Most of petroleum in the world is found in sedimentary rocks and these constitute roughly 40 per cent of the earth's land surface.

### *Factors for the Late Development of Petroleum*

Efficient use of petroleum depends on a complex refining process. Thus, petroleum and gas are new as natural resources. They may have been formed millions of years ago but man found a use for them only recently. This late but rapid development as compared to coal can be attributed to a number of factors.

1. The larger reserves are found far from established industrial regions, often in place which are backward and sparsely populated.
2. While coal can be used in its original form, petroleum has first to be refined to make it usable. This is a complicated process which requires a considerable degree of technical skill.
3. The uses of petroleum are more specialised than those of coal. Overwhelmingly, the most important one is that of powering the internal combustion engine, which has come into large-scale use only during the present century. Even today this fuel has not generally become an important localising factor in industry.

### *Oil Production in India*

At present oil is produced in two sedimentary basins, those of the Assam Arakan basin occupying parts of Assam extending to Nagaland, Meghalaya, Tripura, Manipur and Mizoram and the Cambay basin in Gujarat. Important fields in these areas are Naharkotiya and Ankleshwar and the nearly 9.0 million tonnes of oil found there is shared equally by them.

In the history of oil production in India May 21, 1976 was a red letter day. On this auspicious day crude oil began to flow from the two wells in Bombay High oilfield on a commercial scale to the refinery in Bombay. The first tanker was received at the Bharat refinery in the month of June 1976.

The recent oil strike at the North Basin and South Basin structures will help in increasing the production of oil and gas from the offshore oilfields.

Domestic oil production rose steadily during the last decade from 3 million tonnes in 1965 to 8.5 million tonnes in 1975. Out of this 5.3 million tonnes come from the ONGC oilfields and the rest from Oil India Ltd. Our annual requirement is about 22.5 million tonnes. Thus there is a yawning gap of 12 million tonnes between demand and supply.

The future looks very bright. Bombay High's potential has been officially put at 10.0 million tonnes per year. But actually it is easily 13.0 million tonnes or more. If the productivity of the North Basin oilfields is found to be higher than that of Bombay High, the build-up offshore oil production will be considerably higher. Thus the dream of self-sufficiency in oil by 1981 would have been brought closer to reality. Let us hope that the country will become an exporter of oil some day not too far in the future.

Consumption patterns for these products vary greatly from country to country; countries at a high level of development use a large proportion of gasoline, but in underdeveloped countries gasoline consumption is relatively low and kerosene is the most marketable item.

Madras Refineries, the ninth in a chain of twelve Indian refineries and the third in the south, was set up as a joint venture among the Government of India, the National Indian Oil Company and Amoco of USA in 1965 and commissioned in 1969 with an initial design capacity of 2.5 million tonnes per annum using imported lubricants crude.

#### *Petroleum Production in India*

India is quite poor in respect of petroleum although the demand for kerosene oil in India is the highest in the world. Until recently, petroleum was found only in the Digboi area of Assam. This region produces about 1 million tonnes of petroleum annually, whereas the country's demand amounts to about 6 million

**Table 1.2: Proven Reserves of Crude Oil Natural Gas in India, 1981 to 1989**

<i>As on Jan.</i>	<i>Onshore</i>		<i>Offshore</i>			<i>PM</i>	<i>No. of years for which reserves would last at annual rate of pm</i>
	<i>Gujarat</i>	<i>Assam</i>	<i>Total</i>	<i>Bombay High</i>	<i>Total (3+4)</i>		
	(1)	(2)	(3)	(4)	(5)		
1981	51.48	89.00	140.48	328.29	463.71	14.90	31.5
1982	53.18	91.52	144.70	325.18	469.88	19.73	23.8
1983	90.58	97.03	187.61	338.70	526.31	25.15	20.9
1984	88.00	99.01	187.01	323.81	510.82	27.93	18.3
1985	86.61	101.80	188.41	311.10	499.51	29.80	16.7
1986	98.84	113.83	212.47	345.54	558.01	31.15	17.9
1987	132.05	119.03	261.08	330.35	581.43	30.14	19.3
1988	143.02	124.38	267.40	371.04	638.44	31.58	20.2
1989	155.12	140.24	295.36	430.86	726.22	33.50	21.7

tonnes. Thus India's production is not sufficient to meet even 5 per cent of its requirements and large quantities of petroleum are imported from the Middle East and the United States.

Besides the Digboi fields in the Lakhimpur district of Upper Assam, petroleum products have also been found at Bappapung and House Pung, the Surma Valley and small quantities of poor quality at Badarpur, Massingpur and Partharia.

The oilfields of Assam are connected with Calcutta by a railway line. Digboi is joined by a branch line with Dibrugarh, an important river port. There are oil refineries at Dibrugarh and Calcutta.

Recently, rich reserves of petroleum have been discovered in the Cambay region of western India. A number of wells have been drilled in this region and most of them have struck oil. There are also possibilities of obtaining oil in the Himalayan foothills ranging from Assam to Jammu, the Sunderban region of West Bengal and the coastal areas of Orissa, Andhra Pradesh, Tamil Nadu and Kerala.

To develop oil resources, an Oil and Natural Gas Commission was set up in 1959 by the Government of India. The Commission has been carrying out all explorations, geological surveys and investigations all over the country. Its work has led to the discovery of oil and gas in the Cambay-Ankleshwar area of Gujarat and the Shivsagar area in Assam.

In 1967-68, production of crude oil in India amounted to 5.8 million tonnes.

Following are the major sedimentary territories of India:

1. Bombay High
2. Narmada
3. Bikaner
4. Tripura
5. Krishna river territory in Andhra Pradesh
6. Cauvery river territory in Tamil Nadu
7. Punjab

#### *Importance of Petroleum*

Petroleum is a very important product in modern times. It is essential for transportation as a fuel for automobiles, aeroplanes, ships and rail engines. Petroleum-derived lubricants for machinery have no substitute. As a raw material in the petrochemical industry its importance lies in space heating.

Petroleum has many advantages over most other forms of energy such as coal which has a high carbon content.

*Diesel Saving*

In the past few years the government has announced several measures for saving petroleum products and, consequently, foreign exchange, since the country is greatly dependent on imports of petroleum products. However, it is surprising that a single measure which could have saved the country a few thousand crores of rupees at one stroke did not occur to the government. If octroi duty and checkposts were abolished at the price of crude oil prevailing before the recent Gulf crisis, a saving of a couple of thousands of crores of rupees could have been made.

*Excess Crude Imports*

The import of crude in 1985-86 was more than India's immediate requirements: 15.75 million tonnes against 13.79 million tonnes. Since the throughput of refineries was higher by only 6.49 million tonnes at 42.05 million tonnes in 1985-86 and availability of crude from indigenous sources was as much as 29.5 million tonnes, utilisation of imports should have been only around 12.55 million tonnes. As actual imports were higher at 15.75 million tonnes, there were excess purchases of about 3.27 million tonnes.

The annual report of the Indian Oil Corporation, which is the main canalising agency for imports, indicates that there was a build-up of inventories of crude and petroleum products at the end of March on account of larger indigenous production and imports. The processing of bigger quantities of Bombay high crude was necessarily reflected in a larger surplus of light distillates as stated above.

The demand for petroleum products in 1986-87 can be expected to rise at the same rate as in 1984-85. On this basis, 44.15 million tonnes of petroleum products will be required from indigenous production and imports, if the needs of all consumers have to be met fully. The throughput of the refineries may rise to 45 million tonnes necessitating gross imports of 15 million tonnes of crude. As the Madras, Vizag, Bharat Petroleum and Cochin Refineries will be in a position to handle the whole of the output of Bombay High crude, exports will be only in the form of surplus petroleum products. As imports in 1985-86 were more than immediate needs, as indicated earlier, only about 13 million

**Table 1.3: Imports of Crude and Oil Products 1982-86**

	1982-83		1983-84		1984-85		1985-86	
	Quantity	Value	Quantity	Value	Quantity	Value	Quantity	Value
<i>Crude Oil</i>								
Imports	16.97	3914	17.00	3663	13.80	3408	15.75	3625
Exports	4.35	1021	4.99	1113	5.63	1363	0.43	110
Net Exports(A)	12.62	2893	12.01	2550	8.17	2045	15.32	3515
<i>Final Products</i>								
Imports	5.52	1673	4.06	1213	5.27	1669	3.74	1160
Exports	-	236	1.47	457	0.80	205	1.80	450
Net Imports(B)		1437	2.59	756	4.47	1464	1.94	710
<i>Total Imports</i>	22.49	5587	21.06	4876	19.07	5077	19.49	4785
<i>Total Exports</i>	-	1257	6.46	1570	6.43	1568	2.23	560
<i>Total Net Imports(A+B)</i>	-	4330	14.6	3306	12.64	3509	17.26	4225

Quantity in million tonnes; value in crores of rupees.

tonnes of crude may have to be imported. The canalising agencies, however, may be anxious to take advantage of the prevailing low prices in international markets and secure even 15 million tonnes. There will, of course, have to be imports of about 4.5 million tonnes of petroleum products which are in short supply.

In 1985-86 imports of 15.75 million tonnes of crude cost Rs. 3,525 crores, against 13.80 million tonnes having a value of Rs. 3,408 crores in 1984-85. Imports of 3.54 million tonnes of refined products had a value of Rs. 1056.04 crores against 5.13 million tonnes costing Rs. 1,594 crores. As exports of crude and petroleum products had a value of Rs. 559.61 crores as compared to Rs. 1,568, the net outgo was Rs. 4,095 crores against Rs. 3,020 crores.

#### *Crude Oil Production in the Eighth Plan*

According to a sub-group on refining set up for the Eighth Plan, crude oil production is likely to increase from 34.61 million tonnes in 1990-91 to 44.77 million tonnes in the terminal year of the Plan 1984-85. Of the 10.16 million tonnes increase in production during the Plan period, more than 5.28 million tonnes are expected to be produced in the relatively new oil finds in the Neelam and Gandhar fields. The total western offshore production would increase from 6.96 million tonnes at the beginning of the Plan to 9.02 million tonnes by its end. In the southern region, production would increase from both the Krishna-Godavary and the Cauvery basins. Production from the offshore fields of the Cauvery basin would commence from 1992-93. Total crude oil production from the southern region is expected to increase from 0.5 million tonnes in 1990-91 to 2.05 million tonnes in 1994-95. The availability of net crude oil from the north-east fields in Assam, Nagaland and Meghalaya is expected to increase from 5.15 million tonnes to 7.40 million tonnes in 1994-95 and to 9.2 million tonnes in 1996-97.

#### **Natural Gas**

Natural gas finds widespread application in various sectors over and above its primary usage for meeting the energy needs of the industrial, commercial and domestic sectors. The World Bank Report of 1984 predicts a decline in the annual growth rate of oil in the world's commercial energy consumption from 2.9 per cent during 1970-80 to a mere 0.6 per cent during the period 1980-85.

On the contrary, the growth rate of natural gas, which was 3.4 per cent in 1970-80, would continue to hold its position during 1980-85, by a slightly lower figure of 3 per cent. This means that natural gas is expected to grow on an average five times faster than oil.

A comparison of India's reserves/production ratio in the case of hydrocarbon reserves is given in the following table:

**Table 1.4: Reserves to Annual Production Ratio**

	<i>Natural Gas</i>	<i>Crude Oil</i>
Saudi Arabia	300	100
OPEC Countries	210	99
World Average	58	42
India	49	19

This indicates that India's reserves of natural gas in relation to its consumption compare favourably with the world average. This is in sharp contrast to the reserves/production ratio in the case of crude oil which is much below the world average. Table 1.5 indicates the sourcewise break-up of the primary energy consumption in some select areas as a percentage of the total consumption. It may be observed that India's reliance of natural gas for meeting its primary needs is significantly less when compared to the other countries. Furthermore, while the world consumption of natural gas to oil ratio is 1:2 the same in the case of India is significantly higher at 1:7. Both the tables indicate the necessity for increasing the utilisation of natural gas for fulfilment of the primary energy requirements of our country.

**Table 1.5: % of Primary Energy Consumption**

	<i>Oil</i>	<i>NG</i>	<i>Coal</i>	<i>Hydro- electric</i>	<i>Nuclear energy</i>	<i>Total</i>
USA	41.3	23.4	24.5	4.2	6.6	100
UK	36.6	24.3	32.8	0.6	5.7	100
Middle East	66.1	30.9	1.4	1.6	-	100
USSR	31.1	36.0	26.2	3.8	2.9	100
S.E. Asia	57.6	7.3	21.1	4.6	9.4	100
World Average	37.6	19.9	30.5	6.7	5.3	100
India	27.8	3.9	62.5	5.5	0.3	100

Natural gas can be used in the domestic sector for cooking, space heating and air-conditioning. In power generation plants



natural gas is used as a boiler fuel and gas turbine fuel. The wider usage of natural gas has been recognised in such industries as iron and steel, cement, glass making, heavy water production and petrochemical and fertilisers. The growth of natural gas as feedstock has also been increasing (see the table below).

**Table 1.6: Natural Gas Utilisation as Feedstock in India**

	1970	1975	1980	1984
Quantity (in mm <sup>3</sup> )	187	465	632	1636
Annual Growth rate (%)	20	6.3	26.8	-

Liquid fuels, in contrast to coal, are given a relatively low preference by industrial consumers because of their high cost though they are otherwise easier to handle and also offer better thermal efficiencies compared to coal. Gaseous fuels are clean and can be burned by a variety of techniques.

#### *Merits of Gas over Other Fuels*

1. *Quality:* Natural gas is of a high calorific value (over 9,000 kcal/kg), uniform in composition and free from undesirable impurities like sulphur. On the contrary coal has a much lower calorific value (ranging from 3,800 to 4,500 kcal/kg), varies in composition, and produces dust, grit and ashes during landing and burning. Oil, on the other hand, has a calorific value of approximate 10,200 kcal/kg, more or less of consistent quality but a high sulphur content of up to 4.0 wt per cent.

2. *Thermal Efficiency:* Thermal efficiencies of the coal fired equipment are 70-75 per cent. In the case of oil fuel equipment, it is possible to obtain efficiencies of up to 80-85 per cent while in the case of natural gas thermal efficiencies obtainable could be as high as 90 per cent.

3. *Transportation, Handling and Storage:* Gas can be easily transported to the consumers through pipelines and its handling is smooth requiring no inventory or manpower. In the case of coal, however, handling is a duty and inconvenient operation. Furnace oil and other liquid fuels are transported through pipes or manually within an industrial unit requiring negligible manpower.

4. *Operational Advantages:* Gas is clean in operation and use and can be burned uniformly and efficiently with minimum proportions of excess air. Coal, on the other hand, can only be burned smokelessly in solid form with relatively high proportions of excess air (730 per cent) and complete automatic control over combustion and control of flame length is not possible.

5. *Environmental Pollution:* Conventional fuels like coal and oil when burned discharge flue gases such as  $\text{SO}_2$ ,  $\text{NO}_x$ ,  $\text{CO}_2$ , CO and suspended particulate matter into the atmosphere. Since coal and oil have a high sulphur content as compared to natural gas, excessive quantities of oxides of sulphur are produced during combustion which pollute the atmosphere causing damage to health and property.

6. *Savings of Foreign Exchange:* Increased foreign exchange earnings are possible by the use of gas in place of conventional fuels like coal furnace oil and LPG. There are savings in foreign exchange on account of less imports of petroleum products, better thermal efficiencies for gas and less transportation costs based on national economics.

#### *Social Considerations*

- (a) Reduction in traffic congestion resulting from the substitution of piped gas for portable fuels.
- (b) Improvement in overall safety resulting from reduction in the transport of hazardous materials in urban area.
- (c) Improved working conditions for industrial workers on account of less usage of troublesome and impure fuels like coal.

#### *Economic Considerations*

The total cost of fuel to a consumer depends upon the following factors:

- (a) Landed cost of fuel;
- (b) Thermal efficiency;
- (c) Inventory carrying costs;
- (d) Labour costs for handling;
- (e) Costs on account of additional spare requirements for storage;
- (f) Handling and transportation costs; and
- (g) Maintenance costs for fuel equipment.

An economic comparison of different fuels based on the above factors on the basis of 1000 kcal of heat available indicates that the fuel cost per useful 1000 kcal\* of coal is Re. 0.48, furnace oil Re. 0.43 and natural gas Re. 0.31.

Thus the use of natural gas has a number of advantages over conventional fuels, such as coal, liquid fuel and LPG.

#### *Criteria for Allocation of Natural Gas*

A policy on the allocation of gas for use in different sectors has been evolved over a period of time. This has also been marked by the emergence of different schools of thought. In the context of the development and utilisation of gas, both associated and free, from the large gas fields in the Bombay offshore, the Government set up two working groups. One to study the optimum utilisation and the other to study the optimum location of gas-based fertiliser units.

The government's policy on the utilisation of natural gas broadly followed the recommendations of the working group headed by Mr. J.R. Satish Chandran set up in 1979. This working group suggested that natural gas should be separated in the following fractions for economic and optimum utilisation.

The working group recommended that priority should be determined on the basis of opportunity costs of each of the fraction.

The working group on fertiliser units suggested the establishment of six new plants in addition to the two already approved.

The Advisory Board on Energy (ABE) set up by the government has also reviewed the energy trends and utilisation of gas. In a report made in September 1983, the ABE suggested that the gas utilisation policy needed reconsideration because of two significant developments:

1. The amount of gas available, both associated and free, increased substantially from about 20 million in m/day assumed by the working group to 25 to 30 m.c.u. m/d.
2. Emergency of substantial naphtha surplus, particularly in the northern and north-eastern regions of the order of 1.5 million tonnes.

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\*Cost per useful 1000 kcal  $\frac{\text{cost per 1000 kcal}}{\text{utilisation efficiency}}$

**Table 1.7: Natural Gas**

Year	Onshore			Offshore		Gross Production	Number of years for which reserve would last at the annual rate of production	
	Gujarat	Assam	Rajasthan	Total (1+2+3)	Bombay High			Total
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
1981	15.99	65.19	0.43	81.61	329.04	410.65	3.49	118
1982	18.18	70.66	0.43	89.27	330.62	419.89	4.66	90
1983	18.95	78.67	0.43	98.05	377.21	475.26	5.77	82
1984	18.60	81.31	0.54	100.45	377.80	478.25	6.82	70
1985	21.87	87.67	0.54	110.08	368.55	478.63	7.91	61
1986	26.99	91.83	0.54	119.36	377.69	497.05	9.46	53
1987	41.26	97.82	0.74	139.82	400.99	540.81	10.91	50
1988	62.11	105.49	0.78	168.38	411.09	579.47	12.78	45
1989	85.59	120.49	1.00	207.08	447.47	654.55		

(a) Data for 1979 onwards are inclusive of Nagaland and Tripura.

In the light of these developments the advisory board also suggested the possibilities of:

- a) re-injection of gas in oilfields;
- b) power production in marginal offshore fields if these are within 60 km from the shore.
- c) installation of methonal/ammonia plants if the distance was more than 60 km from the shore and/or mobile power generation at 3 to 5 mw capacity near marginal onshore fields, particularly in Assam.

#### *Complex Pricing Policy*

The pricing of gas has been a sensitive area, with considerable variations in different regions on account of historical factors. Differences in opinion on the concepts adopted and the actual rates prescribed have been rather common.

But a major development was the announcement of a new pricing policy by the government which was to become effective from February 1, 1987, with a view to introducing an element of uniformity at the national level with appropriate concessions where necessary.

#### **Power Sector in India**

This part deals with the power position in India and Tamil Nadu State. It describes power development during planning, sector and power generation, installed capacity and pattern of electricity consumption by various sectors.

#### *Power Development in India*

Indian economic development has been dependent to a large extent upon the availability of power. And yet at crucial stages during the last two decades, the economy has suffered from crises in the form of power shortage.

Power development in India commenced at the end of the 19th century with the commissioning of electricity supply in Darjeeling during 1877, followed by the commissioning of a hydel power station at Sivasamudram in Karnataka during 1902. Before Independence, power supply was mainly in the hands of the private sector. But after Independence, the Government of India took initiatory steps for the growth of this sector. Now the Government is restructuring the power supply industry with a view to its growth all over the country.

*Power Development under Five Year Plans*

Power development in India received a big boost with the advent of the Five Year Plans. The installed capacity in utilities at the time of independence was 1,362 MW. This rose to 1,713 MW at the beginning of the First Plan.

The eighties witnessed a tremendous growth in the power sector. The installed capacity, which was about 28,500 MW on March 31, 1980, grew to about 42,600 MW by the end of the Sixth Plan and 61,500 MW by December 31, 1989. The Seventh Plan target was expected to be met fully and the installed capacity to touch 64,000 MW.

*Plan Outlays for Power Sector*

In terms of value added, power generation is the second biggest industry in the country. This industry is also the largest public sector enterprise in terms of investment. The outlays for the power sector and their share in the total public sector outlays during the various Plan periods are given below.

**Table 1.8: Outlay on Power during the Five Year Plan Periods**

<i>Period</i>	<i>Outlay on Power (Rs. in crores)</i>	<i>Share of power sector in the total outlay</i>
First Plan	320	16.30
Second Plan	525	11.20
Third Plan	1,334	15.60
Three Annual Plans	1,817	27.43
Fourth Plan	2,523	16.00
Fifth Plan	7,204	18.60
Sixth Plan	19,265	20.00
Seventh Plan	34,270	19.00

*Source:* Planning Commission, Government of India.

The power sector has been on the priority list of Indian planners. The investment in the First Plan (1951-56) was only Rs. 320 crores but this rose to as much as Rs. 34,270 crores in the Seventh Plan. An additional allocation of Rs. 7,500 crores was expected for the Eighth Plan projects for advance action in the Seventh Plan.

The Seventh Plan outlay for the power sector, the largest among the sectors, was 19 per cent of the total Plan outlay. The

outlays have generally been around 19 per cent of the total Plan outlay for the public sector in various Plan periods. The power supply industry has been doubling its output almost every seven years. The progress achieved so far is shown in the following table:

Table 1.9: Growth of Power Supply

<i>Growth of power supply</i>	<i>Unit</i>	<i>Position in 1950</i>	<i>Present position (1988)</i>	<i>Increase</i>	<i>Annual growth Rate (%)</i>
Installed capacity	MW	1,700	55,000	32 times	9.5
Annual energy generation	MW	5,100	2,02,000	40 times	10.2
Rural electrification	Numbers	3,060	4,40,000	144 times	14.0
Pumpsets energised	Numbers	21,000	72,50,000	345 times	16.6
Number of consumers	Million	1.5	50	33 times	9.6
Transmission lines					
i) 400 kv	ckm	Nil	14,000	-	-
ii) 66 kv to 220 kv	-do-	10,000	1,66,000	16 times	-
Per capita consumption	Units	15	200	13 times	7.1

*Source:* Bahadur Chand and Bhasin J.K., "Bold initiative in power", *The Hindu Survey of Indian Industry*, 1988, p. 97.

Table 1.9 shows that the total generating capacity has risen from about 1,700 MW in 1950 to 55,000 MW, a 32-fold increase representing an average compound growth rate of about 9.5 per cent. Annual energy generation increased from 5,100 MU in 1950 to 2,02,000 MU, in 1988. From 1950 to 1986-87 the number of power consumers rose from 1.5 millions to over 50 millions and the per capita consumption from 15 kwh to 200 kwh.

Notwithstanding the significant achievements since independence, power shortage has persisted since the demand

has always been outstripping the supply. This is because the base at which India started was too low and the spurt in demand which socio-economic changes brought about after independence was enormous. Financial resources were not available to the extent required to create the necessary power supply capacity and associated facilities.

#### *Generation Mix—All India*

With a view to meeting the ever increasing demand for power, a massive expansion of the generating capacity was undertaken in the country as seen in Table 1.10.

From Table 1.10 it can be seen that in 1950-51, the total capacity was 2,301 MW, which included 24 per cent of hydro capacity and 76 per cent of thermal capacity. In 1970-71 the power generation was increased to 16,271 MW; 39 per cent hydro, 58 per cent thermal and 3 per cent nuclear capacity. In the last year of the Sixth Plan period, 1984-85, power generation was increased to 47,705 MW. In the year 1987-88; the total capacity was 60,845 MW including 29 per cent hydro, 69 per cent thermal and 2 per cent nuclear capacity. Thermal power constitutes a very large proportion of the power generation of the country, and nuclear power a very low proportion. In the year 1988-89, hydro capacity was 18,197 MW, thermal capacity 38,930 MW and nuclear capacity 1,565 MW.

#### *Growth of Installed Capacity in the Country (Utilities only)*

The total installed generating capacity as in the year 1950 was 1,713 MW which rose to 49,257 MW in the year 1986-87. Table 1.11 gives the installed generating capacity of utilities according to different modes of generation.

The table shows that in the year 1950, the installed capacity was 1713 MW, comprising 559.3 MW hydro, that is, 33 per cent of the total installed capacity and 1153.2 MW thermal, that is, 67 per cent of the total installed capacity.

The total installed capacity in the period 1986-87 was 49,257.41 MW comprising 16,194.10 MW hydro, 31,733.31 MW thermal and 1,330 MW Nuclear.

Table 1.11 reflects the estimated installed capacity during 1985-90. In 1985-86 it was 48,251 MW. The estimated installed capacity during the period 1989-90 was 69,371 MW.



**Table 1.10: Generation Mix—All India**

<i>Year ending</i>	<i>Total capacity (M.W)</i>	<i>Hydro capacity (M.W)</i>	<i>Percentage</i>	<i>Thermal capacity (M.W)</i>	<i>Nuclear capacity</i>	<i>Percentage (M.W)</i>	<i>March</i>
1950-51	2,301	559	24	1,742	76	-	-
1960-61	5,654	1,917	34	3,737	66	-	-
1970-71	16,271	6,383	39	9,468	58	420	3
1980-81	33,316	11,791	35	20,665	62	860	3
1981-82	35,781	12,173	34	22,748	63	860	3
1982-83	39,235	13,056	33	25,319	65	860	2
1983-84	43,706	13,856	32	28,755	66	1,095	2
1984-85	47,705	14,460	30	32,150	67	1,330	2
1985-86	52,399	15,472	30	35,597	68	1,330	2
1986-87	55,405	16,194	30	37,881	68	1,330	2
1987-88	60,845	17,260	29	42,255	69	1,330	2
1988-89	NA	18,197	-	38,930 <sup>s</sup>	-	1,565	2

<sup>s</sup>Thermal only.

Source: Department of Power Report, 1988-89.

Table 1.11: Installed Generating Capacity (Utilities Only)

Year	Installed capacity	Hydro	Thermal (including diesel gas, steam)	Nuclear
1950	1,712.52 (100.00)	559.29 (32.66)	1,153.23 (67.34)	-
1960-61	4,653.05 (100.00)	1,916.66 (41.19)	2,736.39 (58.81)	-
1970-71	14,708.95 (100.00)	6,383.23 (43.4)	7,905.72 (53.74)	420 (2.86)
1980-81	30,213.68 (100.00)	11,791.22 (39.02)	17,562.46 (58.13)	860 (2.85)
1984-85	42,584.72 (100.00)	14,460.02 (33.90)	27,029.70 (63.47)	1,095.00 (2.57)
1985-86	46,769.03 (100.00)	15,471.60 (33.08)	29,967.43 (64.08)	1,330.00 (2.84)
1986-87	49,257.41 (100.00)	16,194.10 (32.88)	31,733.31 (64.42)	1,130.00 (2.70)

Note: Figures in brackets indicate percentages to total installed capacity.  
Source: Public Electricity Supply, All India Statistics General Review, 1984-85.

Table 1.12: Plan-wise Capacity Addition

Plan period	Capacity addition (MW)
First Plan (1951-56)	1,100
Second Plan (1956-61)	2,250
Third Plan (1961-66)	4,520
Annual Plans (1969-74)	4,120
Fourth Plan (1969-74)	4,579
Fifth Plan (1974-79)	10,202
Annual Plans (1979-80)	1,799
Sixth Plan (1980-85)	14,226
1980-81	1,823
1981-82	2,175
1982-83	3,060
1983-84	4,088
1984-85	3,080

Source: Replies to unstarred question No. 167 in the Lok Sabha on March 14, 1985, and unstarred question No. 1860 in the Lok Sabha on April 4, 1985.

During the period 1984-85, a capacity of 2,870 MW was commissioned/rotated up to March 26, 1985 (418 MW hydro and 2,452 MW thermal). The total capacity addition during the year was expected to be 3,080 MW (418 MW hydro and 2,662 MW thermal).

**Table 1.13: Region-wise Capacity Added During 1984-85**

<i>Region</i>	<i>Thermal</i>	<i>Hydro</i>	<i>Nuclear</i>	<i>Total</i>
Northern region	530	96	-	626
Western region	950	12	-	962
Southern region	610	310	-	920
Eastern region	490	-	-	490
North-Eastern region	82	-	-	82

*Source: Department of Power Report, 1984-85, New Delhi, 1985.*

The table shows that the western region was the largest contributor of capacity added during 1984-85, that is, 962 MW, 950 MW of thermal and 12 MW of hydro capacity. The southern region ranked next to the western region, which contributed 920 MW; 610 MW of thermal and 310 MW of hydro capacity. The north-eastern region was the lowest contributor of capacity added: 82 MW. There was no hydro added capacity.

*Pattern of Electricity Consumption—All India*

The electricity consumption pattern of different sectors, of the country from the year 1950-51 to 1988-89 is given in Table 1.14.

**Table 1.14: Pattern of Electricity Consumption—All India**

	<i>Share as Percentage to Total</i>						
	1950- 51	1960- 61	1970- 71	1980- 81	1984- 85	1987- 88	1988- 89
Domestic	12.6	10.7	8.8	11.2	13.6	12.0	13.0
Commercial	7.5	6.1	5.9	5.7	6.1	4.0	4.0
Industry	62.6	69.4	67.6	58.4	55.3	38.0	44.0
Agriculture	3.9	6.0	10.2	17.6	18.4	24.0	23.0
Others	13.4	7.8	7.5	7.1	6.6	22.0	16.0

*Source: Annual Report of the Working of State Electricity Board and Electricity Department, Planning Commission, 1988-89.*

The table shows that the industrial sector consumes a larger proportion of electricity than the other sectors. But comparing the

year 1950-51 the proportion of electricity consumption by this sector is less. In 1950-51, 62.6 per cent of electricity was consumed by this sector which declined to 44 per cent in 1988-89. The electricity consumption of the agricultural sector increased from 3.9 per cent in 1950-51 to 23 per cent in 1988-89, next to the industrial sector. The electricity consumption of the domestic sector was 13 per cent in 1988-89, 12.6 per cent in 1950-51 and 8.8 per cent in 1970-71. The commercial sector consumed only 4 per cent of the total electricity generated in 1988-89.

#### *Transmission and Distribution of Electricity Power*

Transmission and distribution networks were also established to interconnect power stations and power systems and to distribute power over widespread and distant load centres. Greater investment in transmission and distribution is inevitable to avoid transmission and distribution losses. Transmission losses have been high due to the lower voltage of transmission. The basic cause of the system losses can be attributed to under-investment in transmission and distribution facilities. To avoid this kind of losses, the highest operating voltage lines should be used.

At present the highest operating voltage in the country is 400 KV. Development of large hydro resources located in remote areas at long distances from major centres of consumption is necessary. Now, the need for interconnecting facilities among the various states in a region would require voltages higher than 400 KV. High voltage D.C. transmission would be another alternative. The length of transmission and distribution lines also increased from 40,000 circuit kms in 1951 to about 8,50,000 circuit kms at the present time.

Great emphasis has been placed on speedier implementation of the rural electrification schemes by the states and the union territories, financed both by the state governments as well as by the REC.

#### *Rural Electrification*

Electric power is a vital factor in the rapid economic development of an economy. Since the majority of the population lives in rural areas, provision of electric power in such areas is a prerequisite for economic development in India. Rural electrification can bring about significant changes in the methods of irrigation and cropping patterns and create conditions for a rapid growth of industry and commerce.

The report of the Energy Survey of India observes, "Rural electrification cannot be regarded strictly as an economic activity. It has indeed many of the characteristics of social service." So the government should take steps to achieve cent per cent rural electrification in the country. The following table gives the progress achieved in rural electrification in India from 1951 to 1988-89.

**Table 1.15: Progress in Rural Electrification—All India**

<i>Year ending March</i>	<i>Villages electrified</i>	<i>Percentage electrified</i>	<i>Pumpsets energised</i>
1951	3,061	0.54	21,008
1960-61	21,754	3.83	1,98,940
1970-71	1,04,942	18.50	16,29,423
1980-81	2,72,287	47.30	43,30,453
1981-82	2,96,505	51.50	46,49,890
1982-83	3,23,881	56.20	49,73,305
1983-84	3,47,564	60.30	53,08,666
1984-85	3,70,332	64.27	57,08,563
1985-86	3,90,294	67.74	61,51,975
1986-87	4,14,895	72.01	66,56,541
1987-88	4,35,653	75.23	72,25,791
1988-89*	4,46,712	77.00	76,19,814

\* As on 31-1-89.

Source: Department of Power Report, 1988-89, New Delhi.

The table shows that in 1951, 3061 villages (0.54 per cent) were electrified. This rose to 4,46,712 electrified villages (77 per cent) in 1988-89.

#### *Hydro Power in India*

The first hydro electric power plant to be set up in India was near Darjeeling at the end of the 18th century. In 1902, the Sivasamudram Falls were harnessed to produce 4 MW of electric power for supply to the Kolar gold fields. The project was a landmark as the mission line, which was 150 km long, was the longest in the world for this voltage (33 kv). Later, the capacity of the plant was increased to 42 MW by the early thirties soon after the Tata Power Company, a leading private utility firm, set up three units in the Western Ghats to provide electricity to the Bombay-Poona area.

In April 1951, at the beginning of the First Plan, hydro capacity was 570 MW. Five major multipurpose projects were set up in India during the period. They were the Bhakra Nangal and Cambal Valley projects in the north, Hirakud and Damodar Valley projects in the east and Tungabhadra in the south. Some single-purpose hydroelectric projects were also set up. Among these, the important ones were Rihand (Uttar Pradesh) in the north, Koyna (Maharashtra) in the west, Balimela (Orissa) in the east, Uminam (Meghalaya) in north-east, and Kundah (Tamil Nadu), Sharavati (Karnataka), Machkund and Upper Sileru (Andhra Pradesh) and Panniar, Neriamangalam, Sabarigri (Kerala) all in the south.

#### *Thermal Power in India*

Electric power in thermal plants is generated by burning coal or lignite and gas or oil. Thermal power plants based on steam turbine technology were used for urban electrification in the earlier phase of power generation in India. This became the most important source of power supply and consequently industrial units set up private steam power plants in an attempt to produce enough power for their own consumption.

The Bokaro thermal unit, the first of its kind in the country, was built on a reasonably large scale. It had three units of 57.5 MW which were to generate 172.5 MW of electric power on commissioning. This was followed by the setting up of super thermal units which produce at least 500 MW per unit with a total of 200 MW.

The Second Five Year Plan set the process going, and a number of thermal plants were installed. New research and development methods helped expedite the creation of more plants. The bulk of the fresh capacity installed now is through units of 210 MW but the aim is to set up 500 MW units as soon as possible.

The result will be an addition of 14,208 MW of thermal power. In the northern region 11 plants are being set up with a capacity of 3600 MW, in the western region 16 plants with a capacity of 5480 MW, in the southern region 5 plants with 1,890 MW capacity, in the eastern region 12 plants with an aggregate capacity of 2,820 MW and in the north-eastern region six plants with 358 MW capacity. Further, during 1985-90, it was planned to add another 15,920 MW of thermal capacity. The present installed

thermal power capacity totalling 21,430.6 MW in 1983 is 60 per cent of the total installed generating capacity.

### **Nuclear Power**

Minerals, fuels, coal, petroleum and natural gas are all exhaustible sources of power. The only major potential sources of inexhaustible energy are water, wind, sun and nuclear power. Even though man is developing hydro sites all over the world, many of them at a great cost, hydropower today accounts for only 2 per cent of the total inanimate energy utilised by man. The entire water power potential of the earth economically capable of development constitutes but a small part of the inanimate energy needs of the people of the world.

The world's demand for energy is increasing at a compound rate and in order to meet its untapped resources must be made available. The great hope for the near future appears to be nuclear power. Fortunately, the development of nuclear energy shows good signs of proving a major factor in solving the power problem.

### *Uses of Nuclear Power*

Nuclear power uses the earth's uranium and thorium reserves as fuel, and in this way increasing the earth's energy store. Its development has many advantages, such as:

1. despite its very high initial costs, nuclear energy will eventually help to reduce power costs, for relatively minute quantities of uranium and thorium are needed to produce it. Moreover these are abundant elements in the earth's crust, although there are not sufficient concentrations of uranium for mining except in a relatively small number of places.
2. Coal and oil have proved invaluable in the production of chemical and synthetic products. By using nuclear power, these mineral fuels can be used more and more to produce synthetic items, such as nylon, plastics and rubber.
3. Since the weight of the fuel consumed by a nuclear power station is very small in relation to the energy released, it can be located near markets, rather than near the source of fuel.
4. The development of nuclear power is an attractive proposition to the underdeveloped countries, because the

cost of transporting conventional fuel across a vast country like India are extremely high as most of the coal reserves are concentrated in one particular region.

#### *Development of Atomic Energy*

The key to nuclear power was found in the late 1930s through the discovery of the fission of uranium, in which the elementary particles (neutrons) caused the heavy nuclei of uranium to split into two high-speed fragments. These fragments were observed to throw out neutrons, which could be used to produce more fissions, so that in principle a chain reaction was seen to be possible. The energy released by one pound of uranium in the fission process is equivalent to the amount released in the combustion of 2.5 million pounds of coal.

Fission energy is produced when a large atom is split, yielding two smaller atoms. Fusion is the process whereby two light atoms are fused together to form a larger atom. The source of fission energy is exhaustible. The fusion process, on the contrary, depends on light elements, such as hydrogen. Since every molecule of water contains two atoms of hydrogen, the supply of fusion fuels is literally inexhaustible. It will be the fission reactors, which will follow, that promise to make available unlimited power.

#### *Atomic Fuels*

As noted earlier uranium, like coal and petroleum, is exhaustible. This is an important fact, for though uranium is one of the abundant elements in the earth's crust, it is not sufficiently concentrated for mining purposes except in a relatively small number of places. However, there is no shortage. The present estimate of total recoverable uranium and thorium is placed at about 1,700  $\theta$  of energy (one  $\theta$  equals 1,000,000,000,000,000 BTO). This means that far more energy is available from atomic power than from coal, petroleum, natural gas, and oil shale combined.

#### *Nuclear Power in India*

On May 18, 1974, India successfully conducted its first underground nuclear experiment at Pokharan in Rajasthan. The experiment was hailed by the developing countries in Asia and Africa as a unique event breaking the monopoly of the superpowers. No longer was the development of atomic energy the exclusive prerogative of the Big Five. The country has to



continue development of nuclear energy for the following reasons:

- i) India is a poor country today mainly because it missed the Industrial Revolution that took place in the 18th and 19th centuries. Its economic progress has not kept pace with the industrialised countries because of lack of advanced technology. In the years to come, increasing use is likely to be made of nuclear power for development projects. If India does not keep up with the world in the field of nuclear technology it will never be able to catch up with the developed world. The late Prime Minister, Rajiv Gandhi, had repeatedly reminded the nation of the need to leap-frog into the twenty-first century.
- ii) Possession of nuclear power is synonymous with the big power status. India sooner or later has to play a more dominant role in world politics keeping in view its size, resources and population. The Indian nuclear explosion did raise its prestige in the third world.
- iii) Subsequent events have proved that the nuclear powers are very reluctant to part with their nuclear technology. The utility of nuclear research for peaceful uses is too well known, and unless India develops expertise of its own through experimentation, it will not be able to exploit its resources fully. Apart from its use in defence, nuclear energy can help the country in a variety of other ways.
- iv) It has been argued that India would have safeguarded her security better by signing the Non-Proliferation Treaty (NPT), because it will not be in a position to defend itself in the event of a nuclear attack by another country. By not signing the treaty it will be deprived of the nuclear umbrella guaranteed signatories to the threat. In the event of an emergency, it may be left high and dry by its so called friends and benefactors.
- v) Pakistan with the active assistance of the People's Republic of China has often proclaimed its nuclear aspirations. According to *Newsweek*, Pakistan already possesses a few nuclear bombs. The Indian leadership would be risking the security of the country if it did not keep pace with the nuclear developments in Pakistan.

### *India's Nuclear Power Programme*

The initial impetus for India's nuclear programme was given by Dr. Homi Bhabha, who on March 12, 1944, wrote a letter to the industrial house of Tatas that "an institute for this purpose", is needed. This would form the embryo from which he hoped to build, in course of time, a school of physics comparable to the best in the world.

Nuclear power generation was initiated in July 1969 with the commissioning of the Tarapur Atomic Power Plant of 420 MW in Maharashtra. The atomic plant was set up with technical and financial aid from the United States.

The second atomic power plant was commissioned in August 1972 at Rana Pratap Sagar in Rajasthan. This plant was aided by the Canadian government.

In the 1950s, India's nuclear planners drew up a three-stage plan for nuclear power development.

1. Stage 1 was to consist of operating power plants using Indian uranium and also producing plutonium.
2. Stage 2 envisaged use of plutonium in fast breeder reactors which could yield more plutonium and uranium from thorium of which India has an abundance.
3. Stage 3 envisaged use of  $U_{233}$  to sustain breeders, which would convert thorium into  $U_{233}$ , thereby achieving self-reliance.

### *Kalpakkam Atomic Power Plant*

The commissioning of the Kalpakkam atomic power plant near Madras in August 1983 was a landmark in India's nuclear energy programme and in the quest for self-reliance in high technology areas. Kalpakkam was the first nuclear power station in the country to be designed, engineered, built and commissioned indigenously. Kalpakkam power has started flowing into the electricity-starved southern grid and more of it will doubtless be available soon. Moreover, thanks to the work done at Kalpakkam, a great many improvements have already been made in both the design for the next nuclear power station at Narora and the safety measures to be adopted there. Further vistas will open up as a result of the experience gained at Kalpakkam, especially at its Nuclear Research Centre (NRC). The atomic power available at Kalpakkam in 1969-70 was 470 MW, and in 1989-90 1465 MW.

*India's Largest Research Reactor*

"Dhruva", India's largest research reactor designed and developed by Bombay's Bhabha Atomic Research Centre, became critical in 1985. Work on this 100 MW (thermal) heavy water cooled and moderated natural uranium metal reactor had begun in 1973. It was ready for commissioning by the middle of 1984, but a technical hitch and its creators' insistence on ensuring 100 per cent safety delayed announcement of their triumph by over a year.

*Koodankulam Plant*

Two 1000 MW VVER units are being put up at Koodankulam in Tamil Nadu as a turnkey project by the USSR. While the RBMK type reactor at Chernobyl was graphite moderated and light water cooled, the VVER reactors for Koodankulam are of the PWR category, which uses high water both as moderator and as coolant. Over 60 per cent of the world's operating reactors are of the PWR category, and their record of safety and performance has been good. The VVER reactor design had set a standard in the USSR. Several reactors of this category are operating safely in that country and more are being built there.

*Nuclear Pollution*

It was history's worst nuclear power plant accident when a nuclear power plant exploded. The core began to melt. A conflagration ignited that spread a cloud of radioactivity over large parts of world. In this case a large part of the USSR and much of eastern and western Europe were affected.

The European governments warned people in the countryside not to drink rain water. Children were told not to drink milk and farmers instructed to keep their cows indoors. Italy, Sweden, Austria and West Germany took steps to curb fresh food imports from the Soviet bloc countries. On May 7 the EEC banned food imports from the USSR, Poland, Yugoslavia, Hungary, Rumania and Bulgaria—countries within a 624 mile radius of the Chernobyl power plant.

*MAPs Accident:* The Madras Atomic Power Station authorities averted a major mishap when seven tonnes of heavy water escaped into a vault inside the reactor building recently. They were quick in declaring plant emergency as a precautionary measure. A new transformer of MAPS-I had suffered a failure earlier.

The Three-mile Island accident of 1979 in the USA still haunts the world. It has all but destroyed confidence in the USA's nuclear industry.

Sweden, with 10 nuclear reactors is already committed to closing its nuclear plants by 2010. Concrete action is needed to endure that nuclear power is made available without any danger of environmental pollution.

#### *How Safe?*

Nuclear power is as safe as other sources of energy, if not more, but reports published in sections of the press from time to time have created an impression that it is not so. After all, every human activity, whether smoking, drinking, car or motor cycle driving, carries an element of risk.

Nevertheless people have not stopped taking part in these activities. Similarly, nuclear energy has its element of risk. Largely, it is the radiation caused by it. The fear of radiation touched a new high following the accidents at Chernobyl and Three-mile Islands.

#### **Safety Ecological Factors**

No discussion on nuclear power will be complete without considering its safety and environmental factors. These are matters of legitimate concern to the public in the aftermath of the Chernobyl accident and because of the alarming reports about nuclear power appearing in the media. To enable people to choose intelligently the right kind of technologies, they must also be informed of the risks and benefits associated with the use of all energy sources. The elaborate and comprehensive systems for safety and environmental protection provided at nuclear power stations are often lost sight of in the midst of misconceptions about the risks from this technology. The very complexity of nuclear power technology is a result of the indepth safety measures and the highly disciplined culture prevailing at nuclear power plants all over the world. Few realise that among all technologies, only nuclear power technology has reckoned with factors like safety and environmental protection from the very beginning of its development over the past 40 years.

#### **Rich Experience**

Today there are 418 operating nuclear power stations in the world with a total capacity of over 300,000 MW, supplying over

16 per cent of the world's electricity. Work is in progress on 130 units with a combined capacity of over 118,000 MW. Most of these are in the developed countries which, conscious of the environmental and safety aspects of nuclear power, are pursuing this option. Nuclear power technologists have generated more than 4,700 reactor years of experience. Despite the Chernobyl accident it is this track record which demonstrates that nuclear energy is an environmentally clean source of generating power.

### **Conclusion**

In the years to come, nuclear energy can be expected to increase significantly its contribution, mitigating the overall power shortages, estimated at present at about 11 per cent. As a major consumer of electricity, industry is conscious of the necessity of this critical input in improving the quality of life of the people. In the last two decades, the Indian industry has made a commendable contribution in bringing the country's nuclear power programme to its current state of achievement. It is expected that it will continue to participate in the programme in a big way.

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## SOURCES OF ENERGY II (NON-CONVENTIONAL)

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### **Solar Energy**

Sunlight is abundant, dependable and free. With some minor fluctuations the sun has been bestowing its bounty on the earth for more than four billion years, and it is expected to continue to do so for several billion years more. The sun's inconstancy is regional and seasonal, not arbitrary or political, and it can therefore be anticipated and planned for.

The solar system is centred in the sun. The sun is one of the stars in the milky way, at a distance of about 32,000 light years from the centre of the galaxy. The sun is composed mainly of hydrogen. Its energy is generated by nuclear collisions in its interior. It is calculated that the sun consumes about a trillion pounds of hydrogen every second. At this rate, it is expected to burn out its stock of hydrogen in about 5 billion years, and turn into a red giant. The core temperature of the sun is 15,000,000k, the photosphere temperature is 5,770 Kelvin. The chemical composition of the sun is hydrogen 71 per cent, helium 26.5 per cent and other elements 2.5 per cent.

Our ancestors capture the sun's energy indirectly by gathering wild vegetation. Their harvests became more reliable with the revolutionary shift to planned cultivation and the use of animals. As civilisation developed, reliance upon the sun grew increasingly. Slaves and draft animals provided a roundabout means of harnessing large quantities of photosynthetic energy. Winds and currents—both solar powered phenomenon—drove mills and provided means of overseas travel.

In the earlier eras, people were intensely aware of the sun as a force in their lives. They constructed buildings to take advantage of prevailing winds and of the angles at which the sun's rays hit the earth. They built industries near streams to make power generation and transport easier. Their lives revolved around the agricultural seasons. In the 14th century, coal began to contribute an increasing fraction of Europe's energy budget—a trend that accelerated greatly in the 18th and 19th centuries. During the past 75 years oil and natural gas became the principal energy sources in the industrialised world. In the fossil fuel era, the sun has been largely ignored.

About 1.5 quadrillion megawatt hours of solar energy arrive at the earth's outer atmosphere each year. The amount is 28,000 tonnes greater than all the commercial energy used by mankind. Roughly 35 per cent of this energy is reflected back into space. Another 18 per cent is absorbed by the atmosphere and draws the winds and about 47 per cent reaches the earth. No country uses as much energy as is contained in the sunlight that strikes its buildings. The wind power available at prime sites could produce several times more electricity than is currently generated from all sources. Only a fraction of the world's hydro power capacity has been tapped. As much or even more energy could be obtained from biomass each year as fossil fuels currently provide.

Moreover, fuel prices for long reflected only the costs of discovery, extraction, refining and delivery, they failed to include the value of the fuel itself. The world has only a limited stock of fuel and it is only a matter of time before it begins to run out. Unlike finite fuels, sunlight is a flow and not a stock. Once a gallon of oil is burned, it is gone forever, but the sun will continue to cast its rays earthward a billion years from now. Whether or not sunshine is harnessed today for human needs, technical improvements in the use of sunlight are lowering real prices permanently. Similar technical improvements in the use of finite fuels could hasten their exhaustion.

Since sunlight is and can be used in decentralised facilities, many proposed solar options would dispense with the expensive transportation and distribution networks that encumber conventional energy systems. The savings thus obtained can be substantial; transmission and distribution today account for about 70 per cent of the cost of providing electricity. In addition,

line losses during electrical transmission may amount to several per cent of all the energy produced and the unsightly transmission tendril that link centralised energy sources to their uses are vulnerable to both natural disasters and human sabotage, pilferage or unauthorised tapping.

Probably the most important element in a solar strategy is the thermodynamic matching of appropriate energy sources with compatible uses. The quantity of energy sought from the sun and the costs of collecting, converting and storing it usually correlate directly—the higher the desired quantity, the higher the cost. Sources and uses must therefore be carefully matched so that this expensive high quality energy is not wasted on jobs that do not require it.

No country has undertaken a comprehensive inventory of the quality of energy it uses throughout its economy. Moreover, the energy currently employed for various tasks is often of a far greater quality than necessary.

#### *Direct Solar Energy*

Direct solar energy is converted by a wide range of technologies into energies of quality levels ranging from low-temperature heat to electricity. Present applications of solar energy seem to be more appropriate for use in rural areas. These include heating water for domestic, industrial and commercial use; seed drying and dehydration of agricultural products for preservation; evaporation of seawater for salt production; sea water desalination, short-term storage and refrigeration for perishable food products.

(i) *Solar Thermal Technology*: The main components of solar thermal technology—"Solar Collectors"—come in two types: direct passive or direct systems which use the sun's heat to warm water or enclosed living or work space, and 'active' systems, which have a heat storing medium. Flat-plate collectors for low temperature heating systems are usually long flat boxes located on the roof of a building or on the ground near it. The collected energy can be stored and used when the sun is not shining.

Solar collectors can also be used to produce drinking water through distillation of brackish or muddy or polluted water by evaporation, moisture condensation and collection. Solar water pumps are a promising application for flat-plate collectors. The cost of such systems remains high compared to the other alternatives.



(ii) *Solar Thermal Power Generation:* Solar concentrators can also be used to produce steam for driving electricity generators. Electricity from the sun in fact offers an attractive alternative to the inadequate electrification programmes. The technology developed for solar thermal power generation covers a wide range. The simplest is a 10 kw capacity plant, and large scale plants with a capacity of 10 MW. For solar electric power plants the annual number of sunshine hours should be as high as possible. Example of areas suitable for such large-scale power plants is the Thar Desert of India.

The economic competitiveness of solar thermal generating technologies is not clearly established. Technological improvements are required to make the option viable for dependable power generation. Solar collectors are subject to refinement and tracking devices need to be made more efficient.

*Solar Cells:* Using this technology developed in the early 1950s, solar cells produce direct current electric energy by transforming solar radiation into electricity. The best and most popular are the silicon solar cells; cadmium sulfide and others are also available. The advantage of these solar cells is the absence of moving parts and fluids at high temperatures. No cooling is needed. The life time of each cell is up to 100 years. The disadvantages of the cells are that they have a comparatively low efficiency and they cannot be used for thermal storage.

The main construction materials for solar cells are abundant and relatively cheap. But the manufacturing techniques are costly. The World Energy Conference has estimated the minimum cost of a solar cell system at \$ 15,000 per peak kw of electricity. This is from 100 to 200 times more expensive than generation by conventional methods.

### *Indirect Solar Energy*

1. *Biogas:* Biogasification involves anaerobic fermentation of organic wastes in relatively airtight tanks. The resulting biogas contains about 60 per cent methane and is useful in agricultural, domestic and cottage craft activities, cooking and small scale power generation. The residue, a nitrogen rich slurry, is valuable as a fertiliser. Technology for biogas is known and reliable, particularly where livestock is available in abundance. It is widely used by wealthier farmers in Asia and the Pacific.

**Table 2.1: Comparison of Diesel-Solar Power Irrigation Pumping Costs in India (in Rs.)**

<i>Solar</i>		<i>Diesel</i>	
Capital costs (1 kw solar panel battery, pump, borewell)	- 17,500	Capital costs (Diesel engine, pump set borewell)	- 6,000
Annual costs (Depreciation of solar panel and other equipments, interest)	- 3,500	Annual costs (Oil, interest, depreciation).	- 2,825
<i>Cost of Pumping Water</i> Rs. 0.24 per kilolitre		<i>Cost of Pumping Water</i> Rs. 0.19 kilolitre	

2. *Small Scale Hydro Power:* One of the oldest sources of energy, flowing water can be used to operate wheels or rams for mechanical power or electric power.

3. *Wind Mills:* For areas with suitable regimes, wind represents one of the most promising sources of energy for water pumping certain agricultural tasks and cottage craft industries and low-load, high value electrical demands such as lighting and telecommunications.

#### *Solar Thermal Devices and Systems*

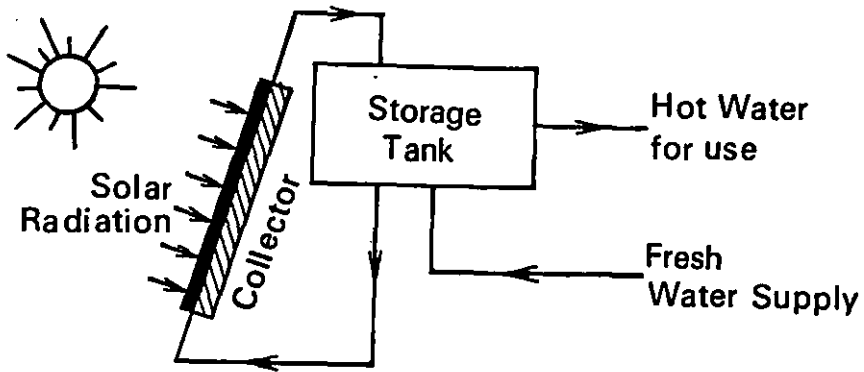
Various solar thermal devices and systems such as water and air heating systems, timber seasoning kilns, dryers, desalination systems and cookers have been developed for low-grade solar thermal energy applications. These technologies are already field proven. They have been commercialised and are finding wide and increasing applications.

*Solar Water Heater:* Solar water heaters are basically of two types:

1. Collector coupled to storage tank, and
2. Collector-cum-storage system.

Under the first category of a solar water heating system there can be two possible ways of extracting heat from the collector, i.e., through natural convention, generally known as the thermosyphon effect and through a forced flow of fluid using an electrically operated pump. The essential components of a solar water heating system under this category are:

1. collector consisting of front glazing metallic absorber, back insulation, and collector base.
2. insulated storage tank with or without heat exchange.
3. pumping.
4. controls and pumps.



**Fig. 2.1. Thermosyphon Solar System**

Source: Maheswar Dayal, *Renewable Energy*, p. 91.

The collector-cum-storage type water heating system is extremely simple. It essentially consists of three main components, namely, front glazing, absorber sheet and insulated storage tank. In such a water heater, sunlight passes through the front glazing and gets absorbed by the absorber which further heats the water. Thus the storage tank acts as a collector and storage for hot water. Solar ponds can also be categorised as given below.

### Water Storage Tanks

#### 1. Pressurised Water Storage Tanks

The pressurised water tanks are either made from stainless steel or enamelled steel, but rarely with plastic materials. Since cold water after getting heated automatically goes up, the heat exchanger in this system, if required, is placed at the bottom of the tanks for a good heat transfer between the exchanger and the fluid in the base.

#### 2. Non-pressurised Water Storage Tanks

These have the advantage that they can be easily fabricated using materials like fibre glass, plastics, metals, etc. These storage tanks are thermally insulated to avoid heat loss.

The inner tank should be of a material which does not contaminate water, is non-corrosive and stable at the temperature of operation. The outer insulation should be covered either with a metal sheet/foil or cemented to protect it from exposure to rain, dust and other atmospheric changes. The thickness of the insulation is to be decided on the basis of the hot water temperature, wind velocity plus thermal resistance of the material. It is desirable that the hot water temperature should not decrease by more than  $6.8^{\circ}\text{C}$  in about 16 hours time.

### **Solar Cookers**

Solar cooker is similar to the cooker we use in our kitchen to prepare food. But it does not require any cooking gas, kerosene, coal any wood or fuel. We do not need any electricity to run it. The solar cooker works on solar energy. It emits no smoke and no soot spoils the cooking utensils. It keeps the environment clean. Above all, it conserves the precious conventional energy sources of the country.

Solar cookers can be broadly divided into two categories: cookers utilising solar heat with little or no concentration of rays, and cookers which deflect solar energy from a huge surface to a smaller area to produce higher temperatures.

The first kind of solar cooker consists of a well insulated box, the inside of which is painted dull black and is covered by one or more transparent materials. The transparent covers trap heat inside the solar energy. They allow the heat from hot black absorbing plate to come out of the box. Because of this, the temperature of the blackened plate inside the box increases and it can heat up the inner space to temperatures up to  $140^{\circ}\text{C}$ , which are adequate for cooking.

The second type of solar cooker uses a lens or a reflector suitably designed to concentrate solar radiation over a small area. It is able to provide high temperatures on its absorbing surface when suitably designed but is usually more expensive than the box cooker.

### **Solar Desalination**

Solar desalination, which is based on the flat plate collector technology, is used to convert brackish and sea water into portable water. The technology is suitable for supplying drinking

water in coastal areas and to large pockets of different parts where water is not suitable for drinking purposes. The distilled water from solar stills can also be used for feeding batteries and so solar stills have important applications in petrol pumps. In rural schools in developing countries solar stills can be used for supplying distilled water to school laboratories as well as demonstrate the utility of solar energy to the students.

### **Solar Drying**

It has long been recognised by the world scientific community that controlled drying of agricultural produce provides realistic approach to getting quality foodstuff and avoiding spoilage. But this idea has not yet found much application in the agricultural sector. However, Indian farmers have started to realise the need for controlled agricultural drying. Under these circumstance solar energy offers a viable alternative for this purpose.

### **Solar Dryers**

Solar dryers can be of a type which transmit heat through radiation. These are often used to dry fruits, vegetables, chillies, fishes, etc.

### **Solar Timber Drying**

Good quality wood can be obtained only when it is properly dried. Open air drying of timber is usually slow and unreliable. Solar dryers are usually able to halve the drying time taken by open air methods and can improve timber quality through controlled drying techniques.

### **Solar Refrigeration and Air Conditioning**

#### *Solar Photovoltaics*

Solar Photovoltaics (SPV) deals with the direct conversion of light into electricity through the use of semiconductor devices. Solar PV system became an effective means of power for almost all space missions starting from the late 1950s. Terrestrial applications of Solar PV began only after the sudden oil price hike of 1973. Since then SPV industries in many countries have been pursuing production and R & D low-cost, high performance SPV systems.

Photovoltaic conversion of solar energy appears to be one of the most attractive ways of meeting the increasing energy demands of the future. Conversion of light into DC electricity takes place in solar cells continuously as long as the sun's rays are

incident on them. SPV systems are not likely to introduce any environmental pollution or ecological imbalance during the energy conversion. The solar PV energy sources have additional advantages. There are no moving components to wear out. There are no pollutants or waste gas left in the atmosphere when the SPV system is used as a power source. Modularity in the SPV power system design is also a great advantage.

Solar photovoltaics have an immense potential for a developing country like India, most of whose land mass receives sunshine almost throughout the year. Today the technological reliability of SPV systems is beyond any reasonable doubt. Such systems are now widely used in India in remote villages, islands and hilltops, performing a variety of functions, including lighting, communication TV power supply, radio power, etc. The major constraint against their greater use in India is the higher capital cost at the ruling prices. But recent major advances in the understanding and fabrication of semiconductor PV devices have prepared the way for large scale SPV utilisation to supplement and complement the available energy. Power from solar photovoltaics has already been shown to be cost effective for many applications when it is displayed at a distance of 4.40 km from the transmission work. India is predominantly a country of villages. Solar PV is one of the interesting possible ways of meeting the electrical energy needs of remote villages having no access to utility grids.

#### *Economics of Solar Photovoltaics*

Many studies have been taken up to assess the economics of solar photovoltaic systems in India. Even though the economics of PV systems greatly depend on the type of application, location where the system is installed and availability of conventional electric power, they can be shown to be cost competitive at distances of about 4 to 12 kilometres from existing transmission networks. But the load requirements are 1 kw to 3 kw even at the current capital costs of PV arrays. For villages 10 km away with a load of 10 kw or so PV is relatively costlier than grid extension. However, even for this load, if the village is 40 km more than the grid, photovoltaic systems are more economical. Since solar PV offers a technology where remote areas as well as regions with power shortages can receive benefits of electricity and several social services like health and literacy in a very short time, investments

in PV system installations in hilly areas, desert regions and other inaccessible parts as well as in electrified villages in the plains, which are more than about 8 km from the grid, can be economically justified even today. There are very large areas where these conditions are met. Hence it is economically justified for public investment to be put in photovoltaic power on a large scale in these areas rather than in conventional power.

One of the most important advantages of photovoltaic power is its extremely low gestation period. Electrical power can be provided for remote locations in an extremely short time. For example, over 4,300 unelectrified villages in India have already been lit up by solar photovoltaic systems. These probably would not have been able to get electricity from conventional sources for 15-20 years due to their difficult and remote locations. A plant of a megawatt size can be built in less than a year in sharp contrast to the time taken for a conventional power plant or a nuclear plant.

Solar PV systems have a number of advantages in addition to being based on clean and inexhaustible resources. They have no moving parts, so that a solar power unit can be virtually maintenance-free, a phenomenon that has been - demonstrated in remotely operated lighthouses, telecommunication relay stations and space vehicles. Solar arrays consist of a number of solar cell modules and allow a wide range of application sizes and types with the same conversion efficiency and technology. Solar cells can easily be mass produced, as transistors and semiconductor integrated circuits. In an expanding market this can be expected to bring about cost reduction resulting from economics of scale. Improvements in the technology of cell manufacture and development of new thin film technologies will further bring down the costs of solar PV technology.

#### *Solar Energy for Pumping*

An average pumpset in India is of 5 H.P. providing a connected load of about 3.75 kw. The average consumption of energy is around 3,000 kwh/years, per pumpset. The pump is run for only 1,000 hours a year. However, the farmer may want to run it round the clock to complete irrigation of his field within the desired period. Alternatively, the pumping rate has to be sufficiently high to complete pumping during the hours when sunshine is available. Thus, solar energy is to be used for pumping; either a larger pump has to be installed, or an energy storage device is

required. In either case, during this period, the energy required for pumping would be 90 kwhr/day.

At the current rate of energy consumption of 3,000 kwhr/year, the cost of electricity at 17 paise per year comes to around Rs. 500 per year. With a discount of 12 per cent and a life of 10 years for the collectors, the cost of collectors has to be around Rs. 3,100. Thus if low temperature turbine pumps were to cost no more than conventional pumps, the flat-plate collector system would be less than Rs. 70/m<sup>2</sup> if solar energy for pumping is to be competitive with electricity.

#### *Solar Energy for Air-Conditioning*

The summer months when the need for air-conditioning is high are also the months when the incidence of solar radiation is high. For most of India, the incidence of solar radiation during the months of April to August at 70 to 75 per cent of the theoretical clear sky values is around 550 cal km<sup>2</sup>/day (6.4 kwhr/m<sup>2</sup>). With a direct focus collector, 50 per cent of the solar energy can be collected as heat. This energy can be used in an air-conditioner to extract at least twice as much heat. Thus the net heat exchange efficiency of solar energy air-conditioning can be equal to 1.0.

An air-conditioner of a 3 kw power can provide a heat exchange equal to the latent heat of two tonnes of ice per hour. This can comfortably cool a room of about 18 sq.m. in a city like Delhi. A 3 kw air conditioner run for 10 hours a day would consume 30 kwhr. To obtain that much solar energy would need  $30/6.4/0.5 = 9.5$  m<sup>2</sup> of collector area. This is about half the area of the room that can be cooled.

The cost of the heat exchanger should not be much different from that of a conventional air-conditioner and the cost of the collector has to be balanced against the cost of energy. Assuming that an air-conditioner is used for eight hours a day for 125 days in a year, the cost of energy consumed at 17 paise per unit for a 3 kw air-conditioner over a year is  $3 \times 125 \times 3 \times 7 =$  Rs. 500 per year. At 12 per cent discount and a collector's lifespan of 10 years, one can spend up to Rs. 300/m<sup>2</sup> for the collector. This seems possible even today.

#### *Solar Energy in Developing Countries*

Most of the developing countries lie between latitude 10°N and latitude 40°S where solar energy is generally available. As a



source it is well suited for production of low grade heat at temperatures below 100°C. The maximum rate at which solar energy arrives at a flat surface is approximately 1 kw/m<sup>2</sup> in a country like Jamaica. This means an average annual energy receipt of around 2000 kw/m<sup>2</sup>.

There is considerable potential for use of solar energy sources for developing countries. But its widespread use depends on the extent to which high capital costs for solar devices can be reduced, costs and reliability of related equipment improved and obstacles to the introduction of new technologies overcome.

### **Planning**

Pilot and demonstration projects and institutions for Research and Development need to be established or strengthened in order to introduce solar energy technology. Here technology means flat plate collectors for water pumping concentrating collectors for cooking solar thermal power generation and solar cells. Energy planning for solar system projects have yet to be incorporated into strategies of integrated rural development in the vast majority of countries. The World Bank recognised that the 1973-74 increase in oil prices made appropriate sources of energy available for rural areas. Recommendations for planning institutions and planning procedures for solar energy systems in developing countries have been made by the United Nations.

The World Bank and UNIDO have suggested application of solar energy technology for water distillation, water heating, drying, cooking and air-conditioning. To proceed with planning for solar energy, developing countries need more information in five areas:

1. The criteria on which policy should be based with regard to energy utilisation.
2. The appropriate government structure and machinery for development planning for non-conventional sources of energy.
3. Indigenous technology relating to application of non-conventional sources of energy.
4. Product-demand analysis and manufacture of production of equipment.
5. Appropriate institutional facilities, work programmes and technical manpower.

**Financial Implications**

Current capital costs per unit of installed capacity are substantially higher for solar cell systems than for hydro power, except for very small facilities. While solar collectors are less expensive than Rankine cycle engines, which are necessary to convert solar into mechanical energy, are expensive. The costs will decline with increases in the volume of production. Research and development in national laboratories also require financing. Funds are available for solar energy development from governments, international agencies and private corporations.

**Government Policies**

Some developing countries have advanced plans for producing capital equipment, and this activity may be encouraged in the private sector through conventional industrial incentives. In India, the Department of Science and Technology funds and coordinates solar R & D nationally, with its emphasis on rapid commercialisation. Solar cells and important aspects of the programmes, for instance, BHEL is developing a 10 kw solar thermal electric generation unit for demonstration purposes.

The Government of India is facilitating research on solar cell manufacture and sophisticated power towers but most attention is devoted to biogas units.

***Solar Energy in India***

A large amount of solar radiation falls in India, and for most of the country, very few days are without sunshine. The annual average intensity of solar radiation in India is 600 calories per square centimetre per day. The variation of total solar radiation over the year in several cities in India is between 63 and 72 per cent. Even the minimum radiation which is available in the month of December, is quite large and for most of the cities it is above 500 calories km<sup>2</sup>/per day. Thus solar energy is an attractive source of energy for India.

However, with the present technology of collection and storage, solar energy is not competitive for large scale power generation. However, for space heating, air-conditioning and refrigeration, solar energy is quite profitable even with today's technology. The table below shows the efficiencies of conversion of solar energy into various useful energy forms. Even when efficiency of conversion of electricity is not too low, the cost of

these devices with today's technology is very high. A technological breakthrough in cost reduction here would have a profound implication for meeting the energy needs of India.

**Table 2.2: Efficiencies of Conversion of Solar Energy: Useful Energy**

<i>Process</i>	<i>Efficiency Percentage</i>
1. Direct focus collector (solar energy heat)	60 - 75
2. Flat plate collector turbine operated by direct focus collector (solar energy-mechanical power)	30 - 60
3. Low pressure (2-5 atmospheres) (solar energy: electricity)	15 - 30
4. Thermo-electric generator (solar energy: electricity)	4 - 10
5. Solar Photocell (solar energy: electricity)	2 - 12
6. Photosynthesis (solar energy: chemical energy)	0.2 - 2
7. Forest growth giving firewood (solar energy; heat)	0.1 - 1.1
8. Plant growth used for food (solar energy: muscular energy)	0.1 - 0.1
9. Wind and water power (solar energy: kinetic energy)	0.001 - 0.002

#### *Solar Energy Programmes in India*

1. *Solar Thermal Energy:* The objective of the solar thermal programme is to develop and promote use of technologies for conversion of solar energy into thermal for supplementing the ever increasing demand for thermal and electrical energy. The objective is achieved through:

1. Research and Development;
2. Demonstration; and
3. Extension.

Research and development projects are aimed to make the technologies technically feasible, economically viable and suitable for site conditions. Feedback data under the demonstration programmes are used to improve upon the

technology to suit the field conductors. Low grade solar thermal technologies which can meet the thermal energy requirement for temperature applications for large scale utilisation are available under the extension programme.

**Table 2.3: Cost Sharing Scheme for Installation of Low Grade Solar Thermal Systems and Devices**

Category of Users	% share of Central Government		
	1987-88	1988-89	1989-90
1. Private Sector	33.3	30	30
2. Government, Public sector Enterprises	50.0	40	30
3. Centre & State Government Buildings, Universities, Religious Bodies	75.0	60	50
4. Domestic Solar Water Heater	50.0	40	40
5. Community Solar Cookers		33.3	33.3

*Solar Cooker Programme:* An investment sharing scheme for solar cookers was launched in 1982. So far nearly 1,40,000 family size solar cookers have been sold in the country. On an average each solar cooker saves 2 kg of wood per day or 600 kg of wood per year, assuming that solar cookers cannot be used for 365 days in a year due to foggy and cloudy weather. Thus the total solar cookers sold so far can save as much as 84,000 tonnes of wood per year (worth Rs. 36 crores).

Community solar cookers for cooking meals for groups of people have also been developed and their working has been found satisfactory.

*Solar Energy Centre:* The Solar Energy Centre (SEC) as a division of DNES is responsible for research and development, testing and certification and standardisation of various renewable energy devices and also for development of technical manpower in the field of solar technologies.

The major activities of the SEC are:

1. Solar heat research;
2. Systems design and engineering;
3. Solar refrigeration and air-conditioning;

4. Testing and standardisation;
5. Materials research activities;
6. Solar thermal power generation; and
7. Solar passive architecture and greenhouse technology.

SEC receives international cooperation, particularly from the United Nations Development Programme (UNDP) to sponsor solar thermal power projects in the country.

*Solar Photovoltaics:* Solar Photovoltaics (SPV) generate electricity directly from sunlight. This technology is suitable to rural, remote and isolated areas not served by conventional grid power.

*Research and Development:* The prime objectives of the research programme are to develop low cost solar cells, improvement in efficiency, reliability and life of SPV modules and development of systems for various applications. During the year, funds were provided for research on various aspects of SPV technology such as silicon material, thin film SPV devices and other SPV devices and systems.

*Technology Mission Projects:* DNES participates in the activities of the National Literacy Mission (NLM) of the Ministry of Human Resource Development for the design and procurement of solar power packs for installation in adult education centres in the Technology Demonstration Districts of NLM.

The Department also takes part in the activities of the National Drinking Water Mission, which is implemented by the Department of Rural Development, particularly in the specification and technical evaluation of the SPV-powered deep well pumping systems.

**Table 2.4: Targets and Achievements of Solar PV Demonstration Programme, 1989-90**

<i>Application</i>	<i>Target</i>	<i>Achievements</i>
1. Water pumping	100	48
2. Street lighting	3000	2150
3. Domestic lighting	100	94
4. Community TV/lighting	100	245
5. Power plants & other applications (kwp)	100	70

The main elements of the demonstration programme are the initial electrification of villages through provision of street lights,

lighting in community buildings, community TV systems and supply of water for drinking and irrigation. The targets and achievements of SPV programmes are given in Table 2.4.

### **Wind Energy**

Wind was one of the earliest sources of power used to increase the production capacity of man. Wind energy has been used for thousand of years to propel boats and ships and to provide rotary windmill power to reduce the physical burdens of man. The windmill, an invention, dates from the earliest times of recorded history. There is evidence that the ancient Egyptians used windmills as early as 3600 B.C. to pump water to irrigate their arid fields and to grind grain. But in recent years wind energy has been used in various other forms. Even some companies in the USA have begun offering windmill generator systems.

In India the application of wind energy was not uncommon. Its efficient and advanced uses are only of recent origin. Of late Holland windmill projects have been set up by the Allahabad Polytechnic in order to pump water for irrigation and domestic uses. Several of these windmills are pumping water in villages near Allahabad and Lakhimpur Kheri. It has been observed that these projects are cheaper to run and easier to maintain than the diesel or electric driven pumps. Moreover, some windmill projects are successfully operating to pump water for agricultural uses in the Ghazipur district of UP.

The major advantage associated with this technology is that windmills as a source of mechanical power have continued to be an appropriate technology for rural applications. In their construction and installation locally available materials, labour and energy resources are used. The village craftsmen who build them and the local inhabitants who use them have the process entirely under their control.

In many studies it has been shown that wind energy is more economical than several other sources of energy. Since it is more economical and that too since it can be harnessed in both day and night, its development would cater to the major energy requirements of our rural areas. It is estimated that in 75 per cent of the areas in our country windmills will provide energy at best at a cost of 30 per cent less than electricity or diesel pumps.

With a view to further exploiting this immense natural source of energy, ATDO is developing windmill technology for

pumping ground water. Locally fabricated windmills have been established in the coastal areas of Sind and Baluchistan and in the Cholistan areas of Bahawalpur. The local people who previously went even without drinking water are now provided with water for all purposes. The windmills also help in under soil irrigation.

Experiments have indicated that the locally fabricated windmills, costing in terms of PRs. 25,000 to PRs. 30,000, are capable of lifting up 2,300 litres of water. Some low-cost designs are also being procured for local fabrication. One of them, fabricated in Karachi at a cost of only PRs. 7,000, can draw 230-275 litres of water from depths of 40-50 feet (12-15 m). A savouring type rotatory windmill is also being fabricated for experimentation under local conditions. Although a technical and economical assessment has suggested that windmills for water pumping can be successful in developing all important farming sectors in Pakistan they have not yet been used on a large scale.

#### *The Main Problems Preventing Wider Use of Windmills*

1. The relatively high cost of locally fabricated windmills;
2. Lack of expertise and experience in manufacturing; and
3. Unwillingness of existing manufacturers to incur expenses on rural development and to produce more cost effective designs, since the existing models work well.

What is needed, therefore, are suitable windmill designs that match the output and reliability of existing commercially available equipment but which would be less material intensive and involve production techniques that are already widely available in small and medium sized engineering workshops.

Small horizontal axis wind machines are available commercially and in some situations compete economically with diesel engines for water pumping. Their high initial cost compared to diesel systems is offset by the savings in fuel over the lifetime of the equipment which range from 10 to 20 years with proper maintenance. The minimum wind speed at which they will operate is typically 6 miles per hour (2.7 m/s) at a wind speed of about 15 mph (6.7 m/s).

The initial cost of wind machines designed for local manufacture can be considerably reduced, but their record in many developing countries has been poor. If the machines are built locally, however, they can be maintained locally.

The vertical axis machines have a long history, and recently there has been a revival of interest in them. Electricity generated by using the system again presents storage problems since batteries can only be used economically with low power, low machines.

Applications of wind energy include water pumping for domestic purposes, livestock, and irrigation, mechanical power for threshing and grinding, and small scale electricity generation for existing rural clinics, etc.

#### *Wind for the Production of Mechanical Energy*

In suitable wind regions, particularly in coastal areas, windmills can be installed to provide mechanical energy. Traditionally, windmills have been in use in China, Iran and Northern Europe for a variety of purposes. Simple windmills can be locally fabricated from local materials.

Developing countries have not established any systematic national policy for integrated applied Rural and Development or local manufacture of windmills on a commercial scale. Cloth soil windmills are fabricated in Greece and Portugal, and Ethiopia. India, Kenya, Thailand, the United Republic of Tanzania and Upper Volta have done some applied Rural and Development prototype fabrication.

*Wind Power:* Recent efforts have been concentrated on reducing the cost of windmills and improving their design for use in developing countries. Mechanical energy from wind power can be used for pumping and crop processing and for the production of electricity. Four specific actions are recommended:

1. The collection of better meteorological data;
2. Improvements of designs for low-cost mills for mechanical power and for electrical power generation;
3. The study of the new concepts; and
4. Arrangements for the dissemination of information.

#### *Windmill Technology*

For areas with suitable wind regimes, windmills represent one of the most promising sources of energy for water pumping, certain agricultural tasks and cottage craft industries and low load, high value electrical demands, such as lighting and telecommunications. Traditionally wind energy machines have been used in China, Iran, European countries and northern Europe.



Most wind machines are designed for windspeeds of more than 10 mph (4.5 m/s). So far there have been only marginal efforts to adopt conventional wind machines to better utilise winds averaging only 6-10 mph (2.7-4.5 m/s). Since development of wind speeds results in the curbing of available power, selection of sites with 10 mph (4.15 m/s) average wind in preference to sites with 8 mph (3.6 m/s) average wind may result in a power difference of 100 per cent.

Wind machines can be classified into the horizontal axis and the vertical axis groups. A vertical axis machine is capable of working only relatively low-torque loads and some designs require supplemented starting. The horizontal axis design commonly found in the USA and Europe can serve for both low and high torque loads.

Both types of wind machines must be carefully matched to the generator to avoid damaging it. They are suitable for pumping shallow water but not deep water. European and US research institutes are developing low cost, small units such as those used in the OMO River project in Ethiopia. An electricity system based on wind power requires some sort of energy storage system. Since wind conditions may not allow continuous generation in Tanzania, the country uses the storage system.

#### *Wind Energy Utilisation in India*

Wind energy is an indirect form of solar energy. About 1 per cent of the total solar radiation that reaches the earth is converted in the atmosphere into the energy of wind. Winds result from the differential heating of the earth and its atmosphere by the sun. As the sun heats different parts of the earth at different rates, air circulates from the cold to the warm areas producing winds. The usable global wind energy potential has been estimated at  $120 \times 10$  kwh a year. Though the total quantity of this resource is extremely large, it is concentrated in certain regions and can vary a great deal with time at any given location. Wind energy is renewable and poses no major environmental problems.

Wind energy has been used for thousands of years to propel sailing ships and for pumping water and grinding grain. The use by Egyptians dates back to 3600 B.C., and reference to lifting water using machines run on wind in India are contained in Kautilya's classic *Arthashastra* (400 B.C.). Windmills with vertical axis spindles were used by the Persians as early as 200 B.C. Later, wind

machines with horizontal axis spindles were developed in Mediterranean countries such as Greece and Spain. In the 13th century A.D. horizontal axis machines were introduced in Europe that could be turned into the wind as its direction varied. By the 14th century the Dutch had taken the lead in developing improved engineering designs for wind machines, and the four-bladed horizontal axis windmills played an important role in bringing about the first mechanical revolution in Europe. By the 19th century Holland had more than 9,000 windmills in operation, and Denmark more than 7,000. Between 1850 and 1970 more than 6 million small multibladed American windmills were installed in the United States, of which it is believed one million are still in use. Inexpensive windmills made of wood and cloth are still in use in the Valley of the 10,000 windmills on the island of Crete, and in Thailand. At the turn of the century, the Danish government initiated a programme to develop a series of wind-powered electric generations. Similar programmes were also launched in other European countries such as the UK, France, Germany and the United States. However, largely due to availability of cheap oil in the 20th century, use of wind energy declined and did not receive much attention till the early seventies.

The oil crisis of 1973 revived interest in the renewable sources of energy, including wind energy. In India, NAL took up the design and development of a sail windmill and Bharat Heavy Electricals worked on a 1 kw Darriens type vertical axis wind turbine. Attempts were also made to develop other low cost designs using local materials, such as the Madurai Sherman windmills, the Central Arid Zone Research Institute, Sail Wing Windmills, the Sholapur VTA windmill, the Murugappa Chettiar Research Centre Arula and Poghul windmills, the Tilonia, Yatch Sail windmills, the Auroville prototypes and the Indian Institute of Science rotor prototypes. Under a windmill project initiated in 1977, six windmills of two types, namely 12-up 500 and 12 PO-3500, suitable for low wind regimes were installed in Ghazipur, UP, to study the feasibility of introducing windmills for irrigation. These developments were greatly accelerated by the Department of Non-Conventional Energy Sources after its formation in 1982. As a first step, a comprehensive analysis and collection of data on wind speeds were carried out, which

indicated that there was great potential for setting up windmills for irrigation. Likely sites for this purpose were also identified.

#### *Typical Costs of Wind Energy Utilisation in India*

Cost comparisons of wind pumping systems are usually made with diesel pumps. Based on certain assumptions made with regard to capital cost, annual maintenance, depreciation and interest rates, the cost per cubic metre of water pumped by each system has been calculated for a typical wind pumping system, such as the 12-P-U-500, on the basis of field experience in India. For a system costing Rs. 21,000 (about US\$ 1500) and capable of pumping 20,000m water per annum at a total head of 6 metres under average wind speeds of 10-12 kmph, the cost of water pumping works out at 23.5 paise/m (1.5 US cents/m). As against this, with a 5 HP diesel pump set operating 1,500 hours annually for the same total output at the same head, the cost of water pumped works out at 42.5 paise/m (about 2.8 US cents/m). A comparison with electric pumps indicates that given reasonably favourable wind conditions, the cost of a wind pump will be even lower than that of an electrical pump.

The economics of wind turbines involves trade-offs between economies of scale, according to which energy generation increases in proportion to the swept area and to the curbs of wind speed, and diseconomies of scale due to increasing sophistication and complexity of technology. The average capital cost and cost of power generation for the 1.0 mw projects undertaken in India so far range between, Rs. 1.5-1.75 crores/mw (about US \$/1 1-1.16 m million) and Rs. 1.25-1.50/kwh (about 8-10 US cents/kwh), respectively, depending upon the site. The cost of generation projected for the proposed 5-10 mw size wind farms ranges from Rs. 0.79-1.04/kwh (5-6 US cents/kwh). For larger wind farms and generation costs would be even lower. These costs are already comparable to those for thermal power generation and lower than generation of power from diesel units. Furthermore, while the cost for thermal power generation will go on increasing with escalations in fuel costs, the costs of wind power generation will decline further with improvements in technology and discovery of more windy sites as also with increases in size of wind farm power projects.

### *Wind Energy Programme*

It is estimated that India has a wind energy potential of 20,000 mw for power generation in its coastal areas and windy sites. For harnessing this potential the Department of Non-Commercial Sources of Energy (NCSE) has undertaken a programme of installing wind generators, windmills and battery charging systems.

The wind energy programme covers the various aspects of wind energy utilisation. The broad classification of activities in this area is:

1. Wind resource assessment
  - (a) Wind monitoring;
  - (b) Wind mapping; and
  - (c) Complex terrain studies.
2. Research and Development
  - (a) Wind pumping systems;
  - (b) Regional wind energy test station;
  - (c) Wind electric generators; and
  - (d) Wind Energy Centre

**1. Wind Resource Assessment:** The wind survey programme has been carried out in 19 states and union territories. Wind speed measurements in several states have led to the identification of more windy sites.

**2. Research and Development:** Research and development activities are mainly concentrated at the Wind Energy Centre set up at the National Aeronautical Laboratory, Bangalore, for development, field testing and performance evaluation on new designs of wind pumps and improvements in the existing designs and wind pumps to make them more reliable, efficient and cost effective.

**3. Wind Pumping:** The wind pumping demonstration programme was extended to private farmers to make it more effective. Wind pumps were installed primarily to meet drinking water and minor irrigation, requirements. The development and promotion of wind pumping technology is being intensified for different agro-climatic conditions, pumping heads and minor irrigation requirements. The aim is to improve reliability and efficiency, create demand and reach production volumes feasible for commercialisation.

Table 2.5: Statewise Number of Windmills

State	Number of Mills	State	Number of Mills
Uttar Pradesh	198	Karnataka	17
Madhya Pradesh	164	Andaman	14
Andhra Pradesh	162	Pondicherry	10
Orissa	144	Himachal Pradesh	9
Maharashtra	111	Goa	6
Gujarat	94	Chandigarh	4
Tamil Nadu	83	Kerala	4
Punjab	77	Nagaland	4
Rajasthan	76	Jammu & Kashmir	2
Bihar	74	Tripura	2
Haryana	30	Others	677
Delhi	27		
	<b>Total</b>	<b>1987</b>	<b>2000</b>
	<b>Total</b>	<b>1989-90</b>	<b>2524</b>

A total of 2,524 wind pumps (mills), mainly 12-PU-500 types, have been installed in different parts of the country since 1980-81. The increasing utilisation of wind pumps would help to reduce imports of oil by substituting for diesel pumping and reduce electrification costs by substituting for electric pumpsets. It has been estimated that on an average a wind pump can save about 1.28 tonnes of diesel or 2,000 kw of electricity annually provided it is installed in favourable wind conductors where it can operate practically all the year round.

According to experts, about 1.5 to 2.5 per cent of the energy radiated from the sun on to the earth is constantly converted into the energy of atmospheric air currents. Of this, about 3 per cent could be used by wind turbines. This would result in an increase in friction over the land surface of the earth by about 10 per cent with an efficiency of 30 per cent. This would have an energy potential of 30 Tw. Out of this only 30 per cent could be used because only in coastal areas could one expect sufficiently large average wind velocities.

#### *International Cooperation*

The world bank fielded a sitting mission in May 1989 to explore the feasibility of exploitation on a commercial scale of projects in

Gujarat, Tamil Nadu, Andhra Pradesh and Karnataka. The feasibility work and preparation of project reports is being further pursued.

### **Tidal Energy**

Man has been attempting for a long time to produce power from ocean tides. As early as the eleventh century tides were harnessed in a small way in England and other West European countries where small tide mills were used to grind corn. In Chelsea, Massachusetts, USA, in 1734, a "Slade's mill" was built to grind spices. This mill developed about 50 horse power from four waterwheels driven by the head created by damming a small estuary to trap water at high tide.

Tides arise mainly as a result of the lunar and solar gravitational interactions with earth. Of the two, the effect of the moon, because of its close proximity to earth, is dominant.

The sun's tidal attraction is only about half as large as the moon's. Energy of the tides is continuously being dissipated at a rate which is in the order of a billion horse power (Clancy, 1973). This vast power output comes at the expense of the kinetic energy of the earth—the moon system. The energy in the ocean tide is enormous. A large amount of the total tidal is concentrated in a very small fraction of the ocean near the continental coasts. Coastal regions are the most accessible portions of the ocean and hence they are potentially valuable sites for man to harness tidal energy.

The method of producing tidal hydroelectric energy is essentially the same as that used in hydroelectric plants on rivers, i.e., water flows from one height to a lower one and turns a turbine as it does so. However, there is a difference between the two. In the case of tides, there is a two-way water flow and a short periodicity with which the head of the water is established whereas a stream flow, properly regulated by a dam system, is unidirectional and constant.

Since India is surrounded by seas on three sides its potential to harness tidal energy has well been recognised by the Government of India. But the rural and development activities in this area are very limited in comparison to the other non-conventional energy sources. However, the tentative studies conducted off the Gulf of Bombay and the Gulf of Kutch have indicated that the power obtained from the tides in these two

areas can raise the energy production of the region by 40 per cent. That is why the central government has recently sanctioned Rs. 2.18 crores to determine the feasibility of establishing a tidal wave power project in the Gulf of Kutch. A number of other sites have also been chosen.

### Geothermal Energy

Geothermal energy is the natural heat generated from within the earth. Underneath the earth's relatively thin crust, temperatures range from 1,000 to 4,000°C and, in some areas, pressures exceed 20,000 pounds per square inch (PSI). Geothermal energy is most likely generated from radioactive thorium, potassium and uranium dispersed evenly throughout the earth's interior which produce heat as part of the decaying process. This process generates enough heat to keep the core of the earth at temperatures approaching 4,000°C composed primarily of molten nickel and iron. The core is thought to be surrounded by a layer of molten rock, called magma chambers, that rises through the crust, often resulting in volcanic activity. Molten rock also rises in the earth's crust where the plates are moving away from each other, and in other areas where the crust is thin. Volcanoes, hot springs, geysers and fumaroles are natural clues to the presence of geothermal resources near the surface and perhaps where economic drilling operations can tap their heat and pressure. Additional heat can be generated by friction as two plates converge and one moves on top of the other.

About 10 per cent of the world's land mass contains accessible geothermal sources that could provide several million quads of energy annually. Table 2.6 indicates the resource potential for specific countries.

There are five types of geothermal energy resources—hydrothermal, geopressured, hot dry rock, active volcanic vents and magma.

Table 2.6

<i>Country</i>	<i>Potential</i>
Canada	4,46,700
China	5,37,050
India	15,200
Japan	79,450
USSR	2,38,900
USA	5,01,200

*Prospects of Geothermal Energy in India*

Geothermal manifestations are widespread in India in the form of 340 hot spring localities, many of them approaching boiling point at their places of occurrence. Large tracks of hot ground waters with 15-20°C excess temperatures over mean ambient values and high bottom hole temperatures (140-200°C) recorded in many of the boreholes drilled in various sedimentary basins of hydrocarbon are known to exist. These manifestations are localised among 12 well defined and structurally controlled geothermal provinces.

1. Himalayan geothermal Province
  - (a) NW Himalayan sub-province
  - (b) NE Himalayan sub-province
2. Naga-Lushai geothermal province
3. Andaman-Nicobar geothermal province
4. Cambay-Garben geothermal province
5. Narmada-Tapti geothermal province
6. West-coast (Konkan) Faulty geothermal province
7. Damodar Valley geothermal province
8. Mahanadi Valley geothermal province
9. North Indian Precambian geothermal province
10. Godavari Valley geothermal province
11. East Indian Archean geothermal province
12. South Indian Archean geothermal province

Systematic geothermal exploration carried out by the Geological Survey of India (GSI) during the last one and a half decades has generated considerable basic data to facilitate evaluation of the prospects of the existing geothermal resources and possibilities of their utilisation in India.

An order of magnitude estimation of the available stored heat energy in the upper 3 km depth range has been attempted for about one-third (113) of the known geothermal areas of India for which basic geospecific data was available. The value obtained was  $40.9 \times 10^{18}$  calories, which is theoretically equivalent to the heat energy that can be obtained by the combustion of about 5,730 million barrels of oil. If all these 113 identified geothermal systems are developed and utilised for non-electrical uses, the energy available will be equivalent to 10,600 mw.

More recently, a similar exercise, including the sedimentary basins explored by the ONGC computed the total geothermal



resources up to 5 km depth. It estimated the available stored heat as  $3244.35 \times 10^8$  mw years, i.e., about  $10^{24}$  calories of heat which is equivalent to 750,000 billion barrels of oil.

### **Ocean Energy**

The ocean contains the vast energy potential in its waves, in its tides and in the temperature difference between cold, deep waters and warm surface waters. Caused by winds blowing across miles of open ocean, waves offer a power source for which numerous systems have been conceived. Tides are a result of the gravity of the sun, the moon and the rotation of the earth working together. In some areas of the world, the ocean rises and falls over 12 metres twice a day. The ocean also acts as a gigantic solar collector capturing the energy of the sun in its surface water as heat. The temperature difference between warm surface waters and cold waters from the ocean's depths provides other potential sources of energy. Tidal power, Ocean Thermal Energy Conversion (OTEC) waves, ocean and tidal currents and salinity gradients are various forms of ocean energy receiving attention at present.

The original idea of utilising the temperature gradient existing between surface and deep waters was suggested in 1882 by D'Arsonval, a French physicist. Later studies by Campbell, an American, in 1913, and Milanese Boggia and Marius Doring, two Italians, in 1923, confirmed the possibility of utilising the temperature between surface and deep waters at Matanzas, Cuba, with a capacity of 22 kw output of electric power. Claude's experimental plant obtained a  $14^{\circ}\text{C}$  thermal difference by pumping 700 metre deep waters through a 1.6 metre diameter pipe, extending about 2 kilometres from the shore.

In 1948, a French corporation (Energie Electrique de la coted' Voire) constructed a similar plant at Abidjan on the Ivory Coast (West Africa). This installation, based on a thermal differential of  $20^{\circ}\text{C}$ , was planned to produce 7,000 kw of electrical power. The principle of this ocean thermal plants differs from that of traditional steam engines in that such plants do not use the steam artificially produced by combustion of some material but use sea water in tropical regions, which is brought to boiling point by being channelled in a vacuum ( $0.04 \text{ kg/cm}^2$ ) (Charlier, 1970).

Cold water from deeper layers of the sea was pumped to the surface and used in the condenser of a turbine whose 'steam'

source was the vapour obtained from warm lagoon waters heated by the sun. The entire ocean thermic installation consists of an evaporator, a condenser, a turbine, an alternator, a tubing and pumps. The volume of water passing through the evaporator is considerable. To produce 7,000 kw of power, a discharge of cold water at the rate of 10 m<sup>3</sup>/sec and of warm water at the rate of 30 m<sup>3</sup>/sec is required. About 3,400 kw and 850 kw of power will be used up by the pumps and the extractor respectively. Full operation of this plant was never achieved due to difficulties in maintaining the 2.5 metre diameter offshore pipeline extending to a depth of 4,000 metres, approximately four kilometres from the shore.

According to Beau Nizery (1952), the environmental problems include tapping of cool water often found at some distance from the coast, blocking and removal of fauna which could be sucked in gas concentration in water, protection against corrosion and sea bottom relief. Anderson and Anderson (1975, 1966) have suggested a floating sea thermal power installation using liquid propane, a low-cost non-corrosive heat transport medium as a power fluid. Gearard and Roels (1970) suggested the utilisation of deep cold ocean waters by constructing multi-purpose plants at suitable coastal or island locations where submarines should provide access to deep cold waters within a few kilometres from the shore.

The most promising possibility for thermal energy is in tropical islands, sites where deep cold waters are close to the shore and where conventional fossil fuel power sources are generally imported. Some of the sites suitable for the exploitation of ocean thermal energy are located along the coasts of Brazil, Peru, Columbia, Cuba, Mexico, the Ivory Coast, Mozambique, Tanzania, Kenya, Malagasay Republic, India, Sri Lanka, the Philippines, Indonesia and New Guinea.

By the methods discussed above electrical power could be generated from ocean thermal energy along our coasts, especially along the east coast, the Andaman and Nicobar islands and the Lakshwadeep islands where deep cold waters are close to the shore.

#### *Ocean Energy in India*

India has a few potential sites for tidal power development. The most attractive locations are the Gulf of Cambay and the Gulf of

Kutch on the west coast where the maximum tidal range is of the order of 11m and m with an average total range of 6.77 m and 5.23 m, respectively. The Ganges delta in Sundarbans in West Bengal has also good locations for small-scale tidal power development. The maximum tidal range in Sundarbans is approximately 5m with an average tidal range of 2.97 m. The identified economic tidal power potential in India is of the order of 8,000-9,000 mw with about 7,000 mw in the Gulf of Cambay, about 1,200 mw in the Gulf of Kutch and less than 100 mw in the Sundarbans.

The research and development activities of the ocean energy cell put up at IIT Madras, are progressing well.

DNSE is examining the setting up of a 5.8 mw pilot Rural and Development Ocean Thermal Energy Conversion (OTEC) plant off Andamans mainland in order to save diesel transportation costs.

The wave power (ocean energy) potential along the Indian coasts has been estimated using the wave data published by the India Meteorological Department. The coastline is divided into six zones and wave power has been computed monthwise for each zone. The estimated wave power varies seasonally and geographically from 1.2 to 29.6 kw/m with an average of 9.4 kw/m. The largest wave potential occurs along the Konkan coast in July. The south-west monsoon period (June-September) offers a greater potential all along the coast with a mean of about 15.5 kw/m.

Besides ocean energy, the other sources of energy are:

- (a) Alternate fuels for surface transportation;
- (b) Methanol programme;
- (c) Ethanol programme; and
- (d) Thermal energy recovery from municipal waste, and rice husk.

### **Magneto Hydrodynamics**

The principle of Magneto Hydrodynamics (MHD) power generation is the same as that of conventional electric generators, i.e., electro-motive force is induced in conductors moving across a magnetic field. The electro-motive force is generated through the movement of copper conductors across magnetic fields in conventional electric power generators whereas in MHD the movement of conducting combustion plasma is used for power generation.

The MHD power generation efficiency is estimated higher, at around 49 per cent compared with 25-30 per cent by conventional power generation methods. So, MHD saves in fuel of about one million tonnes of coal per year for a 1,000 mw of power. Increased efficiency also reduces thermal pollution and water requirements. The MHD power generation systems are used in steel, aluminium, fertiliser and coal gasification industries. Since 1986, 12 MHD plants have been completed.

#### **Micro/Mini Hydel Development**

The responsibility for the development of micro/mini hydel projects was transferred from the Department of Power to DNES in early 1989. Prior to that, DNES's role in this area was limited to research and development and demonstration.

After the reallocation of the work, DNES, in consultation with state electricity boards, examined measures to rapidly develop mini hydel schemes which could deliver power cheaper than thermal power in electrified areas and at competitive rates in remote power in electrified hilly areas where grid power may take a long time to reach.

Detailed project reports for a number of projects which are cost effective in many states are being prepared for consideration.

At the instance of DNES, the World Bank is conducting a pre-investment survey for rapid development of mini hydel projects in Andhra Pradesh, Kerala, Karnataka, Tamil Nadu and Punjab.

#### **Chemical Sources of Energy**

Under the chemical sources of energy DNES covers the following three activities:

1. Chemical routes of trapping solar energy;
2. Storage batteries; and
3. Fuel cells

##### *1. Chemical Routes of Trapping Solar Energy*

Semi-conductor based photoelectro chemical cells form one of the chemical routes for trapping solar energy. These can be classified into photoelectrolytic cells, electro-chemical photovoltaic cells, rechargeable photoelectro-chemical cells, photogalvanic cells, and photoelectro catalysis cells.

##### *2. Storage Batteries*

These are useful to store excess electrical energy during off-peak hours. Research and development in this area is going on for

projects like kinetic and equilibrium studies on non-aqueous batteries with Na/Li anodes, development of sodium sulphur batteries suitable for electric vehicles and development of iron ore batteries.

### **3. Fuel Cells**

A fuel cell is an electro-chemical device consisting of an anode, a cathode and an electrolyte in which chemical energy of a conventional or non-conventional fuel is directly and efficiently converted into low voltage direct current electricity. The different fuels used are mainly hydrogen, hydrocarbons, aldehydes, alcohols, etc. Fuel cells have high efficiency and also advantages of low volume, weight, absence of moving parts, silent operation and capacity to withstand overloads. Many research schemes are in progress in this area undertaken by different organisations with the coordination of DNES.

### **Hydrogen Energy**

Hydrogen in the form of fuel energy will atmost certainly be one of the most important energy components of the early next century. Hydrogen is a clean-burning and easily transportable fuel. Most of the pollution problems posed by fossil fuels at present would practically disappear with hydrogen since steam is the main product of its combustion. As a gas it can easily be piped to long distances with much less cost. At the consuming points, internal combustion engines, fuel cells, furnaces, a variety of appliances are amenable to the use of hydrogen. Harnessing of hydrogen energy is one of the important goals of the total renewable energy efforts in India.

It was first discovered in 1766 by a British chemist, Henry Cavendish, as inflammable air and rediscovered in 1783 by the French chemist Anteine Lavoisier as a constituent of water. In 1923 Haldane put forward the idea that wind energy can be used to produce electricity which can be used for the elctrolytic decomposition of water to produce hydrogen. Emmen in 1932 patented the idea of using hydrogen to operate I/C engines. The use of hydrogen as an aircraft fuel was foreseen by Sikerski in 1938. In 1956 the National Aeronautics and Space Administration, USA, successfully operated a hydrogen-powered aircraft.

The 1950-60 period witnessed considerable progress in the development of H-O fuel cells for power generation. Hydrogen

as an energy option for the future was seriously considered in the late 1960s. In 1968, Hoffman developed the metal Lydrides for vehicular applications. In 1972, the Institute of Gas Technology, USA, prepared a report entitled "Hydrogen Energy System" which highlighted the hydrogen concept. In 1974 the International Association for Hydrogen Energy was formed. The subsequent World Hydrogen Energy Conferences have generated a good degree of enthusiasm and interest in this subject.

#### *Technical Developments*

The introduction of hydrogen as an energy source on a sizeable scale involves five basic issues:

1. Production;
2. Storage and transport;
3. Usage of hydrogen as energy source;
4. Safety; and
5. Economics and management.

#### *Production*

The following methods are generally considered suitable for hydrogen production.

1. Electrolysis of water;
2. Thermal decomposition;
3. Thermochemical methods; and
4. Photobiolysis.

The first method uses electrical energy to break down water.

The second method uses heat at very high temperatures (73,000°C) to thermally decompose water into hydrogen and oxygen.

The third method uses some specific chemicals like iron, iodine, lithium, cadmium, etc.

Photobiolysis depends on the action of certain catalysts to produce hydrogen from water by the direct action of sunlight at ambient temperature. Though it appears attractive the present efficiency of the system is only about 1 per cent.

#### *Storage and Transportation*

At normal temperature and pressure (NTP) hydrogen is the highest inflammable gas. It can be stored as a gas, as a liquid or as a chemical compound. The density of hydrogen in many compounds of hydrogen called metal hydrides is more than its density in liquid stage.

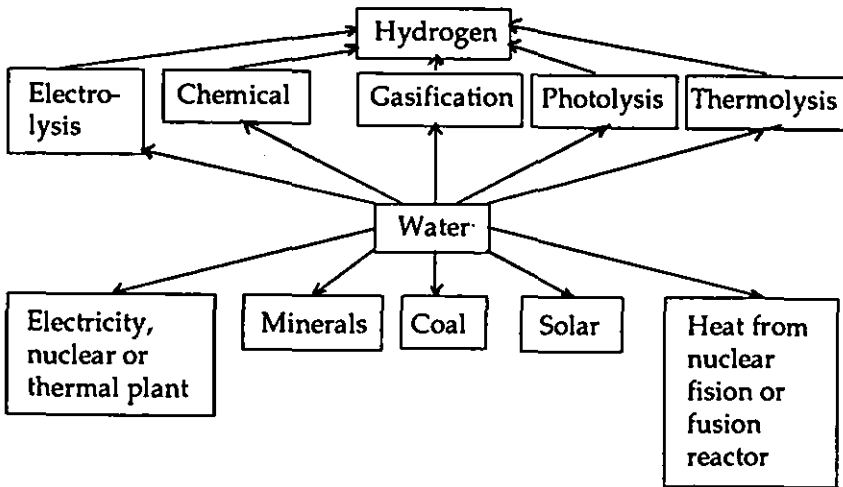
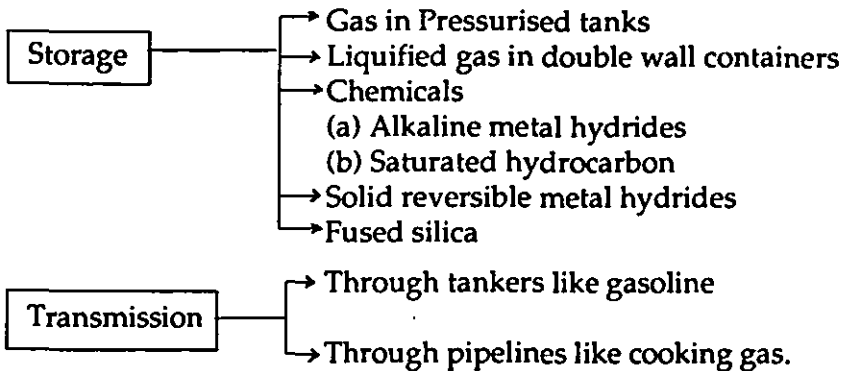


Fig. 2.2: Production of Hydrogen

Source. Maheswar Dayal, *Renewable Energy Systems*, p. 167.



Chemical storage of hydrogen is good for laboratory uses only. Its storage as saturated hydrocarbon needs an additional base material like benzene. Hydrogen storage in the form of liquid is not a safe and economic process. However, it is useful as a rocket fuel most rich in energy. Hydrogen storage in fused silica is a high temperature storage media. The underground storage of hydrogen as a gas in very large quantities is proposed to be made a safe and very economic method. The empty wells of petroleum, oil and gas are considered to be ideally suitable for this purpose.

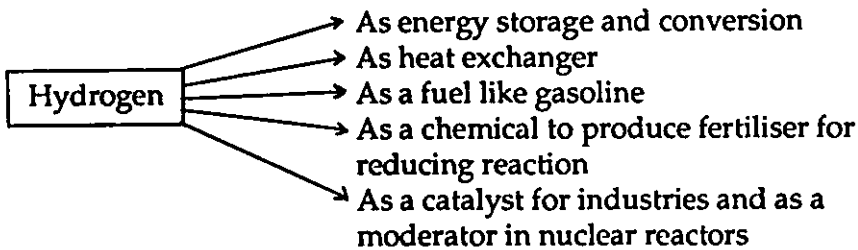
#### Transportation

Hydrogen can be transported as a gas or as a liquid in containers and also through pipelines with much less transmission losses. It

can be transported like cooking gas with some modifications in the pipelines.

#### *Utilisation*

It has been established that application of hydrogen as a direct fuel in automobiles is possible. Its application as energy storage and conversion media has also been proposed and practised as off-peak power storage. Its application as a chemical and a catalyst was realised long ago.



#### *Safety*

On account of its high diffusion and very rapid combustion, hydrogen presents some safety problems. Flame haps, flashback arresters and hydrogen leakage sensors are necessary accessories to hydrogen fuel systems. Additionally, crank cases have to be positively vented to prevent accumulation of explosive mixtures. Bursting diaphragms have to be provided in inlet manifolds.

#### *Research and Development*

1. Solid Polymer Electrolyte Development (SPEED)-Vikram Sarabai Space Centre, Trivandrum, 50 kw demonstration electrolyses module.
2. Bhabha Atomic Research Centre, Bombay.  
The electrolysis plant is designed to electrolyse 20-30 per cent KOH solution at 100-200°C. The capacity corresponds to delivery of hydrogen at a pressure of 21 kg/cm<sup>2</sup>.
3. Solar hydrogen-bio route  
Banaras Hindu University, Varanasi, Osmania University, IIT Madras.

#### *3.9.8. Hydrogen Energy Programme*

Hydrogen is produced easily from water and when burnt in air produces very clean energy without pollution. It is the lightest fuel and richest in energy per unit mass.



However, the use of hydrogen as an energy source involves five basic issues: production, storage, and transportation, utilisation, safety and management and economy. Presently, DNES has 23 ongoing Research and Development projects on the following aspects of hydrogen energy:

1. Production of hydrogen by photoelectrolysis;
2. Production of hydrogen by certain bacterial species;
3. Storage of hydrogen through metal/non-metal hydrides and their hybrids;
4. Problems relating to utilisation of hydrogen as a fuel; and
5. Liquid hydrogen—production, storage and utilisation.

A technical advisory committee on hydrogen energy identifies new areas, monitors the progress of funded projects and recommends new projects for financial support from the department.

### **Wood Fuel**

Ever since human beings discovered fire some 150,000 years ago, firewood has provided them with warmth when it is cold, protection from predators, more digestible food, higher survival rate and colonisation of habitats which were inhospitable earlier. Firewood soon became the principal source of energy and even today 50 per cent of the wood is put to its original use, i.e., fuel. Firewood and charcoal gave way to coal, coal to electricity and since 1859, oil has been the major source of energy.

The pros and cons of developing wood as a fuel are as follows. Wood should be developed as a source of energy because:

1. it is a renewable source;
2. the technology for its production and utilisation is simple and has been mastered by the rural community;
3. wood is a good alternative to oil for cooking;
4. wood is available in and around the villages;
5. planting the trees could help land and water preservation;
6. release of vast quantities (65 million tonnes) of cowdung, at present used as fuel, for use as a biofertiliser to enhance agricultural productivity;
7. being still essentially a local and not an international item, wood does not involve any foreign exchange. Instead, it is likely to help in improving the country's balance of payments by reducing oil imports;

8. Apart from acting as a fuel, it provides a wide range of feed stocks for the organic chemicals industry, which at present is mostly petroleum based;
9. Bioconversion of wood is less energy intensive and involves the higher sciences but not necessarily high and capital intensive technology;
10. Wood is socially relevant, being labour intensive, and having opportunities for generation of employment/income for poorer sections.

The undesirable characteristics of fire/fuel wood are:

1. Fuel wood cannot be utilised immediately after harvesting when it contains about 50 per cent moisture;
2. Drying is rather slow;
3. There is accelerated removal of nutrients and organic matter from the soil;
4. It burns with a long flame and smoke and there is loss of combustion efficiency;
5. Transportation, if required, is costly because of its heavy weight and volume; and
6. Smoke from wood is regarded as a pollutant and is reported to contain even carcinogens.

The increasing demand for fuel wood is the burning issue.

In India 68.5 per cent of energy used in households is in the form of firewood and 64.24 per cent of it is collected from natural sources. For a variety of reasons wood is still the principal source of energy in the rural areas and nearly half of the world's wood production goes into its original use, i.e., cooking and heating.

The Energy Survey of India Committee in the early 1960's reported that about 120 million tonnes of wood, 50 million tonnes of dried dung and 30 million tonnes of vegetable waste were burned every year, largely in the villages and to some extent in urban areas. For example, Henderson estimates that 126 million tonnes of firewood was consumed in 1970-71 of which 83 per cent (0.24 tonne per person) was burnt in rural areas and Data gives a total of 142 million areas. With an energy content of firewood at  $4.4 \times 10^6$  keal per tonne, Henderson's estimate corresponds to a total of  $4.60 \times 10^{14}$  (5 million k wh) of energy supplied annually by burning firewood in rural areas. The energy expended in this is 61.3 million UN equivalent tonnes of coal (138 kg per capita). It increased to 126.5 MTCR in 1975-76 and 43.6 ( $19^{12}$  keal) in 1980-

81. On an average, each person in India uses the equivalent of about 1 kg of wood per day, of which about two-thirds is provided by wood and the rest by crop residues and cattle dung.

*Economics of Fuel Wood: Firewood in India*

Fuel wood is one of the most important fuels for the world's poor. At the international level firewood is used by the people widely for cooking and heating water and other things. From ancient days firewood had been in use. In India fuel wood is an important fuel for the poor, and the firewood trade in India's towns and cities employs millions of people. Firewood is widely used in rural and urban areas because it is low priced and is available anywhere and anytime. Yet energy planners, while acknowledging its importance, have underestimated its prospects.

*Availability of Fuelwood*

More than 90 per cent of fuelwood is obtained from forest areas and formed part of the lifestyle of people in ancient times. In modern days, however firewood is a commercial product. Because of the increase in population firewood consumption has also risen. Fuelwood in India is found most widely in Madhya Pradesh, Jammu & Kashmir, Delhi, Uttar Pradesh, Karnataka, Kerala and east India because these lie in forest areas.

*Demand Pattern*

*Firewood in Rural Areas:* In rural areas millions of people depend upon firewood for cooking and heating water. In India most people in the villages live in poverty. So they cannot afford modern cooking facilities. Firewood is needed by the poor in rural areas because to them it costs nothing.

*Firewood in Cities:* In cities the prominence of fuel is underestimated. If the per capita consumption figures of firewood in urban areas used by the Planning Commission's working group on energy policy are accepted, India's urban population spent Rs. 900 to Rs. 1,000 crores during 1981 on 22 million tonnes of firewood at an average price of Rs. 400 per tonnes. Another 7 million to 8 million tonnes of wood was obtained from trees, worth some Rs. 300 crores in the market.

However, an unpublished National Council for Applied Economic Research (NCAER) study reporting 1973-79 data estimated urban firewood consumption to be only about 16

million tonnes of which 14 million tonnes was purchased, indicating an annual urban firewood market of Rs. 500 crores to Rs. 600 crores.

*Firewood in Delhi:* In most cities substantial amounts of firewood arrive by bullock carts. But in Delhi firewood comes as loaded coal mainly by rail.

At the Tughlakabad railway station 12.423 wagons of firewood, each carrying an average of 18 tonnes, were loaded for sale during 1981-82. Most of the firewood comes from forests in Madhya Pradesh. About 223.600 tonnes of wood were sold at a total price of Rs. 14 crores to Rs. 18 crores to households, roadside restaurants, bakeries and cottage and small industries. The Shahdara railway siding receives two or three wagon-loads of firewood daily from forests in the Himalayan foothills, Assam and Bihar.

The firewood loads delivered at the Tughlakabad railway siding were:

1972-73	-	4,121	wagons
1980-81	-	12,370	wagons
1982-83	-	11,757	wagons

Table 2.7

State/U.T.	Forests millions hectare	% of forest area of geogra- phical significance	Exportable area	Potentiality exportable area
AP	6.512	22.53	4,836	1,676
Assam	4.442	36.38	1,509	200
Bihar	3.059	17.59	1,513	952
Gujarat	1.800	9.18	0.57	-
Haryana	0.142	3.21	1,203	30
HP	2.159	38.78	1,898	447
JK	2.105	9.47	0.108	246
Kerala	1.219	32.66	10.22	224
MP	16.813	37.97	3,820	3,987
Maharashtra	6.696	21.26	2,615	2,471
Mysore	3.510	18.30	0.31	0.895
Punjab	0.202	4.01	2,810	0.791
Tamil Nadu	0.210	16.99	3,462	0.65

*Resolution*

The festival of Holi comes every year, bonfires are lit throughout the country and lakhs of tonnes of wood is burnt. Observing traditions and religious rites is not a bad thing. But when these begin to do harm it is not wrong to break them.

*Consumption of Fuelwood:* It is estimated that in 1973-74 in rural households per capita consumption of energy in the form of firewood was 6 to 8 per cent, while in urban areas it was 45.5 per cent in terms of coal replacement. The share of per capita non-commercial energy is 80 per cent in rural households and 81 per cent in urban households. In terms of value in 1963-64 the consumption of fuelwood to total fuel was 60 per cent in rural areas and 47 per cent in urban areas. In terms of value of consumption of firewood to total household consumption the share was 4.1 per cent in rural households and 2.7 per cent in urban households.

*Expenditure Levels:* The expenditure on firewood in rural areas shows a rising trend, amounting to more than Rs. 800. But the ratio of consumption declines in expenditure level for both urban and rural populations.

*Shortage of Supply of Wood Fuel*

On account of population pressure the demand for wood has outstripped natural regeneration and planting so much so that in some areas there is food to eat but not enough wood to cook it.

With the present level of fuelwood consumption large parts of the forest areas in several countries will turn into deserts. The world forest area is depleting at the rate of 18.20 million hectares per year. Some developing countries have as little as 5 per cent of the total forest area as against the desired level of 33 per cent. Deforestation is now estimated to be reducing the forest cover in developing countries by about 10 million hectares per year. In India the area under forests is estimated to be 23 per cent but recent satellite mapping makes it out to barely 12.14 per cent. The adverse effects this has on the entire agricultural, climatic and economic situation needs no emphasis. Although fuel wood requirement is only one of the reasons for the trend to deforestation (commercial wood use being also largely responsible) requirement for fuelwood is a vitally important factor which is to be adequately catered for.

Although the forest area in developing countries exceeds 1,000 million hectares it is being consumed at such a rate for agricultural settlement that it could disappear within 60 years unless more fundamental changes occur to alter the current trend or unless extensive reforestation programmes are undertaken to offset the losses. Over 90 per cent of wood consumption in developing countries is accounted for by wood fuel. Between 1900 and 1965 about one half of the forest area in developing countries was cleared for agriculture and more than 300 million hectares is currently under shifting cultivation. In the Sahel in West Africa and in parts of Asia, supplies of firewood and woody underbrush are dwindling so rapidly that land is being devegetated.

Natural forests occupy nearly 28 per cent of the land area but about 40 per cent of them are unproductive because of low economic exploitation and lack of industrial infrastructure. Manmade forests are insignificant, covering less than 1 per cent of wood because of their high productivity. The demand may grow to about 8,700 million m<sup>3</sup> round wood.

According to an analysis of the World Bank nearly 10-12 million ha of forests are lost every year and, at this rate, the present-day green cover is estimated to last only 60 years. It would then be too late to mend the fences. Nearly 1.5 billion people in the developing world meet 90 per cent and about a billion more 50 per cent of their energy requirements from wood and charcoal. Thus, half of the world's wood is used for cooking and heating. It is of interest to note that according to FAO and UNESCO estimates, the original area of tropical rain forest of the world was 16 million km<sup>2</sup> but, in 1975 it was only 9.35 million km<sup>2</sup>, i.e., it was reduced by 41.5 per cent. During the same period, destruction of forests in Latin America was 36.6 per cent, South-East Asia 38.1 per cent Africa 51.9 per cent, and in India, Sri Lanka and Burma 63.3 per cent. According to another estimate, by 2000 A.D., forests are likely to dwindle by 20-50 per cent in the developing world and by 0.7 per cent in the developed countries. At the global level, it has been estimated that "in the time it takes to read this sentence, eight acres of forest will disappear, and in India 30 ha of forest area is lost every minute". As stated above, at present 23 per cent of the country's area is under forests in India, but actually less than half of it is under the real forest cover.

In India the shortfall in firewood production by 2000 A.D., has been estimated to be of the order of 137 million tonnes which would require 34 million hectares of land at about four over-dry tonnes of wood per ha/year/and a minimum annual outlay of Rs. 500 crores for years to be made good.

The firewood crisis has led to an increased diversion of demand for dry cowdung as a substitute source, which is a very wasteful one.

According to the Indian National Commission on Agriculture, "the use of cowdung as a source of non-commercial fuel is virtually a crime."

To minimise the problem of wood fuel a multi-pronged strategy has to be adopted. To speed up wood fuel production the following steps should be taken:

1. An appropriate model may be developed for afforestation of degraded soil while taking into account soil, water and ecological factors.
2. High density energy plantation should be prepared, especially for eucalyptus.
3. Energy plantation for promotion of woody biomass on substandard soil may be taken up on the pattern of agricultural production programmes.
4. Research support may be provided for selection of appropriate species suitable for various agro-climatic conditions based on their photosynthetic efficiency and environmental impact.
5. About 93 million hectares of land is lying barren in the country. Keeping in view the energy needs at least 2 per cent of this may be brought under energy plantation programmes and this should be completed with EPP.
6. Attention should therefore be focused upon evaluating biomass of weed parthenium hysterophorus which grows very fast and wild on different types of soil in rural India.
7. Another dimension to the problem is that the degraded lands proposed to be used for biomass production are at present used, free of cost, for grazing. If used for firewood biomass, such lands will have to be closed to grazing immediately. To meet the situation thus created, either tree species with a fodder value will have to be grown or grasses will have to be produced in conjunction with firewood species.

From the consumption point of view the following aspects have to be kept in mind:

1. Destruction of our forests will not stop as long as fuel for cooking is either not provided free to the rural poor or is not made very cheap.
2. Associated with this is the need to evolve and popularise cooking stoves which are energy efficient and smokeless. The smoke itself sometimes contains materials which may be toxic. The smokeless wood burning pragni metal stoves have a better thermal efficiency than conventional stoves, making a saving of about 25 per cent firewood reusable by using these stoves.

#### *Firewood Production and Consumption*

At the national level, consumption of firewood is higher than its production (as shown in the table below). This is mainly because data on minor forest products are generally not satisfactory.

**Table 2.8: All-India Production and Consumption and Value of Firewood, 1972-73 and 1983-84**

	<i>Production</i>		<i>Total</i>	<i>Value of Production (Rs. in crores)</i>	<i>Consumption based on NSSO survey</i>
	<i>Recorded</i>	<i>Unrecorded</i>			
1972-73	117.7	1176.6	1294.3	584.8	1977.1
1977-78	128.9	1288.7	1417.6	1335.2	1745.5
1983-84	98.4	983.7	1082.1	2233.6	1749.7

*Source:* Ministry of Agriculture

#### *Prices of Firewood*

The retail rural price of firewood was Rs. 40.69 per quintal in April 1984. It increased by Rs. 18.85 to Rs. 59.54 per quintal by April 1989. Thus during this five-year period firewood prices increased at the rate of about 8 per cent per annum.

#### **Biogas**

The shortage of fertilisers has created a difficult situation for farmers. Developing countries like India, Pakistan and Nepal cannot buy chemical fertilisers in the international market at the levels they could in the past, because fertiliser prices have



skyrocketed owing to the escalation in the price of oil. Moreover, it is the opinion of agricultural experts that fertiliser in itself is not adequate for cultivation; the soil must be supplied with organic manure along with fertilisers. Organic manure in the form of cowdung has been traditionally used by farmers in India.

The dilemma here is whether the farmer should burn cowdung and satisfy his fuel needs or should use it as manure. Fortunately, there is a solution which will meet both the requirements. Cowdung can be used as manure after fuel energy has been extracted in a biogas generator, commonly known as a 'gobar' gas plant on the Indian subcontinent. 'Gobar' in Indian language means cowdung.

The plant operates on the principle that when cowdung and other organic materials are fermented in the absence of air, combustible methane gas is produced. This method of using cowdung to produce methane gas has been known in India for over 30 years. The extraction of methane gas does not affect the manure characteristics of cowdung in any way. In fact, after the cowdung is passed through the gas plant, the manure is not only rich in nutrients but is also harmless and odourless. It is also free from flies and other sources of infection. The gas produced by the plant burns with a blue flame and without a trace of smell at an efficiency at least five times that of burning cowdung cakes. Thus both improved fuel and organic manure can be obtained from cowdung by using the inexpensive gobar gas plant.

#### *Economics of Biogas Plant*

By using a biogas plant both fuel and manure can be obtained, whereas by converting it into dung cakes or manure only one of the two can be had. It has been seen that both these benefits are obtained to an increasing degree by the use of a biogas plant. For example, in the generation of gas about 25 per cent of the dung is consumed but the useful heat of the gas is about 20 per cent more than the useful heat obtained by burning the entire amount of dung. This is due to the very high efficiency of gas (about 60 per cent) as compared to the poor efficiency (about 11 per cent) of dung cakes. Similarly, the amount of manure obtained through a gas plant is about 40 per cent more than from a manure pit. This is perhaps because the decomposition in a gas digester is selective while in the manure pit it is more rigorous.

The minimum number of animals required for different sizes of plants and costs are shown in the table 2.9.

Table 2.9: Capacities of Gas Plants

<i>Size of plant</i>	<i>Estimated cost (in rupees)</i>	<i>Minimum number of animals required</i>
60	1575	5
100	2075	8
150	2475	12
200	2850	18
300	3675	24
350	4050	30
500	5650	40
700	7450	56
900	8300	72
1250	12300	100
1500	13850	120
2000	17200	160
3000	25200	240
5000	37600	400

*Note:* The prices are based on estimates made in 1973 in India.

The commercial energy consumed in developing countries is overwhelmingly provided by petroleum products.

#### *Anaerobic Fermentation for the Production of Biogas*

The anaerobic fermentation of agricultural and human wastes to produce biogas, which contains a high proportion of methane and has a calorific value of up to 600 Btu/ft<sup>3</sup>, has great potentiality in the rural areas of developing countries. Village-based plants could utilise farm wastes from smaller holdings as well as human wastes more effectively. The technology available is most useful both for its simplicity and for its low cost. A family-size unit would cost between \$200 and \$300 but a family-oriented programme would reach at best about 10 per cent of the rural population. It would seem desirable, therefore, to promote this technology for community use also. Its greatest relevance is that it is capable of producing fuel gas without destroying the fertility properties of farm wastes, crop residues and dung.

There are three principal processes for the conversion of biomass:

Anaerobic digestion;  
Fermentation of alcohol; and  
Pyrolysis.

Now sources of feedstock for all these should be investigated, including crop residues and aquatic plants.

*Biogas Anaerobic Digestion*

This technology is well understood and there is already extensive field experience available, for example, the gobar gas programme in India. However, there should be further research into its microbiological aspects, including the development of new bacterial strains with the objective of reducing the sensitivity of the plant to changes in temperature, PH, carbon/nitrogen ratio and production rate. Chemical engineering aspects also require attention, and an attempt should be made to reduce the overall cost.

*Fermentation of Alcohol*

This is also a well known process, but is confined to starch or sugar. Extensive programmes are being undertaken, particularly in Brazil. There would be some value in developing processes that would permit the fermentation of other carbohydrates.

*Pyrolysis*

The pyrolysis of wood was used extensively in Europe before World War II. There has been a revival of interest in small scale plants for it. This research should be pursued and extended to new uses of other feed stocks.

Five recommended lines of research are:

- (a) Investigation of new feedstocks, including crop residues and aquatic plants;
- (b) Investigation of new microbial strains for anaerobic digesters;
- (c) Study of the chemical engineering aspects of digesters in order to reduce costs;
- (d) Further investigation of the use of carbohydrates as feedstocks for fermentation; and
- (e) Further development of small pyrolysis units.

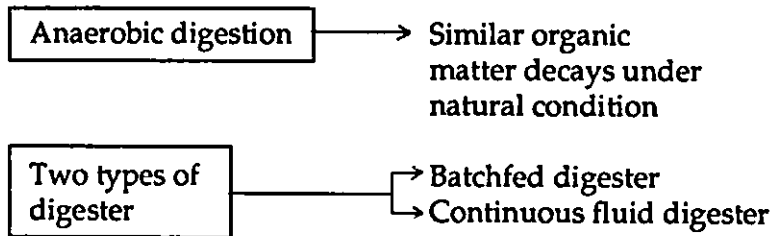
*Technology*

Biogasification involves anaerobic fermentation of organic wastes. The resulting biogas (also known as gobar gas) contains about 60 per cent methane and is useful for agricultural, domestic

and cottage craft activities. Cooking and small scale power generation can also be done through biogas. The residue, a nitrogen-rich slurry, is valuable as a fertiliser.

The technology for the production of biogas is known and reliable, particularly where livestock is abundant. It is widely used by the wealthier farmers in Asia and elsewhere. Problems arise from output variations during the cold season in high latitude and high altitude countries. In addition, costs of construction materials (steel, cement, tubing, gas appliance fixtures, plastic, rubber, etc.) can be an obstacle. Nevertheless biogas is one of the most promising of all small-scale energy technologies. It is most profitable if installed to serve a whole village rather than a single family.

Biogas plants can be made in various sizes ranging from output capacities of 2m<sup>3</sup>/d for a single family to 140 m<sup>3</sup>/d for a community.



### *Anaerobic Digestion*

#### *Three phases*

1. Hydrolysis
2. Acid formation
3. Methane formation

In the anaerobic digestion process acid formation takes place when organic substances are oxidised to acids in a manner that is similar to the formation of formic, acetic and other acids observed in the decay of organic matter.

Certain specific bacteria convert the volatile acids produced in this manure into methane and carbon dioxide. A mixture of these gases is known as digester gas or cowdung gas. This gas generally consists of 30 to 40 per cent carbon dioxide and 60 to 70 per cent methane. Methane-producing bacteria, however, work best in temperatures between 95°F and 100°F. They fail to work below 68°F.

## Phases:

Gas	Biogas	Combustible gas
Liquid	Scum	Fertiliser
	Supernatant	Biologically active
	Digested sludge-spent slurry	Fertiliser
Solid	Inorganic solids	Waste

*Technical Problems Related to Biogas Plant*

1. Handling of effluent slurry is a major problem if the person is not having sufficient open space or compost pits to get the slurry dry.

2. The gas forming methanogenic bacteria are very sensitive towards the temperature compared to those non-methanogenic. During winter as the temperature falls there is decrease in the activity of methanogenic bacteria and subsequently fall in gas production rate.

3. Due to lack of proper training to the biogas plant owners for the operation plant, a lot of problems arise. It has been noticed that many persons increase the loading rate and some also do not try to mix the cattle dung with water, keeping in mind more gas production. Due to this, the flow of slurry from inlet towards outlet is very slow or even stops. This may cause accumulation of volatile fatty acids and drop in PH and then leading to the failure of the digester.

4. Some plant operators add urea fertiliser in large quantities, due to which toxicity or ammonia nitrogen, may cause a decrease in gas production.

5. Leakage of gas from the gas holder, especially in the case of the Senather type of biogas plants, is a major and very common problem. When there is quite enough gas in the gas holder, the leakage should be checked using water and the points marked and got repaired. During repairs, there should be no gas inside the gas holder and the stopcock should remain open until the repaired points get dry. The quality of construction materials used, such as cement, is important.

Much research needs to be done on plant design for improved efficiency, better winter operating performance, use of solar energy to heat the biogas plant, proper utilisation of the sludge output to conserve nutrients, and biogas plant operations in water short regions. Initial breakdowns in administration,

maintenance, or technical components may discourage villages and their neighbours who may become progressively unresponsive to the programme.

It has been observed that gas production goes down in winter months because the temperature is below the optimum for microbial activity. Research should aim at:

1. Isolation of a microbial strain will remain active at low temperatures and evolution of strains which will produce methane instead of the mixture of 55 per cent methane and 45 per cent carbon dioxide as at present;
2. Experimentation with inexpensive additives which will stimulate production of more gas; and
3. Devising of a simple and inexpensive solar heating system which will automatically provide hot water for preparing inlet slurry so as to maintain a higher temperature in the digester.

While the progress achieved in biogas technology in India has been impressive, considerable research and development work needs to be done as outlined below:

1. To work out better and cheaper plant designs using, whenever possible, local or easily available materials;
2. To evolve cheaper designs and materials for gas holders and to improve the efficiency of burners; and
3. To evolve more effective techniques of maintenance.

The general administrative problems include coordination of finance, production, distribution and political activities together with assuring adequate numbers and competence of staff to carry forward the assigned tasks. The success and failure of a biogas plant depends upon the method adopted to start it, controlling and testing its operating parameters from time to time. Some operating parameters, such as temperature, soil concentration, toxic substances like temperature are common to most feedstocks but PH, volatile fatty acids, loading rate, etc., may be different for different influents.

#### *Biogas in India*

The first anaerobic digester in the world was set up in India as early as 1900, but ignored till 1937 when a sewage purification station was set up at Dadar in Bombay.

KVIC has a research centre in Borivili, Bombay;  
NEERI in Nagpur, and a  
Planning Research and Action Institute in Lucknow.

India is one of the pioneering countries in the development and utilisation of biogas from animal wastes. The generation of gaseous fuel from animal dung through anaerobic digestion leads to improved sanitary conditions, availability of a clean fuel for cooking, lighting and even for running engines, reduction of drudgery and improved health conditions for women. Both fixed and floating dome type digesters are being propagated in India through a programme of subsidy and training. It is estimated that fuel equivalent to about 1.7 million tonnes of firewood is being saved annually, thus reducing the pressure on forests.

**Table 2.10: Installation of Biogas Plants in India**

<i>Year</i>	<i>Number of plants installed</i>
1974-75	10,710
1975-76	14,322
1976-77	14,228
1977-78	16,261
1978-79	14,756
1979-80	15,306
1980-81	15,430
1981-82	25,369
1982-83	57,498
1983-84	92,950
1984-85	1,80,430
<b>Total</b>	<b>4,57,100</b>

During 1981-82 over 25,000 plants were set up and in the year 1982 another 11,000 plants were added. Under the National Project for Biogas Development (NPBD), which caters to family-based plants, DNES set up over 3.55 lakhs plants in 1981-85. It allocated Rs. 81.05 crores for technical and training support subsidy to beneficiaries as turnkey job fees to state corporate bodies and voluntary organisations, and as promotional incentives for village functionaries, etc. During the terminal year of the Sixth Plan alone, 1.80 lakh plants were set up, 20 per cent more than the target and 95 per cent more than the plants installed in 1983-84. This has led many people to call it a "brown revolution" taking place in rural areas. The Seventh Plan target was 15 lakh plants.

### *Some Practicalities of Biogas Applications*

1. KVIC has a research centre at Korakendra, near Bombay, where research and development work in various aspects of biogas generation is undertaken. The scientists at the centre have developed burners and lamps which run efficiently on biogas. They have installed an experimental 3 kw electrical gearing set drawn by a dual fuel 5 HP engine operating on 15 per cent diesel oil and 85 per cent biogas. The centre has designed a water heater operating on biogas which has been installed at a laundry in Thana, near Bombay. The heater heats 200 litres of water to 200°F every 20 minutes. Biogas for burning in the water heater comes from a 2000 ft<sup>3</sup> per day plant installed in the laundry compound.

2. Recent developments in electricity production from renewable energy sources show that even in this domain diverse technologies can produce electricity more economically than centralised energy systems. By the application of new technology in the sugar industry, the biogas residue can be used to generate about 2000 mw of surplus power after meeting the power needs of local industry.

3. Apart from biogas plants based on cowdung, the most immediate and practical schemes for biomass relate to the use of municipal and industrial wastes like sewage and distillery effluents. Liquid waste can be biologically processed to yield fuel gas and charcoal. A pilot plant to demonstrate this has been proposed for Bombay.

4. One such sewage-based power plant has already been commissioned at Padravna in Uttar Pradesh. Another was planned with Danish financial aid for Delhi to generate power and process heat. The proposed Rs. 10 crores plant in Delhi would utilise 300 tonnes of city waste daily to generate 3.8 mw of power.

5. Biomass energy consumption levels can be optimised by proper management of fuels and fuel burning devices. Crop wastes can be effectively utilised through gasification as reported by Horsefield and Williams (1978) and Grover.

6. According to a reputed manufacturer, diesel engines can be operated with dual fuels (diesel plus biogas), 80 per cent of the diesel requirements can be served using full supplies of biogas along with 0.2 litres of diesel per hour. This works out at 1.55 m<sup>3</sup> of biogas per hour of engine use (1997 mj/m<sup>3</sup>).



7. A successful biogas programme must be based on a technically sound plant which can function under a wide range of operating conditions.

8. A repair scheme was launched in 1985-86 for revival of old plants that had developed structural defects. Up to Rs. 500 per defective plant is given as grant for rectification purpose. The scheme has helped in strengthening the confidence of the beneficiaries.

The National Project for Biogas Development (NPBD) was introduced in 1981-82. Biogas is a cheap and convenient cooking fuel and also helps in raising agricultural productivity, generating additional employment for masons and other workers in rural areas.

#### *Target and Achievements*

During the first five years—1985-86 to 1988-89—of the Seventh Plan over 7.3 lakh biogas plants were set up, compared with the target of 5.7 lakh plants. For 1989-90, a target for setting up 1.60 lakh biogas plant was fixed with an outlay of Rs. 57.50 crores. During April-December, 1989, about 74,000 plants were set up as against the target of 64,000 plants, showing an increase of 15.6 per cent. According to reports received from various agencies the target was expected to be achieved during 1989-90.

#### *Institutional Finance*

The involvement of financial institutions is essential for the implementation of NPBD because in the total construction cost, apart from partial subsidy, the remaining cost is met by the beneficiaries either through bank loans or through their own resources. DNES has also been maintaining close liaison with the National Bank for Agriculture and Rural Development (NABARD), the Reserve Bank of India (RBI), and the Department of Banking of the Union Ministry of Finance to ensure a smooth flow of funds. As per the RBI directives, the banks do not insist on mortgages or any securities for loans up to Rs. 10,000 for the construction of biogas plants.

#### *Achievements*

During the past 15-year period ended 1989-90 (up to February 1990) over 12.4 lakh biogas plants had been set up in the country. The average capacity of a plant is to generate 4 cubic metres of gas per day. Assuming that 85 per cent of plants worked for 300 days

in the year 1989-90, these plants produced an estimated 1,265 million cu. mt. of gas equivalent to 3.72 million tonnes of fuel wood valued at Rs. 149 crores per year. Besides, these plants also produced 21.08 million tonnes of enriched manure per year valued at Rs. 174.5 crores.

### **Urjagram Programme**

Urjagram projects are based on a combination of locally available non-conventional energy sources such as bio-energy, solar energy, wind energy, etc, and are aimed at making villages self-reliant in energy. The projects take into account energy requirements not only for basic domestic needs but also for agricultural operations, cottage industries and community facilities. The programme also includes the evaluation of technical performance studies of integration of various systems and socio-economic aspects.

### **Improved Chulha**

A National Programme for an improved chulha was launched in December 1983. It forms a part of the Minimum Needs Programme of the government, and by now it has reached almost throughout the country.

### *Target Groups and Priority Areas*

This programme covers all categories of beneficiaries in rural, semi-urban and urban areas on the following priority basis:

1. Scheduled Caste areas and households (20 per cent of the target).
2. Scheduled Tribe areas and households (10 per cent of the target).
3. Hill areas, north-eastern region and islands.
4. Areas experiencing serious deforestation and fuel scarcity.
5. Semi-urban and slum areas.
6. Community kitchens of hospitals, hostels, military and paramilitary forces, religious and charitable institutions, dhabas, hotels, etc.
7. Commercial and industrial establishments using wood as a fuel.

### *Types of Chulhas under Propagation*

The improved chulha programme envisages implementation of fixed and portable models of chulhas. Such models are constructed by using local clay/chimney, pottery or ceramic

lining. The minimum thermal efficiency of fixed and portable models are 20 and 25 per cent respectively as against 5-10 per cent thermal efficiency of the traditional chulhas.

#### *Targets and Achievements*

The targets and achievements of the improved chulhas programme are given in Table 2.11. It shows that since the inception of the programme, achievements are higher than the targets fixed.

**Table 2.11: Improved Chulha: Targets and Achievements**

*(Numbers in lakhs)*

<i>Year</i>	<i>Targets</i>	<i>Achievements</i>	<i>Surpassing Targets (%)</i>
Dec. 1983 to March 1985	5.00	8.12	62.4
1985-86	10.00	11.22	12.2
1986-87	6.50	9.5	39.2
1987-88	12.00	15.18	26.5
1988-89	15.00	18.33	22.2
1989	11.76	11.88	1.0
Jan. 1990			

The actual average fuel saving of each improved chulha is over 700 kg of wood and wood equivalent per year. According to the Department's estimates, by the end of 1989-90, about 80 lakh improved chulhas were functioning in the country. Total showing was estimated at 56 lakh tonnes of wood—wood equivalent to Rs. 224 crores.

#### **Animal Energy Programme**

Farmers with small land holdings depend on animal and human power for their agricultural operations, rural transport and allied activities. The number of draught animals in the country is estimated at 80 million. On an average, a draught animal has a capacity to generate half a horse power of energy. Thus the total power generation may be put at 40 million HP. Production and distribution of power of this order would require an investment of Rs. 30,000 crores. It is estimated that draught animals contribute 6-10 per cent to the country's GNP.

## Energy from the Waste and its Economic Basis

### *Disposal of Toxic Wastes*

The discharge of very toxic materials can occur in the gas given off when substances such as chlorinated and aromatic solvents, pesticide residues, phenols, and polychlorinated biphenyls (PCBs) are incinerated. Even municipal incinerators handling domestic wastes have been shown to discharge measurable amounts of highly toxic, persistent substances such as chlorinated dioxins in the off-gases.

Strathclyde University in Scotland has been developing a Dc Plasma heater that can meet not only organics also but inorganics, toxic gases and tumours. In this plasma pyrolysis system the plasma is formed inside two hollow cylindrical electrodes lying on the same axis with an arc burning between them.

The electrodes are water cooled and the arc root, associated with the sealed end, is rotated at a high speed by means of a magnetic coil. The plasma produced by the arc rotation has a uniform temperature of around 6000°C.

The inventor of the heater, Dr. Leslie Campbell, an electrical engineer, has concentrated on the plasma system, including the plasma torch and electrical elements, to produce a gun with a longer life—a magnetically driven arc that has an electrode life of 200 hours.

Dr. Campbell believes there are a number of outlets for this technology, especially in view of the high cost of the market associated with toxic wastes, where conventional incineration costs can range from 20 to 100 times the cost of land tilling operations. The plasma flame can be used to dissociate toxic material passing through it, and these dissociated molecules combine on cooling to form simpler compounds. Small-scale units can handle quantities in the one tonne per week range, and the next stage, says Dr. Campbell, is to build a pilot plant to prove the viability of the process.

Another new method has been developed by the technology division of the UK Atomic Energy Authority (UKAEA) at Dounneay in Scotland. It is designed for wastes that are particularly troublesome and explosive to destroy by incineration.

Based on a silver salt/nitric acid membrane electro-chemical cell, this electro-chemical oxidation process destroys hazardous

organic waste. It is a spinoff from research and development work being carried out on the dissolution of plutonium oxide (PVO<sup>2</sup>) in nitric acid, which is normally difficult to achieve without the use of particularly strong acid mixtures.

As part of the programme, a simple electro-chemical cell was constructed in which a solution of silver nitrate and nitric was placed in the anode compartment, and nitric acid in the cathode one. This demonstrated, by the presence of an electric current, that the intractable plutonium oxide residues dissolved readily and rapidly.

#### *Sludge Power*

Sewage sludge as a power generation fuel may soon be an option with a new drying process developed in Britain. The UK Water Services Association has said the Bradshaw Hardley Company from Blackburn in northern England had taken a step towards making sludge power feasible by using Mechanical Vapour Recompression (MVR) to dry the sludge. The aim is to use less energy drying it than is used when the sludge is burnt (British Information Services).

#### *Energy Recycling through Expansion Turbines*

One of the highly developed energy saving technologies available involves using expansion turbines originally applied in refrigeration technology.

Gases when exposed normally cool down, provided they perform a "job" in the process such as moving a piston or a turbine wheel. This effect can be used in a different form to cool equipment, an area where the expansion turbine is a recent development. When operating such a turbine, the gas to be cooled must be condensed first and the heat released in the process removed. It is then introduced into a ring of guiding nozzles and on the turbine wheel.

Engineers used to build axial turbines in which the bladed wheel that received the gas runs parallel to the axis as it does in steam turbines. Now, the so-called "radial turbine" has invaded the market. Its blades are bent because the gas steam directed at them originates from the radius. They then channel the gas directing it to the canal point of the axis outward so that it paves the turbine parallelly to its axis.

So long as the adjustable nozzles that embrace the turbine wheel, the size and geometry of the blades, and the number of the

revolutions coordinate with each other in an optimal fashion, efficiency rates up to 90 per cent can be achieved. In the process the expanding gas cools sufficiently so that it is possible to liquefy it simultaneously.

Expansion turbines have been used for expanding natural gas, first at the production site directly at the borehold where the gas is often emitted in large quantities and at pressures of up to 200 bars. If directed through an expansion turbine it cools down so rapidly that all crude oil remnants are "frozen". The natural gas is thus cleansed of undesired higher hydrocarbons. If a generator is hooked up to the turbine, the process can be exploited to produce electrical energy.

Natural gas travels through the long-distance pipelines at pressures of up to 80 bars. Consequently, this pressure should be reduced twice before the gas is fed into households for final consumption. As a first step, the reduction is between 16 and seven bars for transport within the regional networks. It is then lowered further to travel in the community networks at pressures of between 2 and 1.5 bars.

A facility of this kind in use in Italy reduces pressures from 12 to 1.5 bars producing in the process approximately 1.5 mw of current. German experts are certain that expansion turbines will dominate the field of energy recycling.

This technology has immense application possibilities. A large number of technical processes produce relatively sizeable amounts of gases with high pressures and temperatures. In the simplest cases, these gases can be used to produce electricity.

One promising area of application is compression of waste steam to a pressure level that will allow its recycling into a plant's steam systems. Experts base their expectations on two facts. First, many facilities boast of extensive steam systems; second, a bill is expected to be passed that will establish binding requirements for technical industries to use heat energy in the interests of environmental protection.

### *Green Factory*

One way to reduce pollution and protect the environment is to conserve and recycle raw materials. Here, at a new factory on the outskirts of Sheffield, in the UK a range of measures have been introduced to limit the release of damaging byproducts into the environment.

The "Green" factory has been built by SK7 and Dormor Tools, operating in conjunction with the city's "partnership in action" programme. The company has incorporated in the design of the factory effluent monitoring equipment to ensure that waste products are rendered harmless before they enter the area's sewerage system. In addition, an advanced washline has been introduced which removes the need for solvents, such as trichloroethylene. There is this new bulk oil cooking and cleaning system which enables swart and grinding material to be dumped into skips for reclamation by an outside contractor.

Capable of supplying the plant with 4.600 litres/min of oil, the oil cooling and cleaning system gives a longer machine life as well as conserving raw materials. Oil is pumped through pipes laid in ducts in the factory floor to the grinding machines and it returns laden with particles of swart which are removed in the main tank. Earth filters and other equipment enable the oil to be cleaned and used again. Similarly, the swart is removed and dry waste material dumped in skips.

*Waste Recycling and Resources Recovery Systems (WRRRS)*

The objective of Waste Recycling and Resource Recovery Systems (WRRRS) Programme is to maximise recycling organic wastes available in rural areas and to provide essential services and to generate higher economic benefits for the community. The WRRRS Programme includes the setting up of a biogas system besides laying emphasis on comprehensive utilisation of slurry for manure, fish farming, mushroom cultivation and crops. Besides cooking, the surplus biogas is used for decentralised small-scale power generation, lighting, running flour mills, water pumping for drinking irrigation and milk Chillo, etc.

Under this programme, 730 projects have been sanctioned so far. Of these, 500 have been completed comprising 250 community biogas plants, 240 institutional biogas plants and 10 night soil based biogas plants. Another 230 projects are at different stages of implementation in different states.

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## ECONOMICS OF ENERGY AND ENVIRONMENTAL IMPACTS

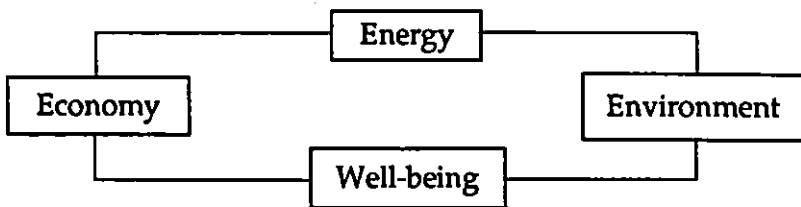
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Energy is the keystone of human life and prosperity as well as a vital component of environmental rehabilitation. Energy is the ultimate resource and, at the same time, the ultimate pollutant. The remarkable growth of the human population and the development of civilisations can be attributed largely to the singular progress of our species in learning to harness natural flows and accumulations of energy and turn them to human ends.

Yet no means of harnessing energy—and no means of applying it—is completely free of adverse environmental impacts. The impacts manifest themselves at all stages of energy processing, from exploration to disposal of final wastes.

It is the dichotomy between energy's roles as an ultimate resource and as an ultimate pollutant that generates the deepest of the dilemmas that make up the energy problem.

These two roles of energy—and the associated dilemmas—are represented schematically in the following figure.



Energy exerts its influence on human well-being through the economy and the environment. Energy's contribution to the production of goods and services in the economy exerts a largely positive effect on well-being. The adverse effects of the



production and use of energy on the environment damage human health directly as well as undermining environmental services that support the economy.

On the expansion of any particular technology and in the expansion of civilisation's energy use as a whole, a point must eventually be reached where the benefits to well-being of additional energy to the economic side of the relationship are not nullified by the damage to well-being caused by the environmental impact of making the extra energy available.

Whether the rate of energy use is growing constant or shrinking the question of what technologies are used to provide energy is critical. Besides, the decisions regarding energy options require comprehensive environmental analysis.

The major environmental impacts of various energy systems are summarised in Table 3.1.

The environmental impacts of production of various forms of energy are given below:

### **Coal**

Coal is mined either by surface or underground methods. Surface mining often leads to acid drainage and silt run-off which degrade water quality. Strip mining can result in serious erosion if adequate plant cover is not available to hold the soil, especially when water is permitted to run off the site from roads and slopes. Erosion causes deposits of sediment in channels, thus reducing the capacity of lowland streams to carry flood waters. Surface mining has contributed to landslides and floods, degraded fish and wildlife habitats, impaired scenic values, and counteracted efforts to conserve soil, water and other natural resources.

Underground mining can also have an adverse impact on the environment. It often results in acid drainage and can cause land subsidence over mined-out areas unless systems are designed to prevent the deterioration and failure of abandoned mine pillars. Some 1,850,000 acres of land in the US has been affected by subsidence due to the underground mining of coal.

About 30 per cent of all coal is transported directly from the mine to the user. The rest is washed to reduce the inorganic and ash content, producing about 90 million tonnes of waste annually. If not returned to the mine, the residue can accumulate in piles which may ignite and burn for long periods, creating an air pollution problem. Rain waters can leach salts and acid from the

**Table 3.1: Environmental Factors Related to Energy**

<i>Environmental element affected</i>	<i>Types of impact</i>	<i>Pollutant</i>
<i>Air</i>	Chemical-Physical	Carbon dioxide
		Carbon monoxide
	Radiological	Sulphur oxides
		Nitrogen oxides
Resource use	Hydrocarbons	
	Photochemical Smog	
Other	Resource use	Particulates
		Organics
	Other	Trace metals
		Noble gases
<i>Water</i>	Chemical-physical	Particulates
		Oxygen
	Radiological	Helium
		Thermal inputs
<i>Land</i>	Chemical-physical	Electromagnetic emissions
		Noise
	Radiological	Oil spills
		Acid mine drainage
Resource use	Tritium	
	Other effluents	
<i>Land</i>	Thermal	Uranium milling wastes
		Thermal inputs
	Chemical-physical	Acid fallout from the air
		Mineral fallout from cooling waters
	Radiological	Solid wastes
		High-level wastes
	Resource use	Land subsidence
		Strip-mining of coal
		Land use for power production and transmission
		Hydroelectric dams
Land use for sludge disposal		

piles to contaminate nearby streams. A major hazard to underground mines, in addition to accidents, is black lung disease. The disease impairs respiration by scarring and deforming lung tissue because of inhalation of coal dust. There is no cure; the disease can be prevented only by reducing levels of coal dust in the mines—principally by better ventilators and water spraying.

#### *Processing of Coal*

More than half the coal produced in the United States is cleaned before combustion or further processing in order to reduce the content of ash and inorganic sulphur. The environmental disruption from cleaning coal includes significant atmospheric pollution in the form of particles, water pollution (black water) and the production of solid wastes.

The motivation for processing coal further is of twofold.

1. To remove sulphur completely since it is a particularly dangerous pollutant if it reaches the atmosphere when coal is burned in electric power plants, and
2. To convert coal into practical substitutes for petroleum and natural gas in applications other than electric power generation. Gasification and liquefaction of coal are technologies that in different variations can serve this purpose. Solvent refining is a technology not unrelated to liquefaction but it has the sole purpose of producing a relatively clean fuel for generation of electricity.

#### *Coal Gasification*

Coal is likely to remain the dominant fossil fuel for generating electricity in the immediate future. One means of reducing the extent of the environmental problems arising from coal production and use in the gasification of high sulphur coal is to produce a low sulphur gas. Because of the inefficiencies of converting coal into gas, a conventional gas fuel power generator would make this system less efficient than the direct combustion of coal. In this context, thermal pollution can be significant because the conversion of coal into pipeline gas is only about 65 per cent thermally efficient. Disposal of coal ash from the processed coal is also necessary. The gas produced would be essentially free of sulphur having only a few parts per billion. The net environmental benefit would be a reduction in sulphur oxides and particulate matter discharged into the air. Although air

pollution is reduced, coal use would increase with its mining impacts and waste disposal problems.

A typical coal gasification plant of 250 million tonnes daily capacity would consume about 6 million tonnes of bituminous coal annually with 100 gal of water per minute required for circulation, of which 20,000 gal would be consumed. Special precautions would be necessary to prevent discharging water soluble contaminants such as phenales.

### **Oil**

Onshore oil production, except for accidental occurrences, does not present any difficult pollution problem. Nearly 3 bbl of brine must be disposed of for every barrel of oil produced. Environmental degradation resulting from offshore production causes the serious oil leak a more difficult pollution problem, although much progress has since been made in preventing and controlling oil pollution from spills and blowouts.

### *Oil Refining*

Refineries themselves have significant effects on the environment. They emit substantial amounts of a wide variety of hydrocarbons of both air and water which are variously odorous, unsightly toxic, carcinogenic or combine these features. Refineries and the associated storage facilities also represent possibilities of major fires which, if combined with adverse weather conditions that confined the combustion products in a highly populated area, would have serious public health consequences.

### **Natural Gas**

Natural gas extraction in many ways is similar to oil production with fuels often taken from the same well. Gas extraction on land affects some acreage through the use of drilling rigs, and also produces brine posing a disposal problem.

Pipelines having extensive rights of way then transport the gas to processing facilities where impurities are removed resulting in some air pollution.

### **Nuclear Fission**

Nuclear power has already produced some of the stronger environmental actions to date. Public controversy over thermal pollution radioactivity releases, wastes disposal and nuclear accidents promises to grow more vociferous in the coming year with the nuclear industry undergoing much closer scrutiny.

Uranium, mined by either open-pit or underground methods, creates problems similar to those involved in mining coal, only a much smaller scale. Because of the high potential energy content of nuclear fuels relatively little land is affected.

In processing uranium ore, some of the potentially hazardous radioactive elements or isotopes, particularly Ra-226 and Th-230, are partly dissolved during the leaching operation used to recover uranium oxide.

While a coal miner is exposed to black lung the underground uranium miner is exposed to radon gas, a member of the radioactive decay chain leading from Uranium-238. The radon seeps from the walls into the air in the mine, where it is inhaled. As a gas it is inhaled again but the radon atoms that happen to undergo radioactive decay while in the lungs deposit there the solid radioactive daughter, Polonium-218. Polonium-218 and its daughter Lead-214 are both called radon daughter and have been responsible for lung cancer among uranium miners about four times the number of such cases in the rest of the population.

At a Light Water Reactor (LWR) power plant fission energy is released in the form of heat and transferred to a conventional steam cycle which generates electricity. Because of coolant temperature limitations in the LWRs, their thermal efficiency is lower than that of modern fossil fuelled plants. Due to their lower efficiency and absence of hot gaseous combustion, products are released through the stack.

The spent fuel containing highly radioactive fission products is stored at the reactor for several months while the radioactivity decreases. It is then transported to a reprocessing plant where the fuel is chemically treated to recover the remaining uranium and some plutonium. In the entire fuel cycle radioactive emissions into the air are greatest from the reprocessing plant.

### **Nuclear Fusions**

Fusion offers the potential for significant environmental and safety advantages compared to fissions in many respects.

The fuels and reaction products of fusions are non-radioactive except for tritium. Being a fuel it can be burned up and need not become a waste management problem.

The environmental promise of fusion relative to fission is even greater if one considers the possibilities of clever designs that minimise the opportunities for neutrons to come into contact

with structural materials and the possibility of harnessing fusion reactions more difficult than DT which produce fewer neutrons.

#### *Hydroelectric Power Systems*

These may cause environmental degradation through the destruction of natural scenic values, fish and wildlife habitats and deterioration of water quantity.

#### *Coal Burning Power Plants*

The most visible air pollution from coal burning power plants is particulate matter. The substance widely regarded as the most dangerous air pollutant emitted by coal burning power plants is sulphur in the form of sulphur dioxide (SO<sub>2</sub>) and the more oxidised sulphur trioxide.

#### **Geothermal Energy**

Geothermal steam or superheated water is naturally produced when the earth's heat energy is transferred to sub-surface water from rocks in the earth's crust. Geothermal energy sources are beginning to be exploited on an increasing scale. Recent explorations have revealed that this resource is more extensive than had been supposed and that there is evidence that reserves of steam, and not hot water, are widespread in the earth's crust. Where the pressure and temperature are adequate, the steam output may be used in turbines for conversion to electricity.

Most of the environmental effects of geothermal energy are local because it must be used near its source. At the site, up to several thousand acres are used for extraction wells. The sound of the steam issuing from the well-head is usually rather loud, presenting a noise pollution problem. Geothermal wells also release gaseous pollutants, such as hydrogen sulfide. Waste water discharge may pose a problem because the geothermal stream power plant condensate contains traces of harmful chemicals such as boron.

Other problems arise in the disposal of geothermal energy because of its mineral content which can be as high as 30 per cent. These materials can corrode or solidify and block the pipes and turbines. Once through the turbine, the condensed water is often too full of contaminants to be dumped into natural streams or lakes. Trails at several fields have shown that the contaminated effluent can be injected back into the field without reducing production. Problems may be encountered when the saline and

siliceous solids precipitate out as water temperature and pressure drop making this injection more difficult. Although the reinjection of water into faulted areas would relieve the stresses and reduce the possibility of land subsidence used by the removal of large quantities of fluid, seismic activity is possible.

### **Oil Shale**

Oil shale production requires extraction by underground or surface mining, more like mining coal than drilling for petroleum. This is followed by heating or retorting to produce crude oil, or the shale could be heated *in situ* and then withdrawn by drilling as with crude oil.

At the midpoint in the lifetime of a 1,000 MW power plant, surface mining of oil shale would disrupt an estimated 1,000 acres. If underground mining without back filling were employed, about 2,000 acres would be affected; but if 60 per cent of the spent shale were returned to the mine, the possibility of subsidence would be greatly reduced and less than 300 acres would be affected by the excess spent shale. Use of an *in situ* process would minimise the amount of the land disrupted.

The retort process would produce significant amounts of hydrogen sulphide. It would also produce extensive solid waste byproducts, the volume of which, before compaction, is 50 per cent more than the in-place shale. Because the solid waste is far less adverse than the shale and cannot be readily compacted, only 60 to 80 per cent can be returned to the mine.

Retorting spent shale disposal and shale oil upgrading would use large amounts of water in a region where water is already scarce. Producing enough oil for a 1,000 MW power plant would require almost 1.5 billion gal of water annually—primarily for spent shale disposal. Surface disposal of the spent shale could lead to the leaching of salts which could contaminate surface waters. The retorting also discharges water containing organic and inorganic pollutants, increasing the water pollution problem.

One benefit of the residual oil that could be produced from shale crude would be its low sulphur content. Thus, air pollution at a power plant would be reduced.

The development of shale oil holds promise of greatly increasing domestic oil resources, but environmental and water supply problems remain major obstacles.

**Tidal Power**

The renewed interest in tidal power systems stems from their environmental advantages. They produce no harmful wastes, cause only minor scenic and ecological disturbances and are inexhaustible. Though not economically feasible at this time tidal energy is another future source which could reduce the environmental consequences of power generations.

**Solar Energy**

The environmental characteristics of direct use of solar energy seem preferable to those of other technologies, but the solar option is not entirely without significant impacts. For example, materials requirements for covering large areas with collectors will be significant and extracting and processing those materials will produce some environmental disruption. Extensive land use itself pre-empting other uses is a significant effect. Installation of large solar electric plants in sunny areas would probably encourage extensive industrial and residential activities. And there will be waste heat. Although much of the solar energy collected would have been converted into heat on the earth's surface by natural processes, solar technology somewhat increases the heat burden because a collector absorbs more and reflects less than the natural surface. Also there would be a redistribution of energy in so far as energy was collected, say, in the desert and then used in cities elsewhere.

**Environmental Effects of Energy Consumption**

The main effect of energy consumption is concerned with fuel residues, conversion efficiencies and the rejected heat. The interaction of energy used with the components of the biosphere, the hydrosphere, the atmosphere the ecosphere and the sociosphere is to be considered. These effects determine the level of air pollution, water pollution, chemical and radioactive pollution.

*The Atmosphere*

Besides conversion losses, all energy after degradation is released as heat into the atmosphere. The conversion efficiency of fossil fuels, notably that of coal, is about 35 to 40 per cent. The rejected energy in the form of waste heat is dumped on to the atmosphere, acting as an external heat sink. The residuals of combustion of fossil fuels are also released into the atmosphere. These mainly



consist of oxides of carbon, nitrogen and sulphur and petroleum hydrocarbons. These constitute air pollution.

The thermal energy exchange in the biosphere depends upon the carbon dioxide content and the water vapour content to maintain the necessary temperature limits for life support. It has been calculated that if all the existing world resources of fossil fuels are consumed (about 27 Q) the CO<sub>2</sub> (carbon dioxide) released will raise the atmosphere temperature by 7.5°F. If such temperature rise takes place the polar ice will vanish flooding the coastal cities and the plains.

### *The Hydrosphere*

Atmosphere and hydrosphere are viewed in the same perspective. The waste heat dumped into the atmosphere vaporises the moisture and it is this moisture which acts as the heat sink. The cooling water requirement for waste heat has become increasingly critical. Nearly 50 per cent of water that is utilised is consumed by industry, 90 per cent of it for cooling purposes. The heated water thus used remains with the cold surface and this raises the temperature of the cold water source. This is termed 'Thermal Pollution'. In atomic power plants with lower conversion efficiencies compared to that of fossil power plants, this problem of thermal pollution is more serious. The cooling towers introduce large quantities of water vapour and this produces fogging and excessive local rainfall. For example, the temperature raises from a 500 MW nuclear power plant in a river whose flow is 10 M<sup>3</sup> per second can be 8°C to 10°C. The heated waterways may have considerable effects on the flora and fauna, particularly on fish life, mainly because of the lowered oxygen content in the hot water.

### *The Ecosphere*

Chemical pollution is assuming alarming proportions in certain areas. Industrial effluents contain toxic materials such as lead, mercury and cadmium, which are harmful to plant and animal life. The extensive use of insecticides, fertilisers and detergents, all products of high energy technology, leave behind chemical pollutants which find their way to the human body through the food and water chains. Cadmium release results from nickel plating, manufacture of cadmium salts, incandescent light filaments, ceramic coalings and so on. Cadmium, along with heavy metals such as zinc and lead, is absorbed by the vegetation

and when used in the form of sprays is deposited on plant leaves and destroys microflora, leaving space for occupation by harmful fungi. This may be harmful to plant life in the long run.

If we consider radioactive pollution, large quantities of radioactive wastes, which are lethal, are produced by nuclear power plants. First, liquid wastes contain such longlife neucleides as strontium 90, iodine and other noble gases, plutonium and its isotopes.

If even very small quantities of Strontium 90 find their way to drinking water sources, the radioactivity released would be lethal. The biological and genetic effects of exposing living tissue to low levels of radiation over prolonged periods are also uncertain. Many psychosomatic ailments can be traced to radiation exposure.

Secondly, if some accident like explosion or seismic disturbance occurs at an atomic power plant which has been operating for some time, large quantities of stored radioactivity will be released which will be highly dangerous.

Thirdly, safeguarding of nuclear wastes over periods of time such as 800 to 1,000 years, which is necessary, brings in problems of longevity of social institutions. The nuclear option as an energy is severely limited by these constraints. No satisfactory method of permanent disposal of high-level wastes from the nuclear fuel cycle has yet been found.

### **Environmental Effects of Energy Storage and Transmission**

Energy is easy to store in the form of fossil fuels, and its transportation by various means—trains, bogies, pipeline tankers, trucks—is generally technologically straightforward, if not always cheap or environmentally benign. Electricity is generally more expensive to transmit than moving the amount of fuel required to make the electricity and electricity is much more difficult to store. The environmental impacts of overhead transmission comprise the use of significant amounts of land, the unsightliness of towers and wires in scenic areas and the effects of the strong electric fields that high voltage lines produce in their vicinity.

### **Environmental Effects of Energy Transport**

Refined residual oil is usually transported directly to a power plant by bogie or tanker. Transfer operations can result in oil spills and water contamination occurs if tankers discharge oil

during bogie and tank-cleaning operations. Discharge of oil during routine operations and pre-emption of land and the concomitant loss of other environmental services owing to the construction of pipelines and port facilities for tankers are caused by the transportation of oil over long distances.

### **Conclusion**

Energy systems must be evaluated in the light of their impact on the total environment in all aspects of their respective production methods and uses. As more and more air and water pollution control devices are employed, air and water emissions will be reduced considerably, but increasing amounts of solid waste will be generated. More land will then be needed for the disposal of this waste, which will reduce the net effects of reclamation of mined-out areas.

Although with controls damages resulting from air and water pollution are much less severe the need to avoid, unintentionally, shifting of environmental problems from one medium or location to another must be recognised.

Finally, much of environmental damage from the use of energy lies in the systems which provide it to the consumers. If these systems were to function more efficiently, the adverse environmental effects of energy production would be lessened.

Similarly, if less energy were to be expended on achieving desired ends, energy production and environmental damage would be reduced. It is most necessary that the environmental impacts of various energy policies and of new energy technologies be considered to meet reasonable energy demands without significantly harming the environment.

As Gandhiji said, "There is enough for everybody's need but not for anybody's greed." It is the acquisitive greed of man which, through its violence and plunder of nature, has brought humanity to the brink of disaster. It is not the lack of physical resources that haunts man but the lack of moral resources. Gandhiji's idea of trusteeship should be practised in our relationship with our environment which is the only way to avoid a crash into the ecological ceiling.

**Table 3.2: Energy Resources and Reserves in India**

Source	Proven recoverable reserves		Quality reserve and add. resources in place			Million tonnes coal equivalent proven	
						Reserves	Resources
Coal	13.4 x	10 <sup>9</sup> tonnes	85.8 x	10 <sup>9</sup> tonnes	13.4 x 10 <sup>3</sup>	85.8 x 10 <sup>3</sup>	
Oil	0.29 x	10 <sup>9</sup> tonnes	1.62 x	10 <sup>9</sup> tonnes	580	3240	
Natural gas	162 x	10 <sup>9</sup> m <sup>3</sup>	418 x	10 <sup>9</sup> m <sup>3</sup>	292	752	
Hydropower			216 x	10 <sup>9</sup> kwhr		120.10 <sup>3</sup>	
Firewood			216 x	10 <sup>9</sup> kwhr		120.10 <sup>3</sup>	
Animal dung			120 x	10 <sup>6</sup> tonnes		114	
Agricultural waste			210 x	10 <sup>6</sup> tonnes		84	
			25 x	10 <sup>6</sup> tonnes		24	

Source: Dr. N.L. Ramanathan, "Environmental Considerations and Energy Planning in India," *Urja*, May 1981, p. 297.

**Table 3.3: Forecast of Energy Demand 1981-2000 A.D.**

Energy Form	Units	1982-83	1992-93	2000-2001
Coal	Million tonnes	26.8	170.0	266.0
Oil	Million tonnes	25.2	37.0	54.8
Electricity (at consumer level)	TWH	128.3	241.0	395.6

Source: *ibid.*, p. 298.

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## RESOURCE DEPLETION AND AN APPROPRIATE POLICY TO MINIMISE IT

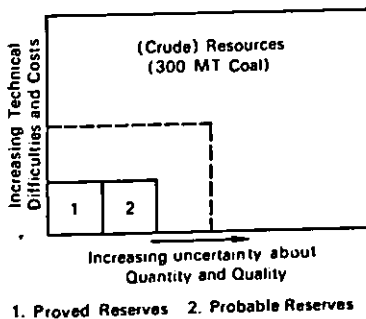
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### Introduction

One can distinguish the term "reserves" from the term "resources". The term "reserves" generally means material whose location is known or inferred from strong geological evidences and which can be extracted with known technology under present economic conditions. "Resources" as a substance include the reserves as well as the material whose location and quantity are less well established and which cannot be extracted under the prevailing technological and economic conditions. In other words, "resources" mean the resource endowment of a country. Ultimately, recoverable resources are proved estimates of material that have to be found out and extracted.

### The Relation between Reserves and Resources

The relationship can be explained with the help of the following diagram:



**Fig. 4.1: Relationship between Resources and Reserves**

Though resources include land, labour, capital, air, water, energy, etc., now we are only concerned with energy so we assume energy as a resource.

*Fixed Resources (Non-Renewable Resources)*

Once the fixed resources are exploited, then it moves towards zero resource point. This can be explained with the help of the following diagram:

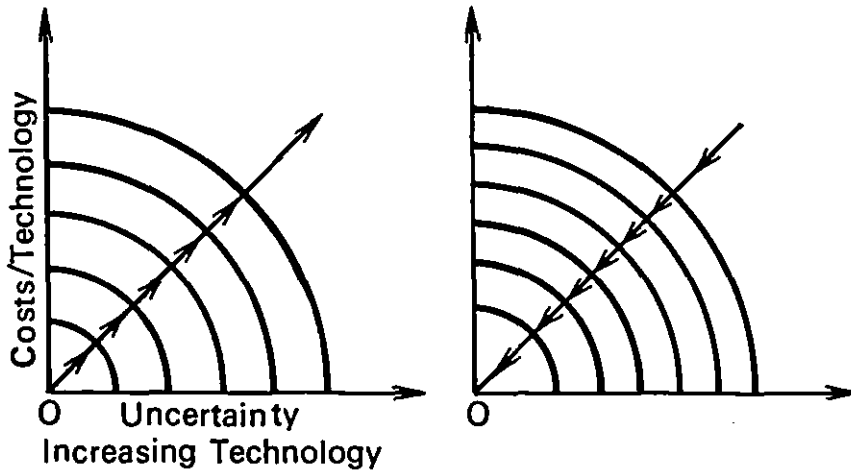


Fig. 4.2

*Reserves*

Increasing technology  $\longrightarrow$  finding up of more resources.

**Approaches to Analyse Depletion of Energy Resources**

*1. The Least Sophisticated Approach*

The least sophisticated approach to the analysis of depletion is to estimate the life time of the supply of any resources. The procedure to complete this as follows:

$$\text{Life time of the supply} = \frac{\text{Present proved reserves}}{\text{Present rate of cons/n}}$$

$$\text{Suppose} = \frac{100 \text{ (MT Coal)}}{2\%} \quad \text{then coal will be}$$

available only for 5,000 years.

Suppose we want to reduce the consumption rate of coal to conserve it for a long time. It is possible to do so by adopting two

ways (1) finding a new technology and (2) substitution of energy. This approach is the origin of the often heard statement to the effect that we have some specified years of petroleum left.

#### *Defects of this Method*

1. Consumption is likely to stay constant because proved reserves often bear little relation to ultimately recoverable resources.

2. Generally, it does not pay to do the exploration and evaluation needed to establish new proved reserves if the material is not to be extracted and profit earned until 15 or 20 years in the future. This is the main reason why proved reserves rarely amount to more than a few decades supply.

#### *2. Hubbert-Production Cycle Approach*

Hubbert notes that there are several phases of a production cycle for any stock limited resources.

*First Phase:* There is an increase in the rapid growth in the rapid exploitation as demand increase. In this stage production becomes efficient and cost per unit of material may fall leading towards the resource becoming scarce and starting to rise in price.

*Second Phase:* The second phase is having a continuous decline in the rate of exploitation. The resource becomes scarce in the declining quantity produced and there is a slower growth of improving technology to compensate to provide substitutes. This

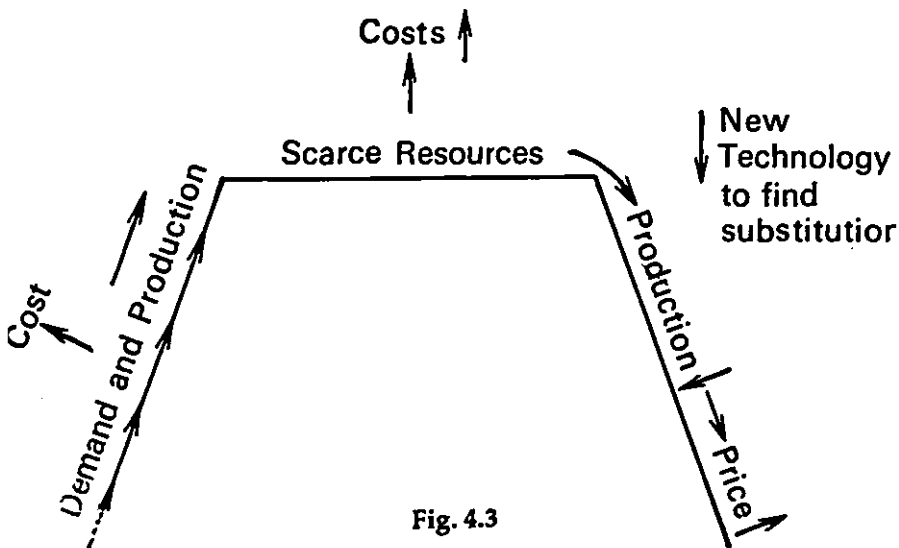


Fig. 4.3

approach incorporates explicitly the fact that any scarcity or crisis occurs not in a sudden moment but it takes several phases and finally reaches the position of resource crisis.

### 3. Life Time of a Fuel

This method is the improved version of the first method, because it takes into account the ultimately recoverable resources and the present rate of consumption for finding out the life time of fuel.

$$\text{Life Time of a fuel} = \frac{\text{Ultimately recoverable resources}}{\text{Present rate of consumption}}$$

#### Defects

1. Constant rate of consumption is assumed.
2. It may overestimate the life time of a fuel.
3. A component of uncertainty is also present in the ultimately recoverable resources.

### 4. Geologist Method

This is based upon the production cycle approach. But it has taken into account the time period.

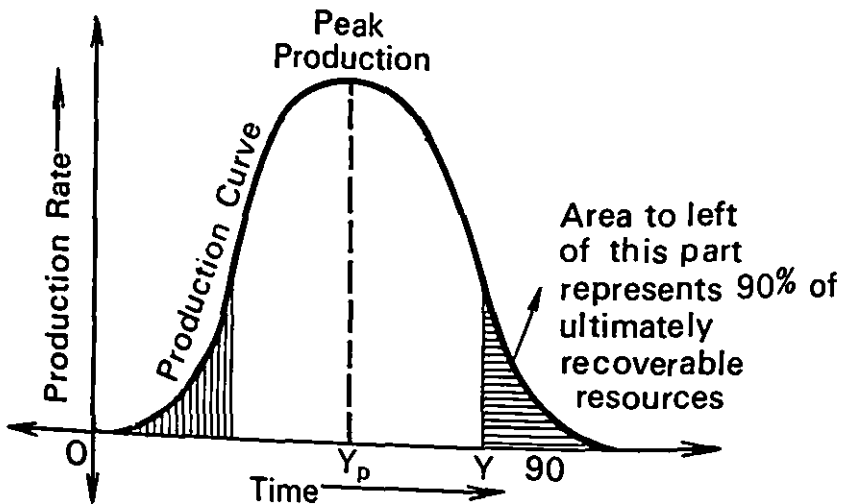


Fig. 4.4

It is a combination of Hubbert Production Cycle approach and a life time of a fuel approach. The area under the production curve at any time represents the cumulative production up to that time and the amount under the completed curve represents the magnitude of the ultimately recoverable resources.



The important measures of the lifetime of a fuel in this approach are the year in which the level of consumption reaches its peak and the year in which the 90 per cent of the ultimately recoverable resources have been extracted.

**Optimal Resource Use of Appropriate Policy to Minimise it**  
*Cake Eating Model*

The simplest model is the so-called cake-eating model, the first studied by Hotelling. A finite cake (natural resources) provides an individual with his sole means of subsistence. Consumption implies depletion, and when the cake is exhausted, life terminates. If we take its declining marginal utility with its consumption in the absence of other forms of preferences, the constant rate of consumption will always be optimal. It is less clear what that rate should be. Longevity is maximised by a frugal policy of subsistence. At the other extreme, if the whole 'cake' is gobbled immediately, life would be short and sweet. In general, there is a continuous trade-off between longevity and standard of living.

*Das Gupta & Heal Model*

(a) According to Das Gupta and Heal, when the cake is exhausted, the individual can still use (i) a substitute resource and (ii) there is always the possibility of recycling the resources. It now becomes optimal to spread consumption equally over a duration of time. So this model goes completely against the exhaustible nature of resources. The other dimension of this model refers to renewable resources. If renewable resources are provided sufficiently to sustain life, then an exhaustible resource should be depleted very slowly. This model is otherwise known as the 'conservation model'.

(b) Dasgupta and Heal have also made another modification to the simple cake-eating model in which future utilisation is discounted by introducing a time preference.

(c) They have elaborated this model by taking into account technical progress, capital accumulation and uncertainty.

**General Properties of Optimal Path of Resources**

I. There must be a particular trend of consumption, whether an upward one or a downward one which depends on the balance of the following considerations:

1. Technical progress and possibilities for capital substitution;

2. Time preference; and
3. Uncertainty.

II. Resource use must eventually decline but may rise at first. It may be optimal to deplete exhaustible resources fully in a finite period of time if technical progress and substitution possibilities are sufficiently strong.

III. Resource rent will rise at a rate equal to interest rate.

### **Exploitation of Resources: Problems of Resource Measurement**

Resources are means of supplying a want; stock that can be drawn on and means of support.

It is obvious then that measurement of resources is as complex as estimating demand for a commodity. The known estimates are those of the proven reserves, which exclude deposits that are available, but there is no incentive to explore and exploit them, either because current prices are low, or because current technology is inadequate.

### **Determinants of Long-term Resource Availability**

Adequate and relevant information about ideological and economic factors are essential for analysis of long-term resources availability. The first provides details of locations, grades of deposits, size of reserves and projections of growth in the use of a resource. The second refers to the use of resources in economic activity.

The problem of resources measurement has just been discussed. The size of an available resource is related to the state of technology available for extracting it which in turn is closely linked with the state of the economy. In other words, reserves of a resource are usually defined as the quantities available at a given cost and technology.

### *Geological Factors*

Leaving the technical aspects of measurement aside, information available about resources which have been proved or are known to exist with the highest degree of certainty are given here.

Some idea can now be had about the locations and approximate size of known reserves. Further analysis of these reserves would provide information about grades or, quality of the deposits. Projections of growth in the use of a resource would seem to depend upon the socio-economic set-up and the state of technology in use.

*Economic Factors*

For a realistic development programme, it is essential to have some idea of the growth of demand in the future and the supply which may be available. Demand is a function of a host of factors which are always difficult to cope with any great degree of confidence. The variables which are likely to prove most difficult to manage are:

1. the rate of increase in population;
2. the rate of increase of total demand which for its part is dependent upon social and technical factors, in themselves impossible to see far ahead; and
3. the amounts of material and energy resources available along the time-scale given the technology.

Economic factors must therefore take into consideration the following points:

1. Energy supplies available or to be made available for extraction and processing industries;
2. Complementary minerals which must be used in a certain technical mix.
3. Competitive minerals or substitutes which can replace wholly or partly a particular mineral, depending upon the state of technology. Improved technology therefore may mean substitution among resources as also use of lower grades of areas which become economically worthwhile. Further, improved technology may mean raising output per unit of time, thus increasing the quantity of a resource which becomes available.
4. Extension of life of a product by using better grades of minerals or improved technology.
5. Recycling, that is, salvaging resources from the junk heap for reuse.
6. Material conservation, that is, making a little go far, considering the fact that there is sporadic and uneven distribution of mineral resources in the earth's crust which is a major geological constraint on unrestricted use of a resource.
7. And finally, political factors influencing availability of resources are of crucial importance. Politics is a most unpredictable factor but it cannot be wished away.

Any realistic determination of exploitation rates for a long-

term period must, therefore, take into account depletion of resources, both internal and external, and availability of power supply. In addition, it should be considered whether "greater efficiency in planning and implementation, hard decisions, rigorous discipline and major sacrifices" would be possible. These factors are bound to influence the course of development and, hence, growth rates as planned.

In a perfectly working market, resources would be rationed over time through the price mechanism. Assuming that there is a perfect market the following effects follow resource scarcity:

1. A rise in price will reduce the rate of growth in demand.
2. It will lead to substitution which will further reduce demand for the scarce resource.
3. A rise in price will encourage scavenging the junk yard, that is, recycling will increase, which again will reduce demand for the scarce virgin resource but recycling will only pay if the price of the scrap is less than that of the scarce resource, and if it can really be used.
4. A rise in the price of the scarce resource may induce exploration to find new deposits and even existing inferior grades of mineral ores may become economical to use.
5. And, lastly, the very use of the goods made from the scarce resource may be given up as an extreme case. For example, if oil disappears, the transportation system will completely change.

#### *Estimation of Exhaustion Period*

The "exhaustion period" of a mineral is a vague term, since considerable amounts may not be recovered for technical reasons when "blocked out". It simply indicates the period during which a known resource is exhausted and no more of it may be available, other things remaining the same. The problem of resource availability in the long-term period have been discussed in the section dealing with it earlier. To recapitulate, it is influenced by the size of the proven reserves, technology power supply, and the price people are prepared to pay. These factors mainly determine long-term resource availability. Politics is another important factor which can and does create havoc—the oil crisis is the current problem faced by all importing countries. The effect on the environment of resource exploitation will, no doubt, become an important factor when the cumulative effect of

damage begins to harm human health, agriculture and other sources of human existence.

It may be useful to have some idea about the size of population and its growth rate. This is of crucial importance in evaluating, however imperfectly, the welfare function of any development project, and has an important bearing on the depletion of resources.

Growth rate in percentage per year is calculated by the following formula:

$$\text{Exponential index} = \frac{\ln [(r \times s) + 1]}{r}$$

where,

r = growth rate, and

s = static index.

The static reserve index shows the number of years the present known reserves of a resource will last at the current usage rate. This measure is usually used to show future resource availability at the current usage rate with present technology and assuming no substitution.

Exponential indices give the probable lifetime of each resource given the current growth rate in consumption.

It must be noted that static and exponential indices by themselves cannot determine future resource availability, because that is influenced and determined by very complicated factors. Some indication of the dimension of the problem has been given earlier in discussing "determinants of long-term resource availability". But for a more realistic assessment it is also essential to consider the many interrelationships among these factors such as the varying grades of ores, production costs, mining technology, the elasticity of consumer demand and substitution with other resources. Thus, it is of crucial importance to consider the changes in industrial technology.

### **The Incentives to Conservation**

#### *Price Mechanism*

Optimists place great reliance in the price mechanism as providing an incentive to conservation. Whenever a marketed resource produced becomes scarce, its price will tend to rise. This will provide incentives (1) to economise on its use, (2) to seek substitute products and processes, (3) to prospect for new

supplies, (4) to recycle old ones, and (5) to reduce the rate of extraction in anticipation of future price increases. Thus, according to the optimists, if we adopt the price mechanism, conservation of resources will take place automatically.

#### *Lowering the Discount Rate or Interest Rate*

It is argued that the current decision of the resource holder depends upon the expected future prices which, in turn, depend upon the discount rate or interest rate. Thus lowering of the discount rate may encourage resource conservation. This is highly questionable for the following reasons:

#### *Problems*

1. The suggestion that a lowering of discount rates is required to encourage resource conservation may seem paradoxical. For we have become accustomed to the idea that a low discount rate always promotes growth which aggregates the exploitation of resources. So the expected prices do not play a higher role in the conservation of resources.
2. Technically, it gives rise to the problem of uncertainty.
3. The decision makers of the future projects are likely to formulate expectations rather than project the current trends.

#### **Private Ownership of Resources**

Some of the resources owned in common will always be overexploited. If some of the resources yield both market goods and free goods, there arises the problem of providing ownership, for example, when a waterfall (free good) is passed through a pipe to generate electricity the resource is renewable. But it is non-renewable in its production capacity when the waterfall is disturbed by the presence of big stones. The question of assigning private ownership in this case is highly impracticable.

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## ENERGY CONSERVATION

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There is no miracle solution to the energy problem. Energy conservation has a role to play alongside production from all acceptable sources. Conservation has many faces and some of them are not so gruesome. Collectively, the various forms of conservation mean restraint, not hardship, prudence or starvation. But it may well be that without self-discipline and the intelligent use of energy in short, without some measure of conservation the result will be both energy hardship and starvation on a broad and devastating scale. The potential for energy conservation is large but due to the complexity of values and choice by the decision-makers only a part of it will be realised. A wider range of action is required by institutions, individuals and governments. Some of them will prove more successful than others.

Conservation and energy use efficiency form part of the overall energy policies of nations. The responsibility for energy conservation and its ultimate success depend on the cooperation of all who produce and consume energy: mining and petroleum recovery interests, industry, commerce and domestic consumers.

### **World Bank Study**

A World Bank survey of energy efficiency, using annual growth rates of energy intensity as an indicator, reveals that it was negative during 1971-80 in the developed countries, which means an improvement in energy efficiency. In contrast, the energy intensity growth rate was positive in the case of India, where energy utilisation in selected industries was about double that of the developed nations, indicating a great challenge and scope for improvements. M.K. Raju Consultants (MKRC) armed with

Du Pont's technical knowhow on energy conservation technology have done considerable work on energy saving in Indian industries.

**Table 5.1: Savings Identified (MKRC) in Industrial Units in India**

Industry	Annual Savings		Percentage of savings requiring no significant capital investment
	Rs. in lakhs	Percentage of energy bill	
Foundaries	100	25	41
Aluminium	180	10	24
Cement	45	8	48
Fertiliser	500	14	17
Paper	165	18	65
Glass	70	10	46
Textiles	60	16	33

Source: *The Hindu*, January 9, 1991.

A comprehensive energy conservation programme has two broad components. The first one consists of government regulatory activities and the second the implementation of activities at the user level. The responsibility for energy conservation and its ultimate success will depend on the cooperation of all who produce and consume energy. Effective coordination is needed to ensure the setting up of and realisation of goals. The regulatory agency should provide focal points for direction and guidance, create awareness about the benefits of energy conservation, set priorities to the techniques which are most appropriate, establish measures for evaluation of progress and ensure continuous monitoring of various programmes.

In India, organisations like NPC, PCRA steam and fuel users' associations and others have initiated conservative measures in household, transport and industrial sectors. They have presented a number of energy conservation awareness programmes and developed techniques and initiated measures for conservation. These will result in major changes in fuel mix reducing the use of oil, an increase in efforts to develop and use renewable energy resources and reduce the amount of energy, especially oil,



required per unit of production/service/activity—a vital contribution to economic growth. Energy saving methods can produce quicker results and conservation is more attractive than investing additional resources to increase energy supply.

#### **Four-Path Strategy**

There are four energy use paths that can be followed by the country to increase its overall productivity.

First, waste of electricity (energy loss) can be cut down and more goods and services produced using less energy. Industrially advanced countries are already using less electric energy than they did 30 years ago by better utilisation and by employing energy efficient appliances.

Second, less total energy substituting a more efficient kind of energy can be used in place of a less efficient form.

Third, solar and other renewable energy sources may also be considered.

Fourth, factors that are not directly related to the amount of energy used must sometimes be considered. Some energy conservation methods (such as turning off lights and fans when they are not needed) and others (such as forming car pools) improve fuel efficiency or make a certain amount of fuel do more work.

#### **Conservation at Electric Utilities**

Energy conservation is appropriately considered together with power development as a unit of energy saved which is a unit available to meet the growing demand for electricity. In other countries, electric utilities play a vital role in their energy conservation efforts. A utility produces energy most efficiently when the total demand of its customers for electricity does not vary widely. Load management promotes maximum efficiency by bringing about reductions in peak energy demand so that additional capacity to meet it can be reduced to a minimum.

Fuel is burnt in power plants to heat water. In the process, energy in the form of heat escapes at several points, it is impossible to convert all the energy stored in a fuel to electric energy. Some of the escaping heat can be put to use. However, heat from the fire beneath a boiler can be piped back to the fuel combustion channels to help keep the burning process going. The leftover heat from the steam that turns the turbine blades can be used to help heat water for the boiler.

### **Minimising Losses in Generation and Transmission of Electricity**

Electricity losses can be minimised by transmitting electricity, as far as possible, at high voltages and minimising the reactive power flow by providing capacitor compensation.

India's transmission and distribution system must be made energy efficient so that the energy reaches the consumer with minimum losses. Efforts should also be made to persuade the consumers to make their installation energy efficient.

### **Rural Areas**

Rural areas should receive special attention in the context of energy conservation in irrigation pumpsets. If farm loads could be diversified and rural electricity cooperatives organised efficiently, as in the US, there could be even greater energy savings enabling the utility to extend more power to people in rural areas. The integrated energy project concept is gaining ground whereby a village is not merely electrified but also energised. Rural energy needs are thus effectively met from non-conventional sources avoiding high-loss transmission of power from grids.

### *Conservation in Industrial Plants*

Conservation possibilities include heating or cooling different parts of large industrial plants by transferring low-grade heat from the environment or from industrial processes.

Another means of reducing energy losses at factories is through "dual energy use"—production of two useful forms of energy from the same resource. Through a process called co-generation steam produced in a factory's manufacturing process can be used at the industrial site where it is produced or it can be distributed to other sites through the electric utility system.

Industrial co-generation is most likely to enjoy renewed popularity among industries that can burn their own waste products, thus producing electricity at a cost lower than that of power provided by the local utility.

In a second kind of dual energy use, steam left over from a factory's manufacturing process is piped to nearby industries or nearby homes where its heat can be used to warm space or water.

In India the industrial sector, which consumes about 60 per cent of the total power produced in the country, has a large

potential for conservation of energy. Studies carried out by various committees have indicated that at least 20 per cent saving in energy can be effected without loss of industrial output. In certain energy-intensive industries like cement, steel, aluminium, the scope of conservation is even greater. The D.V. Kapur Committee has shown that Indian industries save 20 per cent of the energy consumed at present. A saving of Rs. 2,000 crores can be achieved every year through an investment of Rs. 3,600 million. The payback period is less than two years. An inter-ministerial working group had pointed out that savings in energy of this magnitude would save the country's investment on new capacity to the extent of Rs. 5,780 crores for the industrial sector.

Thus substantial savings of 10 to 15 per cent can be achieved with a marginal investment by taking simple measures like proper housekeeping practices, use of energy efficient machines and equipment, planned lighting and proper maintenance.

The National Energy Conservation Organisation also proposed to create an awareness about the dire need for and relevance of energy conservation by putting R & D on a sound footing, without any duplication of effort by training energy experts. The worldwide project taken up in the major factories of three countries, viz., China, Nepal and Thailand, showed that training proved to be an effective instrument. Energy saving amounted to 90 per cent in Chinese and Nepalese industries and 75 per cent in Thai factories.

To implement energy conservation measures the Energy Manager must have an action plan. This action plan may be divided into three phases:

- (a) Short-term plan: This requires no capital investment. It mainly focuses on methods for avoiding energy wastage and minimising non-essential energy use;
- (b) Medium-term plan; and
- (c) Long-term plan.

While finalising a long-term plan, the required latest energy saving technique is to be studied. The payback period should not be longer than that of the production investment.

To translate the principles of conservation into action a clear-cut strategy is needed. It includes:

- (a) Identification of fixed and variable elements of energy input in the process;

- (b) Conservation of fixed elements in variable ones;
- (c) Estimation of energy intensity for each product;
- (d) Preparation of an energy use index, etc.

All these actions demand considerable investment and a timely adjustment of capital stock. For this purpose the Energy Manager needs the following information:

- a) size and distribution of energy using equipment, e.g., electric motors, boilers, furnaces, ovens, etc;
- b) load factors;
- c) thermal efficiencies;
- d) age profiles;
- e) specific output data;
- f) characterisation of waste energy, i.e., steam, the temperature range and volume; and
- g) the nature of energy carrier where considered appropriate.

Since much of the information is of a technical nature the Energy Manager can very well seek technical assistance or while staffing he can have one such person to assist him.

#### **Need for Petroleum Conservation**

In India, the existing petroleum reserves are sufficient for about 20-25 years at the current rate of production of 34 million tonnes of oil/year. Even then we are not self-sufficient and we imported petroleum products worth Rs. 6,260 crores last year. Due to the recent Gulf crisis imports of petroleum products and crude oil are likely to cost more than Rs. 10,000 crores.

The present per capita consumption of petroleum products in India is only 70 kgs. A person living in a developed country consumes petroleum products 40 times that of an Indian. Our per capita income is only \$ 380 against \$ 20,000 of a person in a developed country. Various expert groups have estimated the saving potential at 25 per cent—more than 10 per cent saving worth Rs. 2500 crores is possible mainly through improvement of operating practices mainly. It is not difficult to conserve energy. An industrialist can recycle the heat going out in flue gases from furnaces, adjust the air/flue ratio, improve the insulation. Investment is often recovered in 1-2 years. Additionally, he can have targetting and monitoring programmes for energy consumption. One can drive a vehicle at a uniform speed of 40-50 kmph, avoid frequent acceleration/breaking, anticipate stops, stop the engine on long stops, keep proper air pressure in tyres,

get the vehicle tuned periodically and thus save at least 10 per cent fuel.

A housewife should use fuel-efficient ISI mark stoves, pressure cookers covered with shallow vessels, optimum quantity of water for cooking, etc., thus saving 20 to 30 per cent of gas kerosene. An agriculturist can save 30 per cent of diesel in working his water pump by using efficient foot valves, pipes of proper size made of suitable material, an ISI mark pump and prime mover of matching size, etc.

The Petroleum Conservation Research Association (PCRA) has helped 2,000 industrial units, more than 12 state road transport undertakings and 2,500 diesel water pumps in about 100 villages. It has also helped in the development of fuel efficient kerosene/LPG Nutan stoves—about 40 lakh Nutan stoves have been sold, saving 20-25 per cent fuel. Thus savings of petroleum products worth Rs. 300 crores/years have been achieved.

PCRA has an awareness programme wherein:

- a) 30 lakh copies of 30 books in 10 languages are distributed free per year;
- b) mass media like TV, newspapers and, magazines are used to propagate energy conservation measures. PCRA provides the following free services:
- c) 50 per cent subsidy for energy audit in industries;
- d) Grant for R&D demonstration projects;
- e) Training of operations engineers;
- f) Booklets containing petroleum conservation measures for various target groups;
- g) Diagnostic study of industrial units;
- h) Loans of PCRA films; and
- i) Soft loans for replacement of inefficient oil-fired boilers.

### **Energy Conservation in ONGC**

ONGC had identified oil conservation and its efficient use, assisting in the development of alternative sources of energy as one of its corporate objectives in the early 1980s. A number of initiatives were taken in support of this corporate objective. Energy conservation was declared as one of the key thrust areas and a multi-pronged strategy was initiated at the corporate, regional and project levels in support of this objective.

### **Monitoring Energy Conservation Data and Target-setting**

Energy consumption in the various activities of ONGC like data acquisition, drilling, production, cargo operations, LPG production, etc., are monitored operation-wise and region-wise. The data is compiled in the data bank and is used for various studies and for future reference.

### *Creating Awareness*

Various methods have been adopted for spreading energy conservation consciousness. Colourful stickers and posters have been distributed and displayed. Energy bulletins have been started. Video films are being shown at various work centres.

### *Energy Auditing*

In-house energy audits have been initiated at the corporate, regional and project levels for monitoring energy consumption in various areas of operations. Regular energy audits identify and locate energy intensive units and plants and are helpful in drawing up and implementing specific improvement programmes.

### *Use of Energy Efficient Equipment*

Use of energy efficient equipment with necessary modifications in place of obsolete energy guzzlers has helped in saving costs to the extent of Rs. 50 lakhs per annum.

### *Non-conventional Sources of Energy*

A few of the areas where non-conventional sources of energy are being used in ONGC are solar thermal heaters in remote work site projects, residential buildings, hospitals, etc., with a capacity of about 1 lakh litres of hot water per day, thus saving about 4 lakh units per annum. Solar photovoltaic cells at offshore well platforms have helped in saving about 3.45 lakh units per year. A solar-powered cathodic protection system has also been installed for the Daba-Dhuvaram pipeline in the western region. A breakthrough in tapping wind energy has been achieved by installing a 1000 watts wind-driven generator on unmanned platforms of Bombay high yield.

### **Conservation of Petroleum Products**

Demand of the petroleum products in our country has been growing at a rapid rate. The consumption of oil, which stood at 17.9 MMT in 1970-71, rose to 53.82 MMT by 1989-90 and the

projected demand by the turn of the century is estimated at more than 100 MMT per year. Even after stepping up the exploration and production activities with adequate financial outlays, production is not expected to increase beyond 58 MMT by the year 1999-2000. The import bill for crude oil and petroleum products in 1989-90 had increased to Rs. 6260 crores from Rs. 2,773 crores in 1986-87. This is likely to increase substantially because of the Gulf crisis. It has therefore become imperative to restrain the growth in demand of petroleum products both in the short term and in the long term.

However, this has to be achieved without retarding the growth of the economy. The main thrust areas for reducing the demand of petroleum products would be:

- (i) Improvement of efficiency of the equipments used in industry and by mass consumers;
- (ii) Bringing about changes in the consumer habits and attitudes towards conservation; and
- (iii) Substitution of petroleum products with other fuel and energy sources other than conventional ones.

### **Strategies for Energy Conservation**

A few of the effective strategies on the part of government or power utilities or consumers that could be developed and implemented are as follows.

#### *Supply Restriction/Allocation*

This strategy involves a predetermination of energy consumption for each unit of economic growth, such as transport and agriculture and then using some non-market allocation scheme to distribute this limited supply. For example, the number of units can be fixed for industrial consumers and their electricity requirements met out of the allotted quota. In this way, entrepreneurs/consumers can play a vital role in energy conservation by making the best use of the limited power supply.

#### *Pricing*

This strategy depends on consumers' reaction to higher electric rates to cut energy consumption. Electricity rates are part of a utility's tariff, which it must file with its regulatory commission. In addition to rates, the tariff includes terms, conditions and definitions. The tariff structure should be such that it should discourage wasteful use of energy and restrict maximum demand.

Where a price subsidy or concessional tariff policy is required for social or political reasons, the rate of inflation, cost of living, effects on Gross National Products (GNP) and the economy should also be carefully considered before any measures are introduced.

#### *Legislation and Regulations*

This strategy will place constraints through legislation on the supply of electricity, particularly with a view to avoiding wastage and inefficient usage. Such a strategy will have the advantage of concentrating energy restrictions in those areas where the economic and social side-effects are least harmful or where there is necessity to speed up conservation by mandatory measures. New building regulations as would conserve energy could be framed. For example, all new buildings should be constructed in such a way as to make maximum use of natural heat and light resources, thus contributing to energy conservation. For example, the concept of solar architecture can be incorporated in building design and layout.

#### *Incentives and Penalties*

This strategy will provide incentives to encourage conservation and avoidance of uneconomical use of energy, especially in the industrial and agricultural sectors. A system of providing fiscal incentives, subsidies and tax exemption on electricity bills in respect of companies' units which show efficient usage of electricity could be an encouragement to promote energy conservation. On the other hand, disincentives in the form of taxes/penalties will help to discourage specific kinds of energy wastage. Higher fiscal concessions could be given to industries manufacturing energy-saving equipment so that such devices are made available at cheaper rates. The aim should be to make it more economical for consumers to adopt more energy-efficient systems and make investments in energy saving devices.

#### *Energy Assessment*

This strategy will call for the setting up of committees to study areas of energy conservation and assess the potential for immediate conservation in various sectors. The committees should also monitor and audit energy consumption of all government departments. The Planning Commission and the financial institutions should also insist on making assessment of



the energy implications of projects just as at present an assessment of the environmental impacts of specified large projects is made before granting issuance of licences. For example, the project reports for setting up new industrial units should identify, as well as justify, the necessary provisions made for conservation of energy. The projects that will yield maximum output with minimum energy consumption should be cleared on a priority basis.

#### *Education and Information*

This strategy will attempt to change consumers' habits of energy use through change of lifestyles or by pointing out the advantages of energy saving practices. Information on ways of saving energy in all sectors may be published by the Government, Industrial Departments, State Electricity Boards, consumer organisations and commercial and professional bodies. Special programmes should be developed to educate the general public about the necessity and means of conservation. Public utility undertakings could display various exhibits demonstrating energy, conservation methods in the domestic sector and providing advice through audio-visual presentations and publicity/coverage in the mass media like TV and radio.

A separate energy consumption office or conservation centre could be set up and seminars and conferences on energy conservations organised from time to time to help educate consumers. Introduction of subjects like "Role of Energy in Life" in educational institutions would go a long way in educating the people about conservation of energy. Consumers' organisations should also come forward to actively promote energy conservation through publications of articles, giving information on consumption of electric appliances and by imparting useful tips for energy saving.

#### *Research and Development*

The development and adoption of innovative energy efficiency technologies should be speeded up through R & D joint ventures between the private and public sectors. A new methodology of energy saving should be explored in various sectors. For example, in the area of combined generation of heat and power (CHP) the government should develop/encourage the setting up of CHP plants with a view to selling steam and electricity to

industrial users. This may require some sort of safeguards to private utility/companies so that they could be protected from legislative implications as well as the effects of changes in government policy relating to energy pricing.

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## ENERGY COSTS AND PRICES

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Energy prices respond to the forces of supply and demand as do the prices of any other commodity. But other factors besides supply and demand have a powerful impact on energy prices. Here are a few:

1. Costs of production and distribution;
2. Prices of competing fuels;
3. Incentive pricing to create demand;
4. International price-fixing;
5. Government regulations.
6. Tax policies; and
7. Non-tax government subsidies.

### *Costs of Production and Distribution* •

Production costs have a particularly striking effect on the prices of experimental or unconventional energy resources. Prices of more conventional forms of energy are also strongly influenced by production costs. For example, electric power prices are much lower in areas with a high percentage of hydroelectric generating capacity than in areas where most electric power is produced by manpower plants. This is because the costs of operating a thermal power plant are much higher than those of operating a hydroelectric plant.

Distribution costs also affect energy prices. Fuel costs are generally higher in remote areas than in more densely populated places. This is largely due to the added transportation costs. Distribution costs are also an important factor in the price difference.

*Price of Competing Fuels*

The price of an energy resource is determined less by the costs of production than by the prices of competing fuels.

*Incentive Pricing*

Sometimes prices are set at an artificially low level in order to produce an increase in demand for the product. In principle, the increase in demand and the resulting higher production will result in greater production efficiency, a reduction in costs and greater profitability for the producer. Thus, by setting prices at an artificially low level, producers hope to lower their costs to reach those levels.

*International Price Fixing*

International price-fixing has been a significant element of world energy pricing but only to the extent that world energy supply and demand have favoured such practices. The power of international cartels has been shown to fade rather quickly when decreases in demand result in a temporary oversupply of energy resources.

*Government Action and Energy Prices*

1. Price controls - Low domestic price compared to international price.
2. Tax policies - viz., tax concessions and tax subsidies - 27.5 per cent - tax credit.

*Non-tax Government Subsidies*

Direct and indirect subsidies offered by the Government would also influence the prices.

*Public Utilities and Energy Prices*

Public utilities are regulated monopolies. Because of the monopolistic structure that is established by such a system, prices cannot be set by the normal process of supply and demand. If given a free hand, utilities could raise their prices at will and threaten to cut off any customer who refused to pay them. To avoid this problem prices are set by state governmental agencies, as public service commissions, public utility boards, or state utility commissions. These state agencies evaluate an electric company's costs and operating procedures and set the prices that the utilities may charge. If a utility wants a price increase, it must obtain approval of the concerned agency.

**Factors Affecting Rate Decisions***Rate Base*

It is important to understand that only capital investments are eligible for inclusion in a utility's rate base. Operating expenses are excluded. This means that between a facility with high capital costs and low operating costs (such as a nuclear power plant) and one with lower capital costs and higher operating costs (such as a coal-fired plant), the higher capital costs utility can earn a greater profit. Theoretically, this could lead utilities to choose uneconomical investments in order to maximise their profits, and some critics of the energy industry claim that this has been the case with nuclear power plants. However, in order to receive approval to investment in an energy facility, it must convince the public service board that the investment is financially sound. Thus, in principle the public is protected against such unethical practices.

*Return on Investments*

Once a utility's rate base has been determined the guaranteed return on investment can be computed. Energy projects are not designed to lose money. If everything goes according to plan, the project will enable the developers to recover all the capital costs, including interest, and all the operating costs. Projects undertaken by privately owned energy companies should also make a profit.

*Repayment of Capital*

Whether the original capital for a project is borrowed or paid out of past earnings, it is necessary to recover the capital; otherwise the project will be an economic failure. The repayment of the capital does not have to be made immediately, but must be completed before the energy project has lost its value. Usually, the capital costs are recovered gradually through amortisation or the use of a sinking fund. When a debt is amortised the lender is paid back in periodic instalments. In the case of a sinking fund, the developer makes contributions to a special fund earmarked for recovering the capital.

The following formula will determine the payment required to recover the capital.

$$\text{Payment} = \frac{P \times r(1 + r)^n}{(1 + r)^n - 1}$$

where,

- P = amount of capital (principal),  
 r = interest charged per payment period, and  
 n = number of payments.

A simpler, if less precise, method is to consult the table of repayment factors and multiply the amount of principal by the value given in it. These values assume that interest is assessed once a year and payments are made annually.

*Illustrative Example:* Suppose that a group of farmers has decided to invest in a small (100 kw) hydro plant. The plant will cost Rs. 2,50,000 and the capital can be obtained through a bank loan at 12 per cent interest per year. Payments and interest calculations are made monthly, and the loan is to be paid off in 15 years. Substituting for the values in equation, we compute the following:

- P = Rs. 2,50,000  
 r = 0.01 (12 per cent per year = 1 per cent per month)  
 n = 180 (15 years x 12 payments per year)

$$\text{Payment} = \text{Rs. } 2,50,000 \times \frac{0.01 \times 1.01^{180}}{1.01^{180} - 1} = \text{Rs. } 3,000$$

Looking at the values we arrive at an approximate annual payment figure of  $0.147 \times \text{Rs. } 2,50,000$  or Rs. 36,750. For the purpose of estimating costs, this is close enough to the actual figure of Rs. 36,000 per year ( $12 \times 3000$ ).

### *Operating Costs*

In addition to its guaranteed return on investment, a utility is allowed to recover its operating costs from the ratepayers. These operating expenses include fuel costs, salaries, taxes, operating and maintenance expenses, and miscellaneous changes. In some cases utilities are allowed to include costs of advertising and promotion materials in their operating costs, whereas in others these costs must be absorbed by the stockholders.

Utilities are not permitted to earn a profit on their operating costs but critics alleged that this principle is not always followed. For example, utilities are permitted to pass to their customers.

It is difficult to generalise about operating costs because each resource has different costs. For oil-fired electric power plants, fuel constitutes the main operating cost. Hydro systems have no

fuel costs at all. Maintenance and repair costs are high for wind energy systems and low for passive solar heating systems. A project developer usually estimates the probable operating costs by studying other projects with similar characteristics.

#### *Fixed and Variable Costs*

Some operating costs are fixed, that is, they do not change with the amount of energy produced. Taxes, insurance, easements, and building maintenance are examples of fixed operating costs. Other costs are variable; they increase as more energy is produced. Fuel, equipment maintenance, and labour costs are examples of variable costs.

The total cost of a project is the sum of the capital costs and the operating costs, both fixed and variable. This cost will tend to increase as energy production increases. But that is not the whole story. The cost per unit of energy will actually decrease as energy production increases. Clearly, the lowest unit cost can be achieved if the plant works as at its designed capacity.

The capacity factor is an important measure of how fully an energy facility is being used. It is calculated according to the following formula:

$$\text{Capacity Factor (CF)} = \frac{E}{P \times T}$$

where,

E = Energy produced, KWh,

P = Maximum power output, KW, and

T = Hours of operation.

*Illustrative Example:* In the earlier illustration, a group of farmers were building a hydro plant with a maximum power output of 100 kw. Suppose that the facility is completed according to plan, and that during the first year it produces 4,75,000 kwh of electricity. The capacity factor is equal to:

$$\text{CF} = \frac{4,75,000}{100 \times 365 \times 24} = 0.54$$

In general, the higher the capacity factor, the better. A higher capacity factor means a lower unit cost. A word of caution, though: the capacity factor should not be used as the sole criterion for choosing between two design alternatives. The only fair method is a direct comparison of energy (or energy savings).

### *Marginal Costs and Average Costs*

A distinction needs to be made between average costs and marginal costs of energy-producing facilities.

When utilities establish their rates, they base their cost estimates on the average cost of all energy producing facilities. This means that the higher cost of new energy facilities is somewhat balanced by the lower cost of older facilities. So while a utility may charge 10 paise/kwh for electricity, the electricity produced from the newest facilities may be much more expensive.

When considering the setting up of a new power plant its cost should be compared not with the average cost of power production (the average cost), but with the cost of alternative methods of producing additional power (marginal cost). In many cases, this can make a significant difference in evaluating the feasibility of a project.

Consider, for example, the hydro plant described above. The capital costs total Rs. 36,000 per year, and taxes, insurance, operation, and maintenance cost an additional Rs. 10,000 per year. The plant produces 475,000 kwh per day for an average total cost of 95 paise/kwh. This is actually more than the utility's cost of 78 paise/kwh. So the project does not appear to be cost-effective.

However, the figure of 7.8 paise/kwh is an average figure for the utility. If the utility were to build a new thermal power plant, the electricity from the plant would cost 1.35 paise/kwh. This is substantially higher than the cost of power from the hydro plant. For this reason, the utility agrees to buy power from the hydro plant.

These are only representative figures. But they illustrate an important point: cost-effectiveness depends on the perspective of the person doing the analysis. If the cost of a hydro project is compared to the cost of electricity to the farmers, the project is not cost-effective. But from the point of view of utility, the hydro project is less costly than the alternative of building a new thermal power plant. Whenever cost comparisons are made, it is essential to use the same basis for comparison. Average costs must be compared with average costs, and marginal costs must be compared with marginal costs.



### **Setting Utility Rates**

After the rate base, the return on investment and the operating costs have been determined, the utility adds those figures together to determine the amount of income that can legally be obtained from the rate payers. Then the utility estimates its sales of electric power and establishes its rates at a level that will allow it to recover the legal amount of income. If the utility's calculation shows that the rates must be raised or lowered in order to match the guaranteed level of income, the utility asks the public utility board to grant a rate change.

### **Other Factors in Utility Bills**

1. Fuel adjustment charges.
2. Construction work in progress. Most inequitable features of utility rate structures due to:
  - (i) Invested rate structures,
  - (ii) Fuel adjustment clauses, and
  - (iii) Ratcheted demand charges. Inclusion of promotional expenses in utility costs.

### **Economic Assessment of Energy Projects**

They are economically justifiable if the following conditions are fulfilled:

1. The benefits of the project exceeds its costs.
2. The project is more profitable than alternative methods of achieving the same objective.
3. The project is on the proper scale to achieve optimum economic results.
4. Capital is available to complete the project.
5. Each segment of the project is economically justifiable.

*Illustration:* Electricity tariff may be taken as the function of energy costs. Costs of electric energy can be divided into four components: (a) capacity-related costs, (b) energy-related costs, (c) maintenance costs and (d) consumer-related costs. The capacity related costs are generally the fixed portions of the total costs, i.e., costs for installed capacity known as kilowatt costs. Energy-related costs are the costs for energy used. The unit of this is kilowatt hour (watt x time/1000). The maintenance costs have fixed and variable portions, the fixed portion being for depreciation of machineries, equipment, etc., that's, capacity related to costs, and the variable portion being energy-related

costs. Finally, some costs such as metering, billing, etc., which are different from the costs in items (a) and (b) are known as customer-related costs. The average cost, i.e., cost per unit sold has, therefore, three components: (i) per unit fixed cost; (ii) per unit variable cost; and (iii) per unit transmission and distribution losses. In a country like India where tariff policy is mainly guided by accounting criteria, though in some cases the administered price also reflects the marginal costs, the tariff should cover at least the average costs.

If we assume that the average cost determines tariff, then the charge of the consumer would be determined by the per unit fixed cost and per unit variable cost (including transmission and distribution losses). The tariff for the consumers therefore covers, first, the demand-related charge, and, secondly, the energy-related charge. The demand-related charge varies according to load factors with the rise in consumption, the load factor rises and the demand related charge varies. Thus the tariff rate ( $T$ ) varies with average total costs ( $A$ ). Symbolically,  $T = A$  and if  $a$  = fixed of the average cost,  $b$  = variable portion of average cost and  $L$  = local factor, then

$$PA = a/L + b;$$

hence for a particular situation if  $a$  and  $b$  remain constant, then the tariff rate varies with the change in the percentage of the load factor. The policy of tariff making should be such as to cover the cost per unit sold. It is assumed that in tariff making both fixed costs and variable cost are considered. The cost per unit sold constitutes both fixed and variable costs per unit sold.

### Economic Aspects of Renewable Energy Systems

In India, nearly 1.05 million biogas plants were installed in March 1989, saving a firewood equivalent of 4.5 million tonnes/year, and fertiliser worth of Rs. 3,000 million per year. The smokeless stoves provided for 4.79 million families have saved 3.35 million tones of firewood and Rs. 1,340 million per year. 250 million KWh of energy per year is supplied by the solar thermal system. In 1989, 4,300 villages were powered with solar photovoltaic systems.

### Special Characteristics

1. Decentralised production and use involving a large number of producers and consumers requiring extension services and coordination of activities.

2. Higher initial cost compared to that of conventional systems but zero or low cost of fuels.
3. Low gestation periods.
4. No requirement of transmission lines and distribution systems, thus reducing costs and/or time for construction.
5. Use of local resources and indirect benefits along with positive environment impacts.
6. Modular nature of equipment through which the size of the system can be adapted to requirements.
7. Variability in supply during the day as well as over seasons/years requiring back-up or storage systems.
8. Location and site specificity of resources.

These characteristics of the renewable energy system would require an appropriate methodology for economic analysis which should:

1. explicitly consider the levels of output along with its variation over time.
2. effect the advantages of lower gestation lags in the case of RES when compared with conventional systems.
3. consider the high shadow price or opportunity cost of power.
4. renewableness and no negative environmental impact.

#### **Analysis in Terms of Social Cost Benefit Analysis**

The benefit-cost ratio of the micro hydel systems is 1.68.

The bio-mass conversion capacity of 3 tonnes/day: 2.39.

#### **Costs**

Cost of power 5 MW windfarm in

Muppandal	- 0.68/kwh.
Cost of power from diesel	- Rs. 2/kwh
Coal	- Rs. 1/kwh.
Micro hydel	- Rs. 0.47/kwh
Sludge gas power	- Rs. 0.40/kwh.
Biomass-based power	- Rs. 0.60 to Rs. 1.65/kwh

#### **Solar Thermal**

Jha (1987) has compared the cost of power generation in Punjab from a 30 MW solar thermal power plant with that of a coal-based thermal plant. The cost of power generation from the solar thermal power plant was reported to be Rs. 1.74 per kwh, which included a cost of 15 per cent auxiliary power through a rice

straw based power plant. He also estimated the cost of power generation with a storage of 4 hrs per day which came to Rs. 1.45 per kWh.

The cost of power generation through a coal-based thermal plant was estimated at Rs. 1.11 per kwh in 1986, Rs. 1.76 in 1966 and, Rs. 2.58 per kwh in 2006 assuming a cost escalation of 10 per cent per annum

**Table 6.1: Comparison of Economic Costs (Raju, 1988)**

	<i>Coal</i> STPS 1000 MW	<i>Coal</i> TPS 210 MW	<i>Hydro</i> 275 MW	<i>Diesel</i> 30 MW	<i>Solar</i> 30 MW
Economic cost with adjustment of fuel price Rs./kWh	1.11	1.43	0.53	1.13	.164
Benefit adjusted cost of generation Rs./kwh					
Punjab	1.11	0.85	0.63	0.69	0.57
Rajasthan	1.11	0.80	-	0.62	0.40

Cost of power generation from some renewable energy sources without taking account of environmental and gestation benefits.

*Source*

1. Wind Rs. 0.68 - 1.25/kWh
2. Micro-hydel Rs. 0.47 - 1.25/kWh
3. Biomass co-generation Rs. 0.60 - 1.00/kWh
4. Agro-waste based gasifier (5KW) Rs. 1.85 - 2.00/kWh
5. Sludge gas based engine Rs. 0.40 - 0.60/kWh
6. Solar thermal power plant (30 MW) Rs. 1.50 - 1.60/kWh

### 7.8. Problems of Energy Pricing

The fiscal and welfare objectives of public utilities have several implications for pricing. While the fiscal objective is related to fair returns on capital invested, the welfare objective is related to the minimisation of utility from the output for the benefit of society. The technical characteristics of public utility industries are often such as to enable the practice of differential pricing of the product for different consumers or consumer groups. The

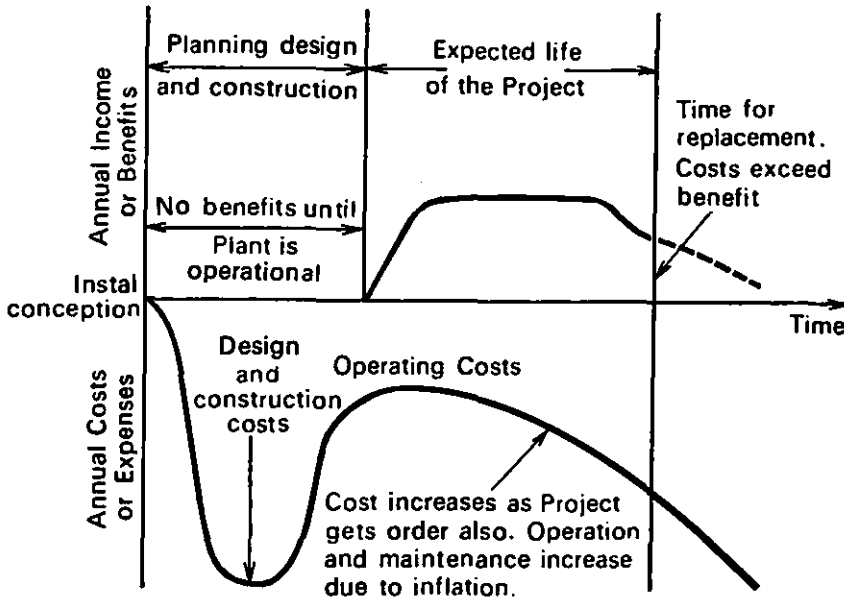


Fig. 6.1: Benefits and Costs of Energy Projects

conditions necessary to practise differential pricing are: (1) monopoly near-monopoly conditions on the supply side (2) a total demand that can be further divided into separate markets each with a different price elasticity of demand; and (3) some means of insulation of each market from the others, so that those who buy at the lower price cannot sell the product to those who can pay higher prices.

*Problems of Pricing in Electricity Supply*

Electricity undertakings also have fiscal objectives, which are usually decided by the government, and not unoften the welfare objectives of the undertakings come into conflict with those of the former. Price discrimination, cross-subsidisation and multipart tariffs often serve as mechanisms of solving this problem.

A sound pricing structure is expected to fulfil at least three objectives: (i) accrual of a fair return on capital invested; (ii) a fair distribution of costs among the consumers; and (iii) reduction in wasteful uses of electricity and promotion of all justified uses of electricity.

The technical problems of electricity pricing are those of tariff-making which are (a) 'complexity' due to the mass of technical detail which must be considered in designing and administering rate schedules; (b) 'ignorance' of rate-makers of demand and supply functions; and (c) the need to consider numerous conflicting standards of fairness and functional efficiency.

#### *Traditional Approach to Electricity Pricing*

Historically, pricing policies in the electricity industry have been dominated by professional public utility managers and engineers. As explained by Turvey, the traditional approach is basically an 'accounting' approach. It usually begins with a comprehensive stocktaking of all assets, old and new, from which certain 'capacity-related' costs are derived. Then various 'energy-related costs' are evaluated.

The basic principle underlying this approach, which still governs rate-making in many public utilities around the world, is that accounts or historical costs should form the basis of pricing.

Economists have now generally agreed that the accounting approach is inadequate for efficient resource allocation. Accounts are concerned with recovering historical or sunk costs, whereas resource allocation emphasises the actual (existing) resources saved or used by every consumer decision.

The accounting approach also ignores the incentive effects of tariffs. Tariffs give incentives to consumers by telling them when electricity is expensive, e.g., during peak hours. Incentive effects are thus relevant in regulating electricity demand in accordance with the requirements of the undertaking, which incurs different costs during different periods of the daily cycle.

#### *The Case for Marginal Cost Pricing*

When discussing the traditional accounting approach, we emphasised that for efficient resource allocation, prices should be related to the resource costs of changes in consumption. This, in essence, is a statement of the marginal cost pricing approach.

The rationale of the principle lies primarily in welfare economics and the need for optimum resource allocation. If society's scarce resources have to be allocated efficiently among alternative uses, the price of a commodity must equal the marginal cost of its production. Prices have two main economic functions, viz., to discourage excessive consumption of a commodity, and to induce the desired supply of that commodity.

Such pricing will cause individual consumption decisions to conform to the national interest if (a) consumers are well-informed and rational, (b) the distribution of income is taken as given, (c) the cost to the industry of responding to consumption charges coincide with social costs, i.e., value to the economy of the resources involved (this means absence of external economies or diseconomies) and (d) prices of substitutes and complements from electricity are equal to their marginal (social) costs.

#### *Peak Load Pricing*

Peak load pricing is nothing but a corollary and an application of the marginal cost pricing principle and denotes a system based on marginal costs which vary by time of day or season in the year. Even with the existing capacity, which is itself a mix of plants of differing efficiencies, energy costs (i.e., variable costs) can vary during different hours. With unevenly distributed demand, plants come into operation in accordance with the rule that the most efficient plants are operated first, followed by successively less efficient (i.e., giving higher unit costs of electrical generation) plants in the 'merit order' of operations.

It is known that the study of electricity pricing requires a detailed analysis of cost structure, particularly a marginal cost analysis. Also the different types of costs, viz., generation, transmission and distribution costs, and the structure of their marginal costs are required to be studied. In India, the accounting criterion, i.e., the average cost is mainly considered for tariff-making. However, a study of the pricing policy of an electricity undertaking has examined the general problems involved in fixing tariffs for electricity at levels which would ensure that the undertakings not only covered their costs but also earned a rate of return appropriate to a low risk industry in the existing conditions.

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## ENERGY DEMAND MANAGEMENT

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Demand management is necessary for two reasons: to reduce the energy used per unit of output in the economy and to induce a shift from high cost sources of energy towards cheaper ones, either domestic or imported. Recent experience shows that both effects can be achieved by the use of a range of demand management methods.

Most of the experience with energy conservation has been gained in the industrialised countries where a variety of programmes have successfully reduced the energy used for a given level of economic activity. There are many obvious differences between industrialised and developing countries in the level of per capita energy consumption and in the sectorial pattern of energy consumption. However, there is a growing body of evidence, including the energy conservation projects and energy sector assessments carried out by the World Bank, which indicates that in developing countries, too, substantial energy and cost savings through better demand management are both feasible and cost effective. Many developing countries have embarked on programmes to influence demand for various sources of energy, but few have as yet formulated comprehensive strategies for managing energy demand.

The substitution efforts already under way in other developing countries include the replacement of oil by gas in Bangladesh, Bolivia and Pakistan; by coal in Zambia; and by bagasse in Mauritius. In the vast majority of developing countries, however, this process has barely begun and progress will require the resolution of a variety of institutional policy and informational difficulties and the development of a well defined national energy demand management programme.



## **Management of the Energy Sector**

### *Scope of the Problem*

There are several reasons why management issues, at the national and enterprise level, tend to be complex in the energy sector, particularly during this period of transition. Not only are individual projects complicated to design and execute, but certain energy investments are complementary to each other while others are mutually exclusive and decisions on energy are inevitably closely linked to almost every other aspect of development strategy. Moreover, these decisions have to be taken on the basis of imperfect information about the energy resource base and in an environment where future energy demand and relative prices are subject to considerable uncertainty because of factors over which energy policy makers themselves have little control.

Several peculiar characteristics make the planning and management of energy investments especially complex.

The resource base is unavoidably uncertain—either because its physical characteristics cannot be perfectly known before exploitation starts (in oil, coal, gas, geothermal energy and hydro power) or for other reasons. For example, variations in the supply of bagasse for power generation or of molasses or sugar for ethanol production, depend on the weather or the state of the world sugar market.

The technology is now rapidly changing and risky. Offshore exploration, deep drilling and enhanced oil recovery are difficult technologies to handle even for international companies, who often rely on specialist contractors. The more sophisticated technology of power generation, such as nuclear, require extraordinary caution to avoid technical and economic errors. Underground coal mining presents natural, environmental, health, accident and organisational problems.

The investments are lumpy: single investments often amount to several hundred million dollars and in some cases are as large as the nation's annual GNP. Mistakes are costly. The scale of investment can give rise to formidable problems in assembling the finances from several different sources, both external and domestic.

Projections of energy demand are highly sensitive to macro economic developments which are difficult to predict. Every

investment requires a long planning horizon of 10 to 20 years. Over such a long period, there is a wide range of possible patterns of growth and structural change and hence of energy demand. This may make it worthwhile to keep some strategic options open as long as possible. The risks of so doing must be evaluated along with the conventional level cost analysis of options.

Since energy investments tend to be large, their gestation long, and their benefits difficult to estimate precisely, projects have to be carefully planned and quickly executed. The cost of delay or failure can be enormous. A hydroelectric installation, for example, that happens to have a lower generating potential than planned, or whose commission is delayed, could seriously affect the variability of a number of other projects.

Some investments in fuels, or in equipment to use them must be made before the markets for them are assured, so that efforts are needed to promote their products: examples are improved woodstoves, liquefied petroleum gas for household or vehicular use; and charcoal, solar, or other renewable energy sources.

Because energy investments are both very risky and offer potentially high rates of return, it is often necessary and feasible to involve foreign equity partners. This requires negotiation of suitable arrangements to share the surplus.

The limited extent of domestic private sector activity in energy production and supply in most developing countries places an extra management burden on the public sector in this area.

Environmental considerations are also important. The development of a large hydro project could entail the inundation of settled rural areas; coal burning power stations or industries can seriously pollute the air unless appropriate equipment and controls are installed. These environmental effects have to be explicitly considered in the course of evaluating alternative energy investments.

Decisions on energy investments can rarely be made in isolation. The timing of hydropower investment, for example, depends on the projected growth of electricity demand, which often depends critically on a few large industrial users; the planning of a gas pipeline may be linked to the location and timing of a fertiliser plant; the design of a refinery may depend on the projected evolution of transport demand and the type of

vehicles in use. Investments to supply alternative fuels to households may have to be judged on the basis of detailed market surveys and predictions of consumer behaviour. Such decisions require the installation of an extensive infrastructure (such as roads and pipelines) and equipment (refineries, processing plants and compression stations) that are highly capital intensive. Choices among alternatives can be complex. When there is only one economic option for energy supply, its adoption is not open to question if its actual cost turns out to be significantly higher than estimated. But if there are several options whose estimated costs are close, it becomes much more important to ensure that the initial cost estimates are accurate. At the margin, some of the options (some hydro power projects, coal mines, or enhanced oil recovery) may be more expensive to the economy than the import of oil. The evaluation of these projects must carefully consider the trade-offs between costs of supply and strategic considerations such as achieving national self-sufficiency in energy.

Energy is an input or an output in almost all productive activity and consequently the linkages between energy and the rest of the economy are strong and intimate. Not only do energy investments compete with those in other sectors for scarce investible resources, decisions on them cannot be taken without careful consideration of their interrelationships with policies and trends in the rest of the economy. These relationships have many dimensions.

1. The impact of oil imports and exports on balance of payments prospects is well recognised and, for most countries, production arrangements and depletion policy can be nationally established only in the context of a long term view of development priorities and vice versa.
2. In all countries, industrial strategy is closely linked to energy demand and energy costs have a strong bearing on the profitability of different industrial options. The long term impact of energy prices on industrial structure and efficiency is significant.
3. The same applies to policies affecting the pattern of utilisation, transport, infrastructure and the relative emphasis on different modes of transport.
4. Measures to increase the supply of fuelwood will involve changes in the management of forests and pattern of

reforestation which, in turn, may conflict with existing agricultural practices. These linkages pose a special challenge for the managers in this sector. Though developments outside the energy sector are largely out of their control, the latter have a greater bearing on the success of their efforts.

Linkages are important not only in investment programming, but also in decisions affecting the structure of prices. Energy prices not only influence the choice among fuels and the financial viability of energy investments and energy producers, they also have a direct impact on the distribution of real income, since energy is a significant item in household expenditures. Therefore, energy prices can have a significant indirect impact through their influence on the profitability of industries and services ranging from steel mills to biomass collection.

#### Measures for Managing Energy Demand

The specifics of such a national energy demand management programme must obviously vary from country to country, but it is possible to identify four broad categories of measures that can be used to achieve the twin goals of raising energy efficiency and replacing costly sources with cheaper ones:

- a) Energy pricing policies;
- b) Taxation and other fiscal incentives;
- c) Direct capital allocation; and
- d) Technical assistance, training programmes, regulations, and promotional and educational programmes.

#### *Pricing*

The most important of these measures is an energy pricing strategy which provides energy users with an incentive to eliminate energy waste and to choose fuels on the basis of their costs to the economy. In recent years, many developing countries have recognised the central importance of pricing in strategies to manage the energy sector, and have begun to raise prices to reflect increased costs, especially those of petroleum fuels. However, in some areas and countries there is still a tendency to keep energy prices considerably below opportunity costs.

In the oil importing developing countries, increases in the costs of oil have generally been passed on fully and promptly to final users and the weighted average of retail prices of petroleum

is higher than import parity in nearly all of them. In many countries, the increase in retail prices has been quite substantial in recent years. The real domestic price increase of petroleum products in terms of local currency between 1975 and 1981 was about 40 per cent in Korea; about 60 per cent in Brazil, Pakistan, the Philippines and Turkey; and over 200 per cent in Colombia and Yugoslavia.

The situation is more mixed in the electricity sector of oil importing countries. Of 33 countries surveyed by the World Bank, 18 have increased their tariffs in real terms since 1974, and some, for example, indicate that strategies designed to influence the transport mix should take explicit account of energy costs and the availability of alternative transport fuels. Typically, 65 to 80 per cent of the fuel consumed in transport in the developing countries is used by road vehicles; of this, trucks consume 60 to 80 per cent, indicating the need for special attention to this industry.

The scope for energy saving measures in road transport is significant, but they are less well known or developed than energy saving measures in industry. Experience in some countries shows that the training of truck and bus drivers and supervision of their driving performance can reduce their fuel consumption by 10 per cent or more, while better vehicle maintenance—this includes regular tune-ups, maintenance of tyre pressure, use of radial tyres and wind deflectors and prompt replacement of air filters—can save 5 to 15 per cent of fuel. Even larger savings are possible by improving the utilisation of vehicles, mainly by reducing empty backhauls and by using truck sizes and designs appropriate for the loads to be carried.

As in industry, it is useful to distinguish between large users and small users. In the case of large users (trucks), it is possible to audit the efficiency of vehicles and to train and monitor drivers and vehicle maintenance staff. Among small users, greater reliance has to be placed on information, promotion of awareness, innovative regulations, and the availability of equipment that can monitor and enhance energy efficiency. Appropriate energy pricing is vital, supplemented by a structure of vehicle taxes and import duties that encourages the use of fuel efficient vehicles. In countries that manufacture vehicles, a special effort should be made to stimulate local producers to improve and publicise the fuel efficiency of their products.

Significant savings in road transport fuel are being realised in urban centres through traffic management designed to alleviate congestion. Schemes in Brazil, Singapore, Thailand, Venezuela and other countries have achieved savings of 5 to 15 per cent through various restrictions, special bus lanes, or improved signalling. Compared with their costs, such schemes yield large benefits.

There are opportunities for improved energy efficiency in other modes as well. Trains in North America and Europe have been modified to consume 3 to 10 per cent less diesel fuel; ships and aircraft can also be made more fuel efficient, initially through improved maintenance and operation, and subsequently through replacement by more fuel efficient models. In certain situations, alcohol can replace gasoline in road vehicles. Railways can be electrified (as in India), and some road vehicles can be made to run on compressed natural gas (as tried in Bangladesh) and liquefied petroleum gas (for example, in Thailand).

### **Households**

The household sector accounts for a small portion of the total commercial energy used in developing countries—typically less than 10 per cent in the middle income countries. However, these statistics are somewhat misleading because they exclude fuel wood, which is the principal fuel for households in developing countries. If fuel wood and agricultural and animal residues are included in the national energy balance, the household sector is the largest energy user in most developing countries, accounting for almost half of the total energy used in most of these countries and up to 90 per cent in some of them (for example, Burundi, Malawi, Nepal and Rwanda).

Because of the limited use of commercial energy in the household sector, coupled with the tendency of government to hold down the costs of kerosene, electricity, and indigenously produced coal, higher international energy prices have had a limited effect on direct energy costs incurred by households. Nevertheless, the economic value of household energy consumption is substantial in some countries, particularly those in temperature zones and considerable scope exists for improvements in home heating and cooling equipment, insulation and substitution by more economical sources (such as coal, biogas and solar devices).

The situation for fuel wood, which is used principally for cooking, is different. Despite its increasing scarcity and, therefore, higher prices and increased gathering time, wood is still burned very ineffectively in the developing world. When food is cooked over an open fire, as is common in many developing countries, only about 5 to 10 per cent of its energy content is typically used. Many traditional stoves are not much more efficient. Laboratory and field tests show that wood requirements can be at least halved through the introduction of improved stoves. Considerable work has been done in many developing countries in designing a first generation programmes aimed at promoting them. However, it has been more difficult than envisaged to design stoves which are simultaneously cheap, much more efficient, and made of materials that can easily be obtained in poor areas. Second, people have been reluctant to use new stoves which do not provide some of the ancillary benefits of traditional open fires or where fuel wood savings are not perceived as important enough to warrant the cost of the stoves. Finally, many of these programmes have been hampered by a weak and uncoordinated institutional framework and by the absence of a clearly defined strategy for action.

Despite the generally disappointing experience so far with this initial series, improved wood stoves should be the main focus of any energy demand management strategy for the household sector in most developing countries. Realising their potential will require greater support for work which has already started on a second generation of stove programmes characterised by the adoption of a more systematic approach to stove design and promotion, and a reorientation of focus towards fuel wood users who are most conscious of the fuel wood problem—particularly urban and semi-urban households. For these households, wood is already a commercial energy source and cash savings could provide them with a strong incentive for buying a stove which reduces wood consumption. An increased focus on urban wood uses will probably also lead to greater emphasis on promoting fabricated metal or ceramic stoves. Such stoves have already been successfully introduced for charcoal use in a few countries.

### **Commercial and Institutional Buildings**

The commercial sector is becoming an increasingly important user of energy in the middle income developing countries and in

some small countries where airconditioning, particularly of hotels for tourists, accounts for a significant proportion of electricity demand. In these situations, the scope for energy savings may be sizeable. In existing buildings, savings of up to 25 per cent can be achieved through better energy management, improved control and monitoring systems, and minor retrofitting investment, improved standards and regulations for the design of new buildings. Substantial advances have been made in these areas in industrialised countries and a variety of new techniques, equipment, and materials have been developed. Governments can help in this regard by providing information on new designs to the local architectural community, by revising the codes and regulations governing new buildings, building equipment and materials and by stimulating audit programmes and the production or import of energy management technology and knowhow for the building sector.

### **Electric Power**

Energy is consumed in the conversion of primary energy into electricity and in its distribution to customers. A review of available data for 76 developing countries shows that in half of them, the power transmission and distribution system 'loses' 15 per cent of the electricity generated. These figures include both technical losses and unmetered consumption. All types of losses cause financial difficulties for the utility and require corrective action, but technical losses represent economic losses for the country. It is expensive to reduce losses, however, so the lowest possible losses are not necessarily the most economic. Their optimal level depends on the load and network characteristics of the system and on the marginal costs of supply. Research by the World Bank indicates that under normal circumstances, transmission and distribution losses should be between 4 and 8 per cent of total annual generation and between 7 and 12 per cent of peak power. Thus, the typical power system in developing countries needs to reduce its losses by one-third to one-half. Many of the countries with higher loss rates also have low per capita incomes and high energy costs and can least tolerate this economic waste.

Reducing technical losses in transmission and distribution requires two sets of actions:

- a) Determination of optimal loss levels and design standards for existing and new facilities, and



- b) Investments in loss reduction facilities, including reactive power control with capacitors, reconducting, addition of feeders, higher capacity transformers, and load switching equipment.

Recently, general budget constraints on public investments have induced utilities to defer reinforcing their distribution systems because, for a year or two, doing so has less effect on the power system's capability than failure to increase generating capacity. The evidence shows, however, that it can be nearly three times cheaper to save one kilowatt (KW) of electricity by improving the distribution system than to produce an additional KW from new generation loss rate from 10 to 15 per cent could be equivalent to one year's demand growth. Programmes to reduce power system losses are an increasingly important feature of the Bank's work in the electricity subsector.

The scope for reducing generation losses in an electric power system depends primarily on the marginal cost of generation, the standards of design, maintenance and management, and occasional possibilities for retrofitting thermal stations. Countries such as China and India, where thermal generation produces more than 80 per cent and 50 per cent respectively of the total power supplied, have considerable scope for such improvements, energy audits of thermal generating plants should be carried out to determine what should be done and how. One major necessity is to restore the efficiency of existing units to their design level through improved management. A second necessity is to ensure that the design of new plants is economically optimal and that it considers future cost structures and levels.

#### **Weaknesses in Management**

Few countries, industrialised or developing, have coped altogether successfully with the challenges posed by energy developments over the last decade. It is hardly surprising, therefore, that developing countries have management problems both at the national and enterprise levels. Weaknesses in management can have an enormous impact. For example, in coal, poor maintenance and failure to plan for the availability of spare parts can keep between one-fourth and two-thirds of the mine-trucks out of action, while operators who lack proper training may lift only half the normal volume of coal per shovel. In power,

huge technical transmission and distribution losses may not even be recognised if operational losses are not properly analysed and revenues are not collected efficiently.

The most common weakness in energy enterprises can be found in all types of public enterprises in developing countries. These weaknesses include insufficient experience and training of the key staff, poor management practices and lack of familiarity with technologies and operating practices in more advanced systems. They are compounded by poor infrastructure, a lack of specialised consultants, and the generally low level of education and skills among the workforce. They are also exacerbated by the tendency of enterprises to use their own scarce managerial and technical staff for tasks that could be subcontracted to private industry on a long-term basis. Where too few technical staff are available, managers concentrate on crises to the neglect of training new staff and of preventive maintenance, leading to a vicious circle of new crisis.

#### **Priorities for Action**

The preceding analysis has identified a variety of areas for urgent action to strengthen the developing countries' ability to manage the energy sector. While the priorities for action in each country will need to be determined within the specific context, two areas which require widespread attention are the need to improve the quality and volume of pre-investment work, and to strengthen the strategy formulation, overall management and manpower capability, at both the enterprise and national levels.

The importance in the energy sector of good pre-investment work needs to be emphasised. To plan power generation, for example, it is necessary to identify the least cost generation plan, which in turn requires a systematic survey of the hydro power potential in the country. Such surveys require hydrological records covering many years to determine river flow patterns under various conditions. Unfortunately, such records are still lacking in most developing countries. In a recent study by the World Bank of pre-investment requirements in hydro power generation worldwide, it was concluded that about \$2 billion would be required for surveys and studies over the next decade. Related roughly to the 180 GW of hydro capacity to be added during 1985-86, this amount is only about 1 per cent of the final investment cost and is well justified in terms of potential cost savings alone. Apart from the financing, what is lacking is the

recognition that such surveys are important as are the preparatory work and administrative arrangements to implement them. On a smaller scale, but equally important, is pre-investment work in other energy subsectors; geological and geophysical studies to guide petroleum exploration; preliminary studies of the market potential for natural gas so that discoveries can be speedily exploited; and the collection of site-specific data on wind speeds and insolation.

The organisation of pre-investment work is only one aspect of a broader need to strengthen institutions in the energy sector. It is necessary to establish a working environment that will maintain the continuity of management and help to retain qualified staff and to upgrade their skills. The latter will involve formal training and refresher courses as well as closer contact with experienced staff in international industry, consulting firms, and leading agencies involved in project preparation and appraisal.

It is also necessary to ensure that major proposals concerning investments and pricing are analysed with a broad perspective of the sector and the nation, rather than in an isolated, uncoordinated manner. This is particularly important given the uncertainties affecting the future evolution of energy demand and supply. To achieve these changes will require both staff devoted to long-run planning at the national level and a small, qualified group of analysts at the national level to advise the key decision makers on overall sector policy issues and on ways to strengthen the institution operating in the energy sector.

The planning staff at the national level would be responsible for coordinating enterprise plans, and for formulating a strategy to achieve specified goals. They would also be responsible for evaluating the effects of exogenous changes (for example, in economic growth or international energy prices) on the demand and supply prospects for individual fuels and for ensuring that subsector investment programmes and pricing policies were altered quickly to take account of these changes. A central energy secretariat may also be concerned with efficiency in energy use. It may oversee programmes to reduce energy for improving efficiency in the use of energy and disseminate information on how to save energy. It would ensure that adequate financial and managerial sources were being devoted in each of the subsector operating agencies to improve the efficiency of existing plants and operations. This is important even if the energy source is

imported. Significant reductions in the oil import bill can be achieved by switching to a alternative source or methods of supply.

### Role of External Assistance

The main effort to improve energy management has to come from the countries themselves. In some vital areas, for example, in the reform of the relationship between government ministers and public enterprises, external agencies, such as the World Bank, can highlight the problem and advice how it is being addressed in other countries. In other areas, there is greater scope for external assistance in improving enterprise management structures, accounting systems, and procedures for billing and collection, planning, operations, and maintenance, even though the social and political frameworks within which solutions must be sought are fully known only in the countries concerned. International financial agencies can also help by preparing terms of reference for selecting and supervising the performance of consultants for pricing studies, in establishing the manpower and financial requirements, and mobilising the funding. Through their joint energy assessment and sector management programmes, the UNDP and the World Bank are assessing the major energy problems of developing countries and helping to evaluate options for solving these problems and improving energy sector management (Tables 7.1 and 7.2).

**Table 7.1: Commitments of Bilateral Concessional Assistance for Energy (1975-80)**

<i>Donor</i>	<i>Dollars</i>	<i>Per cent</i>	<i>Energy as percentage of donar's total</i>
Canada	366	5	23
France	249	3	8
Germany	879	12	11
Japan	2125	28	25
United Kingdom	41	1	7
United States	1057	14	7
OPEC bilateral	1622	22	12
Others	1162	15	-
<b>Total</b>	<b>7501</b>	<b>100</b>	

*Source:* World Bank Debt Reporting System.

**Table 7.2: Multilateral Commitments for Energy (1975-81)**

	1975	1976	1977	1978	1979	1980	1981	Total
Asian Development Bank	153	147	217	249	325	480	480	1950
African Development Bank	19	13	27	28	64	52	32	235
Inter-American Development Bank	270	288	407	923	297	416	935	3636
European Investment Bank	26	90	41	48	188	348	140	881
SUB-TOTAL	4468	538	692	1248	974	1201	1687	6702
World Bank	584	1009	1102	1156	1467	2849	2233	10400
<b>TOTAL</b>	<b>1052</b>	<b>1547</b>	<b>1749</b>	<b>2404</b>	<b>2441</b>	<b>4048</b>	<b>3820</b>	<b>17102</b>

Source: Annual Reports of the World Bank

Training is an area where specific external assistance may be useful in several ways.

- a) Programmes within countries to train specialists in energy planing, economics, technolgies, finance and environment aspects; on the job management and technical training in energy companies.
- b) Workshops and seminars at which technical experts from development countries exchange ideas and experience.
- c) Overseas training courses in various specialities.
- d) Secondment of key individuals to foreign energy sector institutions and financing agencies.
- e) Re-orientation of training and educational institutions and programmes in the country concerned.

Training should be carefully focused to benefit the country in areas where it is most needed and can be of lasting use. For instance, unless the petroleum prospects of a country are well established, there is no point in training people for specialised tasks in petroleum production or gas pricing rather than in the basic skills of geophysics or surveying which can be employed in a wide range of activities, including mining and construction. Similarly, training in building sophisticated models of the energy

sector is of little value in countries where basic data and analysis of energy issues are still rudimentary. At the same time, the benefits that accrue from a well designed and well administered training programme must be emphasised. The high rates of return for such training make its higher cost well worth incurring and it is frequently a prerequisite for realising the full benefits of far greater investments in plant and equipment.

### **The Energy Sector Management Programme**

The United Nations Development Programme and the World Bank have recently launched an Energy Sector Management Programme designed to provide a rapid and flexible response to governments who request assistance in implementing the policy, planning and institutional recommendations of the Energy Assessment reports or in carrying out prefeasibility studies for energy investments identified in these reports.

The Energy Sector Management Programme can finance:

- a) assistance to improve a government's ability to manage its energy sector, for example, by defining staffing and work programmes, evaluating management information needs, identifying sources of public and private finance, and developing a medium-term investment plan.
- b) prefeasibility work on priority investment plans, especially those which will improve the efficiency of energy use and those which will provide enough affordable energy to rural areas.
- c) providing specific short-term assistance in institutional and manpower development.

The programme aims to supplement, advance and strengthen the impact of bilateral or multilateral resources already available for technical assistance in the energy sector. Though it is already under way, further resources are being sought from major donor agencies in order to realise its full potential to respond to the urgent requests of developing countries.

### **Official Lending for Energy Investment**

The World Bank is the largest and most diverse multilateral lender for energy; its commitment nearly quadrupled during 1975-81 totalling \$ 10 billion in that period. Commitments from the other main multilateral institutions also increased more than

threefold in the same period to a total \$ 6.7 billion. OPEC multilateral agencies also increased their energy project lending, with a total commitment of \$ 1 billion over the period. The share of energy in the total operations of multilateral agencies in 1975-81 ranged from 46 per cent for the OPEC fund, 27 per cent for the Inter-American Development Bank, 25 per cent for the World Bank, to 9 per cent for the African Development Bank.

Commitments of concessional bilateral assistance for energy rose from \$ 500 million in 1975 to some \$ 2 billion in 1980. Though bilateral assistance for energy has risen more slowly than other public external capital, energy has been the fastest growing area in many bilateral aid programmes. For the Development Assistance Committee members (including EEC), the share of energy in total aid programmes increased from 3.5 per cent in 1975 to 8.5 per cent in 1980. Over the 1975-80 period, Germany, Japan, OPEC and the United States accounted jointly for over 75 per cent of total concessional bilateral financing for energy investment in developing countries.

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## EVOLUTION OF ENERGY POLICY IN INDIA

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Though a comprehensive energy policy is yet to be evolved in India and the general awareness of the importance of energy problems is a recent phenomenon, certain specific issues of energy policy have received serious consideration by the government and influential leaders during the last four decades. Even before the attainment of independence in 1947 among the themes popular with Indian leaders was the wasteful use of cattle dung as a fuel by the rural poor and the depletion of forest resources.

In the early fifties an extensive nationwide campaign to plant trees, called the "Festival of Woods" or Vanamahotsav, was initiated on a national scale. But people viewed it as a typical example of the unimaginative and wasteful manner in which good ideas can be perverted by government agencies.

It was repeatedly stated that the level and pattern of consumption of fuels in rural as well as in urban households were adequately quantified for an analysis from which meaningful policy conclusions could be drawn. A survey therefore was organised in 1953 to assess the consumption of different fuels in the household sector. On the basis of an extensive field survey, the level of fuel usage in homes was quantified. It revealed a much larger dependence on cowdung than had been assumed. The study concluded that the only way of reducing dependence on the use of animal waste and firewood was to produce soft coke from low grade coals and supplying it for cooking to rural areas at subsidised prices.



During the 1960's it was recognised that an adequate supply of energy was a key factor in the development of the country. Any shortage of energy would hold up planned economic growth. The government therefore appointed in 1962 an Energy Survey Committee (ESC).

The Committee suggested that by using closed circuit trains, the cost of coal transported by rail to the power plants located at long distance from the washeries could be reduced to such levels that power produced from such thermal stations would become competitive.

Kerosene and diesel oil demand would increase due to the requirements of the transport sector, naphtha and motor gas would be in excess of the requirements, even if naphtha-based fertiliser plants were commissioned as proposed by the government. The Committee therefore recommended the reduction of the duties and taxes on motor gas so as to increase the level of its use.

The Committee concluded that storage hydroelectric was by far the cheapest method of generating electricity, especially for low plant factors and advised that India should continue to exploit hydroelectric resources wherever there are suitable sites available.

From 1965 to 1969 coal consumption was stagnant and oil consumption increased by over 50 per cent. Alarmed at this development, i.e., inconsistency of the fuel utilisation pattern with the endowment of resources, the government set up a Fuel Policy Committee of India (FPC) in 1970 with the following objectives:

1. To undertake a survey of fuel resources.
2. To study the present trend in the exploitation of fuels.
3. To forecast future demand by sectors and also to recommend,
  - (a) the outline of a national fuel policy for the next fifteen years;
  - (b) The pattern of consumption and measures which would help the best use of available resources;
  - (c) The measures and agencies to promote optional efficiency in the use of fuels.

The FPC identified the areas of feasibility of substitution among commercial fuels in favour of coal. Fiscal and

administrative measures suggested by the committee were mostly aimed at a reduction in the use of oil products. The following are the feasible and desirable areas:

1. In the domestic sector, soft coke could replace kerosene used for cooking and electricity could replace kerosene for lighting.
2. In the agricultural sector, irrigation pumps run on electricity could replace those run on diesel,
3. In the industrial sector throughout the country, furnace oil could conveniently be replaced by oil; and
4. In the transport sector, reduction in the use of gasoline could be obtained by increasing price reduction in diesel oil, this would be possible by the use of optimal-size vehicles and their better maintenance.
5. In the oil sector, the FPC made a systems study on the choice of fertiliser foodstock based on a programming model that simultaneously considered refinery planning and fertiliser production planning. On the basis of this study, the Committee recommended the use of different feed stocks, such as naphtha, furnace oil, and coal at different levels in the future.

The recommendation of the FPC about the electricity sector was more inclined to support pit-head generating stations in preference to load-centre stations.

To meet the demand for energy in the household sector, and especially by rural households, the Committee made a number of suggestions, such as popularising biogas plants, setting up social forests near rural habitats and increasing the efficiency of cooking appliances.

The report of the Committee on power (1980) also known as the Rajadhyaksha Committee suggested a greater role for the Central Government in the generation and control of interest in high voltage transmission lines. It advocated more investment in the transmission and distribution network to progressively reduce power losses. The Committee criticised the under-utilisation of the existing capacity and felt that thermal plant maintenance and delays in getting spares should be avoided.

A Commission on Additional Sources of Energy (CASE) has been set up recently to find ways to meet the country's future energy needs. CASE has suggested that the Rural Electrification

Corporation should be made the model agency for biogas development. Greater attention needs to be paid to Research and Development to evolve techniques for biological conversion of vegetable wastes and agricultural residues into fuel.

### **National Energy Information System**

The Advisory Board of Energy constituted an Expert Committee to study the setting up of a computer energy information system and a data bank. The Committee produced a report in January 1985, which constitutes an important document on the Indian energy scene. The Committee took its task as a centralised source of energy information and presented to the Advisory Board on Energy the following activities:

1. To forecast energy for all important sectors of the economy. Suggest a fuel-mix and optimum strategy to meet the demand for various end-use activities.
2. To identify the scope for improving energy availability from the existing sources through improvements in operating efficiencies and controlling conversion, transportation, and storage losses through the entire fuel cycle.
3. To develop strategies for energy conservation, interfuel substitution and efficiency optimisation.
4. To suggest and promote alternative energy fuels to conserve scarce and depletable energy sources taking into account environmental impacts and economic viabilities.
5. To encourage use of renewable sources of energy or multiple fuel-mix strategies which suit local needs and promote self-reliance.

The committee decided to cover the following sources for the National Energy Information System and Data Bank (NEIS).

1. Energy supply sectors;
2. Energy transformation and transportation sectors;
3. Energy consumption sectors; and
4. Demographic and economic data sources.

The specific objective of NEIS laid down by the expert committee were:

1. To develop an integrated information system on the total energy status in the country, including energy demand, supply fuel-mix, energy and intensity of usages, end-use applications, new capacity augmentation duration, project costs, etc.

2. To determine the energy reserves/sources, the present exploitation levels, the growth rates and trends, the capacity utilisation of various energy fuels and their projected life span to meet energy needs.
3. To quantitatively assess the fuel efficiencies and the total energy losses of different fuels through the entire fuel cycle from production to final consumption and how these compare with the desirable levels or with other countries.
4. To provide information on the average costs of production of various sources of energy and supply prices to various sectors and provide interfuel and interstate comparisons.
5. To develop a more reliable and more consistent data base on potential sources, demand and consumption of non-commercial sources of energy by various sectors and end-use activities and identify factors influencing demand changeover and shifts to commercial fuels.

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## ENERGY PROBLEM AND PLANNING IN INDIA

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Energy is an obvious essential input in all types of human activities. The industrial revolution in the West was fuelled primarily by coal. Later, with the discovery of oil, the world increasingly depended on cheap oil as a source of energy. While the exhaustion of fossil fuels was perceived of as an emerging problem from around the middle of the century, it was the sudden rise in oil price in 1973 that awakened the world to the serious situation arising from the depletion of fossil fuels as well as their rising prices. Since 1981, however, there has been the curious phenomenon of a decline in the rates of growth of oil demand and a sharp fall in the oil prices, giving rise to the feeling that the energy problem has been overcome.

### **Nature of the Energy Problem**

We must realise that the impact of the energy crisis is far more serious for the developing countries than for the industrialised world. In the industrially advanced countries, the main concern is with maintaining a reasonable level of employment, preservation of their lifestyles and protection of their economic and political position in the global polity. The western world, in particular, has been able to insulate itself largely from the impact of the energy transition through recycling of petro-dollars, increased exports to the oil-rich countries and by structural changes in the economy, virtually decoupling energy demand from economic growth. Developing countries like India stand on a different footing altogether. With low levels of income reflected in low levels of energy consumption (and limited availability of capital

resources) and coupled with high population growth, the developing countries face the challenge of requiring increasingly high amounts of energy to sustain even a modest rate of economic growth. In India, the per capita consumption of energy is only about 200 kgs per year, which is about a tenth of the world average and about a fiftieth of what it is in the USA (Table below).

Table 9.1: Per capita Consumption of Energy

<i>Year</i>	<i>Per capita GDP Rs/Year (1980-81 prices)</i>	<i>Commercial</i>	<i>Non- Commercial</i>	<i>Total</i>
1953-54	1263	0.572	1.670	2.242
1960-61	1449	0.734	1.590	2.424
1965-66	1487	0.998	1.660	2.658
1970-71	1671	1.067	1.604	2.671
1975-76	1729	1.294	1.614	2.908
1980-81	1800	1.420	1.559	2.979
1984-85	2037	1.580	1.432	3.012
1987-88	2170	1.785	1.434	3.219

In the developing countries, therefore, continued availability of requisite energy at reasonable prices is crucial for their survival.

It is a fact that India has been fairly successful in withstanding the oil price increases of 1973 and 1979. How did this happen? A combination of fortuitous circumstances, viz., continued good harvests which enabled us to do away with food imports, increase in exports because of availability of idle manufacturing capacity, export of manpower to the Middle-east and slowdown of inflation—all of these helped to tide over the first oil crisis. As for the second, the increase in domestic oil production came in a most opportune time.

The present situation is however not favourable. Our own production of oil seems to have reached a plateau. Exports are stagnant and are running up against protectionist barriers. There is even a return flow of our manpower from the Middle-East. Both domestically and internationally, the environment is far from comfortable. Already, energy shortages are posing a constraint to growth. For India, the energy problem is still a reality and its future dimensions are likely to be even more formidable.

**Present Energy Situation**

India consumes energy in all its forms, starting from nuclear power at one end to traditional fuels at the other. Though, as already stated, the per capita energy consumption is low, the absolute quantities are enormous on account of the huge population. In 1986-87, India produced 165 Mt of coal (plus 7.8 Mt of Lignite), 30.3 Mt of oil, 3700 Mcm of natural gas and 190 Tw\* of electricity (including electricity produced from coal petroleum products. An analysis of the sectoral consumption of energy shows that industry and transport together accounted for 85 per cent, the balance of 15 per cent being shared by the agricultural and domestic sectors. Coal is the single largest source of primary energy, followed by oil. As regards non-commercial sources of energy, there are serious limitations of data. It is estimated that we are consuming about 130 Mt of fuel wood, 70-75 Mt of cowdung and 35-40 Mt of agricultural wastes every year. The share of non-commercial fuels in the total energy consumption has steadily declined, but it is significant even now, being around 45 per cent.

A measure of the energy intensity of the economy is provided by the energy-GDP elasticity, which is the ratio of the growth rate of energy consumption to the growth rate of GDP. Currently, taking commercial energy alone into account, the elasticity is estimated to be around 1.3, which is higher than in the western industrialised countries.

**Future Energy Demand**

For energy planning, it is obviously necessary to first estimate future energy demand. Such exercises have been carried out by various expert bodies and research scholars, using well-known methodologies such as trend, end-use and regression analysis.

According to the projections of the Planning Commission, the energy demand by the turn of the century will be as shown in Table 9.3.

**Energy Strategy**

Given the inescapable need for augmenting energy supply in order to sustain economic growth, one has to look at possible lines of policy action. Broadly, these may be stated as:

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\* Tw =  $10^{12}$  w =  $10^9$  kw =  $10^6$  Mw =  $10^3$  Gw

**Table 9.2: Total Gross Consumption of Primary Energy Consumption in Peta Calories**

<i>Fuel</i>	<i>1960-61</i>		<i>1970-71</i>		<i>1980-81</i>		<i>1987-88</i>	
	<i>Qty</i>	<i>%</i>	<i>Qty</i>	<i>%</i>	<i>Qty</i>	<i>%</i>	<i>Qty</i>	<i>%</i>
1. Coal & lignite	227.05	21.60	354.80	24.87	568.16	28.05	246.01	31.12
2. Uranium	-	-	7.22	0.50	8.96	0.44	15.02	0.59
3. Hydel	6.74	0.64	21.71	1.50	40.03	1.98	40.74	1.61
4. Liquid hydrocarbon	84.85	8.07	192.56	13.28	336.07	16.59	482.35	19.04
5. Natural Gas	-	-	5.98	0.41	14.06	0.69	73.63	2.91
6. Total commercial	318.64	30.31	582.27	40.16	967.28	47.75	1407.81	55.57
7. Rural wood	473.15	45.00	560.02	38.63	684.00	33.71	726.75	28.68
8. Dungcake	131.04	12.46	155.04	10.69	189.60	9.36	201.60	7.96
9. Agricultural Waste	128.52	12.22	152.46	10.52	184.80	9.12	197.40	7.79
<b>Total non-commercial</b>	<b>732.70</b>	<b>69.69</b>	<b>867.53</b>	<b>59.84</b>	<b>1058.40</b>	<b>52.25</b>	<b>1125.75</b>	<b>44.43</b>
<b>Grand Total</b>	<b>1051.35</b>	<b>100</b>	<b>1449.79</b>	<b>100</b>	<b>2025.68</b>	<b>100</b>	<b>2553.56</b>	<b>100</b>



Table 9.3

	1986-87	2000-01
Electricity (Tw)	190	424-465
Coal (Mt)	165	417
Petroleum products (Mt)	42.5	73
Fuel wood (Mt)	130	192
Dungcake (Mt)	70.75	105
Agricultural waste (Mt)	30-35	59

- (a) Maximisation of self-reliance by exploiting domestic energy resources;
- (b) Management of energy demand;
- (c) Energy conservation; and
- (d) Induction of new and renewable energy technologies.

We may now explore the possibilities in each of these directions.

#### *Exploitation of Domestic Energy Resources*

India's energy resources are limited, as will be apparent from the figures below:

Table 9.4

<i>Resource</i>	<i>Reserve</i>
Oil	558 MT (balance recoverable on 1.1.86)
Natural gas	497 bil. cum (balance recoverable on 1.1.36)
Coal	112 bil. tons (includes inferred reserves)
Lignite	2000 Mt
Uranium	70,000 T
Thorium	3,60,000 T
Hydroelectricity (potential)	1,00,000-1,20,000 mw at 40% load factor.

For a country with a population of nearly 800 million, which is still continuing to grow, these reserves must be considered to be very limited. In any case, it is apparent that, in relation to the growing demand, we are not comfortably placed in respect of oil and gas. Even the reserves of uranium are small. It is only if the fast breeder technology is mastered that thorium will prove a valuable resource. So far we have exploited less than 20 per cent of our hydro-power potential; certainly, there is room to tap the

balance potential. It is only in respect of coal that India is relatively well placed; the reserves should be sufficient to last for 60 years or more, even after taking into account the growth in demand.

Let us now take a brief look at the kinds of problems we face in exploiting the domestic energy resource endowments.

1. While quantity-wise the reserves of coal are substantial, we do not have enough coking coal needed for the steel industry. Even the non-coking coal is high in ash and is generally abrasive. The reserves of coal are located, in the main, in the eastern parts of the country, which lays a heavy strain on the railways to transport coal to different parts of India. What is most striking is the low productivity in coal production (output per manshift is only 0.91 t). If coal production is to go up sharply, the most important requirement is technological upgradation of underground mining. This not only calls for heavy investment, but requires large scale retraining of manpower. This will be a formidable task considering that the coal industry employs 600,000 persons. More attention has also to be given to improvement in the quality of coal delivered to consumers and in exploiting the possibility of movement of coal by sea to southern and western India.

2. So far as hydro potential is concerned, almost 40 per cent of the balance potential lies in the Himalayas, where access is difficult; the working seasons are short and the geology is complex. The responsibility for development of hydroelectric power lies mostly in the hands of the state governments, which are in no position to support high-cost, long-gestation hydro-power projects. Latterly, there is also a growing opposition to hydro-power projects from an ecological angle. Even as it is, the proportion of hydro-power in the total electricity generation has gone below the desirable levels. Measures have to be taken to maintain a proper balance between thermal and hydro-power.

3. Given our relatively abundant resources of coal and limited resources of uranium, nuclear power can play only a limited part. The country has made commendable technical progress in the design, manufacture and erection of nuclear power plants. This programme has to be maintained if we are to be able to make the technological advance into the era of fast breeder reactors. Besides, one cannot ignore the strategic aspect of nuclear power development.

4. Only a brief comment on oil and gas. Given our limited reserves and the fact that certain prognostications made a couple of years ago have turned out to be over-optimistic, there ought to be an indepth debate regarding the rate at which we should exploit our reserves, specially, at a time when international oil prices are low.

5. Apart from technical hurdles, the most important problem which the country will face in exploiting its energy endowments is the mobilisation of the required capital resources. All conventional energy industries are highly capital intensive. In the Seventh Five Year Plan, 30 per cent of the total outlay is allocated to energy. Even this is found inadequate. Can we push this up further without sacrificing other goals of national policy?

6. Among non-commercial fuels, demand for fuel wood will register the sharpest increase. In meeting the rising demand, the major problems to be faced are limitation of land, institutional problems at the village level and financial resources. Studies do however indicate that it is possible to sustain fuel wood supplies of over 200 MT a year. As regards cowdung, the strategy is not to increase the number of animals; therefore there is unlikely to be a rise in availability. A similar limitation will operate in the case of agricultural waste since this is dependent on the growth of crop production.

7. Viewed overall, the position is that the country will have to depend heavily on coal and hydro power, as well as on augmenting fuel wood supply. But finding the capital funds on a massive scale will prove extremely difficult.

#### *Management of Energy Demand*

The biggest challenge to India today is the management of energy demand and supply. As of today, some 30 per cent of India's primary energy supply is based on imports. The Gulf War has not only raised the cost of such imports, but the very sustainability of such imports is a matter of grave doubt. As of today, our economy does not appear to be geared to any disciplined, voluntary cutback in consumption even of petroleum products for a short period. Since the just oil shock of November 1973, energy conservation has been a major aim of all developed countries and the OECD countries have succeeded over the years in significantly reducing the elasticity of energy demand to GDP growth. Unfortunately, this elasticity is still quite high in India, more than twice that of the OECD countries.

Even today, non-commercial sources of energy (like cowdung, turgs, and other types of fuelwood and agro wastes collected by rural women and children) provide some 40 per cent of the country's energy requirement. This is exclusive of draught animals, power which accounts for much of the energy required for farming and rural transportation. The primary sources of energy are coal and lignite, diverse oil products and hydro-electric power. Nuclear energy and, of late, biogas and solar energy have provided a small percentage of the country's energy requirements. Added to that, wind power, ocean power and fuel wood constitute the primary sources of energy.

**Table 9.5: Consumption of Commercial Energy**  
(Sectorwise in Peta Calories)

Sl. No.	Sector	53.54	70.71	80-81	87-88
1.	Household	26.768 (14.32)	66.047 (14.64)	71.706 (10.44)	113.599 (13.16)
2.	Agriculture	2.690 (1.44)	10.724 (2.37)	40.401 (5.88)	73.009 (8.45)
3.	Industry	78.841 (42.15)	204.765 (45.39)	376.077 (54.74)	416.845 (48.29)
4.	Transport	74.766 (39.98)	153.452 (34.00)	171.46 (24.96)	217.027 (25.14)
5.	Other Sectors	3.948 (2.11)	16.144 (3.58)	27.341 (3.98)	42.644 (4.94)
	Total	187.031 (100)	451.153 (100)	686.985 (100)	863.124 (100)

*Source:* Energy Policy by Satish Chandran, IESC, Bangalore, Monograph.

The final consumption of commercial energy increased from less than 20 million tonnes of oil equipment (Mtoe) in 1953-54 to more than 92 mtoes in 1985-89. The implicit average growth rate was around 4.6 per cent per annum. However, the relative share of oil and oil products grew from 17 per cent in 1953-54 to 43 per cent in 1988-89 which underscores the increasingly heavy dependence of the country on this primary source of energy. Coal which provided some 80 per cent of energy in 1953-54 accounted for only 4 per cent of it in 1988-89. Oil products are doubtless a versatile as well as a relatively clean fuel. Electricity is also a clean source of energy though certain problems arise in the generation

of electric power. About 65 per cent of the total coal consumed in the country today is used for thermal power generation. Table 9.6 gives the percentages share of different sectors in commercial energy consumption.

**Table 9.6: Consumption of Commercial Energy (1987-88)**  
(Fuelwise in percentages)

S.No	Sector	Coal and lignite	Petroleum	Natural gas	Electricity
1.	Household	2.55	23.12	8.21	13.00
2.	Agriculture	-	12.58	-	18.95
3.	Industry	82.33	13.40	91.79	56.49
4.	Transport	5.79	47.96	-	2.21
5.	Others	5.33	2.94	-	9.35
Total		100	100	100	100

Source: *Energy Policy* by Satish Chandran, IESC, Bangalore, Monograph.

Though the elasticity of energy consumption with reference to GDP growth has come down significantly in the last decade—from 1.37 over 1970-71 to 1980-81 to 0.82 over 1980-81 - 1988-89 owing primarily to the higher rate of growth of GDP, the elasticity of demand is still very high as compared to developed countries where it is between 0.4 and 0.5.

In planning for the future, therefore, two desiderates need to be kept in mind. First, different paths or patterns of growth are likely to have widely divergent effects on the demand for commercial energy.

Secondly, in future the focus of attention needs to be changed from supply management to demand management in respect of energy.

#### *Management of Oil Demand*

Oil demand management will comprise partly substitution by other fuels and partly increase in the efficiency of use of oil products. Almost half of the consumption of oil products in India is in the transport sector. About 20 per cent is used for lighting and cooking in the domestic sector, 5 per cent for irrigation pumpsets and the balance in the industrial sector.

Crude oil production was to be raised to 49 million tonnes by the terminal year, 1994-95. After the Gulf crisis (and before the war), the programme was revised to 52 million tonnes even

though the oil producing authorities claimed that they could produce 54 million tonnes. It is important to remember in this context:

- (a) that very quick expansion of output, if targeted, can easily lead to undesirable practices like the flogging of oil wells to the detriment of the future, and
- (b) that a better and more sensible approach would be to moderate demand expansion through both conservation and interfuel substitution.

Even if we are able to raise oil production to 52 million tonnes and demand is of resources in this sector, there is need for a systematic change in regard to the former and there is considerable scope for improvement of the latter.

Two points are particularly important to note in this context. First, during 1988 and 1989, oil prices had dropped to an extremely low level, the real price of oil being really the same as prevailed before the first oil shock of November 1973. This appears to have induced a sense of complacency in regard to oil use and encouraged a pattern of investment which was particularly oil intensive.

Secondly, the dependence on imports for meeting the demand for oil products increased from some 30 per cent in 1985-86 to nearly 39 per cent by 1989-90. The value of imports of crude oil and petroleum products during 1989-90 was as high as Rs. 5,622 crores accounting for 15.9 per cent of total merchandise imports. Adding the import of coking coal for the steel plants, our imports of primary energy is now some 30 per cent of the total primary commercial energy supply.

The demand/consumption of different oil products in 1989-90 added up to some 54 million tonnes, and with domestic production of some 35 million tonnes, we had to import some 19 million tonnes of oil and oil products in 1989-90. At the rate the demand for oil products has been increasing—diesel oil by 9 per cent, motor spirit by 14 per cent and all oil products taken together by 7.6 per cent in 1989-90—the total requirement of oil products was forecast to increase to 77 million tonnes by 1994-95 to 101 million tonnes by 1999-2000 and to 127 million tonnes by 2004-05. With the best of effort domestic production is capable of being raised to some 52-54 million tonnes of crude oil by 1994-95 and it was felt that crude oil production may flatten out at some

65 million tonnes per annum by the turn of the century. Clearly, the situation points to the imperative need for both conservation and interfuel substitution, for the country cannot obviously afford to import the balance of the crude oil/oil products likely to be required in the event of demand continuing to grow at the present rate.

*Energy Conservation*

1. When we talk of energy conservation, the thrust is not on avoidance of use of energy, but on more efficient energy use. This is an area in which India's performance so far has been very poor. Though it is recognised that there is a large potential for energy conservation, there has really not been any concerted action so far.

2. As the largest consumer of energy, the industrial sector has the maximum responsibility for achieving energy conservation. The fact is that in a large number of industries, the specific consumption of energy (i.e., per unit of output) is higher in India than in the advanced industrial countries. Partly, the explanation lies in the fact that we have a large number of industrial units of suboptimal size and technological obsolescence. But the fact has also to be recognised that, owing to the availability of sheltered markets, Indian industry has not responded in a vigorous manner in achieving energy conservation. Good housekeeping, proper maintenance of insulation and instrumentation can themselves save some energy in the short run. To achieve more lasting results, change of process technology and measures for utilisation of waste heat may be necessary, requiring substantial capital investment. Apart from fiscal incentives offered by the Government, IDBI provides soft loans to meet such capital requirements. If Industry does not respond, there will be no alternative except to institute mandatory energy audits; at least a beginning could be made in selected industries.

3. Cogeneration of heat and electricity is an effective method of achieving energy conservation in industries such as paper, sugar and textiles. It is estimated that there is scope to generate 1,500 MW of electricity through cogeneration.

4. Most of the irrigation pumpsets used in India are poorly designed with a low power factor and often with a mismatch between the capacities of the pump and the motor. Their replacement by high PF motors and use of plastic foot valves and

pipes can result in 25-30 per cent saving in electrical power. In the transport sector, use of more fuel efficient engines and multi-axle vehicles and, of course, better roads, will contribute to energy conservation. We have to spread energy efficient 'chulas' by the million. There has to be a wider use of efficient kerosene and LPG stoves. Replacement of incandescent lamps by fluorescent lamps is also a step towards energy saving.

5. There has to be greater efficiency in the generation and distribution of energy itself. Energy losses in oil refining should be less. The percentage of recovery of coal in the underground mines should improve. Electricity systems, which suffer from large transmission and distribution losses and low fuel efficiency, offer large scope for improvement.

6. In the ultimate analysis, the pricing of energy is crucial for achieving energy conservation. In India, pricing of petroleum products has generally been designed not only to generate revenue to the Government, but to inhibit wasteful use of oil products. But both coal and electricity are underpriced, subsidies being often directed towards those sections of the community which are least deserving.

To repeat, there is still a long way to go in tapping the full potential for energy conservation in our country.

### **New Energy Technologies**

1. Though a large number of new and renewable energy technologies are under development, their immediate applicability on a commercial scale is limited. India does not have any significant resources of geothermal power or favourable sites for tidal power. Leaving aside the futuristic technologies, the areas which may be considered relevant in the Indian context are: solar, wind, micro hydels and biogas.

2. Wind speeds generally tend to be low in tropical countries. There is also not enough data about wind speeds in different parts and different seasons; so far, only the coastal areas of Gujarat and Tamil Nadu have been found to be favourable. As the wind speed constantly varies, any application requiring a steady output, such as power generation, presents some technical problems. The equipment, therefore, turns out to be very expensive (about Rs. 30,000-40,000 per kwh). But wind-operated devices may be suitable for lifting water for irrigation in areas where there is a seasonal match between availability of adequate wind velocities and requirement of water for irrigation.



3. Micro hydels are technologically not new. The main problem is that most rivers in India are not perennial and it is difficult to provide year-round supply. Micro-hydels could certainly be used in remote areas, such as in the north-east and also to tap the power potential where regulated flows are already available, such as in canals.

4. Being a tropical country, solar energy should be a good source of energy for India. But we have to remember that the solar insolation is of thin density and also varying in character. Concentration of energy and its storage make solar devices expensive and uneconomic. At present, solar cookers are commercially available in the market, but are not popular, specially in the rural areas, since rural families do their cooking mostly early in the morning or late in the evening. Solar water heaters are commercially viable and their use in urban homes, hotels, hostels etc., should be encouraged. Solar photovoltaic devices are currently suitable only for specialised applications on account of their high cost and low volume of production.

5. Besides the obvious use of biomass for directly burning as fuel, more efficient utilisation is possible through processes of fermentation to produce either biogas or liquid fuels. Biogas holds out high promise and even though the criticism is sometimes voiced that it is of benefit to rich farmers only, it is a programme which merits encouragement. It has multiple benefits providing energy, manure for the fields and improvement of environmental sanitation.

6. In Brazil, Ethanol based on sugarcane is being used in an extensive manner. But in the Indian context where there is pressure of land and demand for sugar itself, this is not an attractive proposition.

7. The overall situation in respect of new and renewable sources of energy is that they are still characterised by high costs and cannot achieve market penetration displacing conventional fuels. They cannot provide energy on the scale or of the type needed in industry and transport. Their applicability is limited even in rural areas. Therefore, in absolute terms, not much contribution is expected from them in the coming 20-30 years.

### **The Rural Energy Crisis**

The bulk of the energy consumed in the rural areas is today obtained from traditional sources, like fuel wood, agricultural

residues and animal wastes. Energy in animate forms (namely draught animal energy and human energy) is in use for production purposes in most parts of the country even today. The requirements of energy for household consumption are primarily for cooking and lighting. A major portion of the former in the rural areas is secured by the private efforts of individuals at a low private cost but at a high social cost in terms of the denudation of the forests. The consumption of commercial energy by way of electricity, kerosene, oil and diesel oil are increasingly used by the more affluent households, though kerosene oil is used by many low income households for lighting purposes. At the same time electricity is made available—for energisation of irrigation pump-sets—at highly subsidised rates to a few large farmers.

Most of the energy consumed in the rural areas does not enter the organised market place. Though there is no accurate data available on the patterns of supply and consumption of energy in the rural areas but the information on alternative sources of energy is available. These are:

1. Electricity supply, wherever it is available or likely to be easily available in the future.
2. Kerosene oil, used for both cooking and lighting, though usually for the latter in the rural areas.
3. Biogas which can be used for both cooking and lighting wherever available.
4. Fuel wood, animal wastes and agro-wastes used for cooking purposes.
5. Solar energy which can be used for both lighting and cooking.
6. Micro hydel power.
7. Wind energy for water pumping and generation of electricity.
8. Fossil fuels, i.e., soft coke and LPG can be used for cooking.
9. Biomass based on agro-wastes and quick growing tree varieties.

Rural energy planning should, therefore, be a decentralised exercise, with adequate provision of all necessary inputs at the village and block levels and with supplemental effort and investment only to bridge the gap between demand and locally available renewable sources of energy.

### **Energy Planning in India**

The Indian economy took the shock of oil crisis of 1973 remarkably well. While restrictions of various types were clamped on all kinds of imports, there was the Bombay High bonanza of trade surplus in 1972-73. We did it again in 1976-77. But after the U-turn of 1976-77, essentially caused by the execution of the Mahalanobis strategy and dramatised by several fortuitous circumstances, the international payments are once again in a quandary with objects around Rs. 5,000 crores in 1983-84 expected to go up to Rs 6,000 in 1984-85...

Solutions to this have been sought in the directions of:

1. Various forms of aid like the SDR Link;
2. Recycling of petro-dollars by IMF;
3. More respectable treatment of imports from developing countries;
4. Outright grants to them up to 7 per cent of GNP of the donor's invoking those principles of brotherhood and equality which a developing country may not be practising in its own domestic sphere and even a South-South dialogue; and
5. Setting our own house in order.

It may be allowed that, as Bhagwati and Little Mirrlees insist, inefficient restrictions mean several other losses. But there has been systematic liberalisation of foreign trade over about a decade now and the BOP gap is expanding. Success of world south or South-South dialogue is not in the control of the Indian government but economic policy may be so designed that imports in several areas may shrink remarkably and BOP may become more manageable.

### *Integrated Energy Planning*

For the developing countries the integrated national energy planning has come to acquire particular relevance in the context of their development programmes.

There are many aspects connected with energy planning such as:

1. The analysis of demand;
2. Management of energy demand and supplies;
3. Energy pricing;
4. Projections for the future; and
5. Technology development and assessment, investment of funds, etc.

However, there are two overriding considerations which merit the highest attention in energy planning. One, the undeniable need for ensuring an increasing and uninterrupted supply of energy.

Second, the need to examine the centralised and decentralised energy supply systems for meeting the requirements of the population.

One of the factors that needs greater attention in energy planning is the differentiation of energy needs by type of energy and quality of energy required. Thus whether energy is required in the form of heat, light, mechanical power or electricity needs to be examined in each case, and the supply and source of energy matched to get the optimum benefits.

#### *Factors Involved in Preparing the Integrated Plan*

1. Achievement of an optimum distribution of investment between centralised and decentralised systems.

2. Increased efficiency of energy use. This is achieved mainly by improving the efficiency of energy use in industry, transportation, agriculture and other sectors and also through the development of newer processes which are less energy intensive. These can lead to a reduction in the Energy-GDP elasticity ratio.

3. Assessment of availability of different resources, and the economics of their utilisation.

4. Improved and newer techniques of utilisation of existing energy resources including concepts such as cogeneration, MHD power generation, etc.

5. Gestation period relating to energy production. It is well known that large thermal stations, hydro power projects and nuclear power projects have long gestation periods, smaller units, especially those based on renewable energy sources, can be established in a much shorter time, starting production and thus generating economic activity much faster.

6. The overall goals of the energy policy which can include objectives such as provision of increasing supplies of energy, achievement of a smooth transition from hydrocarbons to other energy sources, maintenance of complete sovereignty on national energy sources, minimising problems relating to environmental gradation and transportation of fuels, etc.

7. Investment required in different energy systems. In most developing countries, investments on large conventional energy

facilities are made by the state, whereas investment on smaller and longer systems are expected to be made by individuals. This calls for a national approach to the sharing of investment costs including subsidies and other fiscal incentives.

The task of integrating all these elements and considerations and preparing a national energy plan is an extremely challenging one. The implementation of such a plan will require not only adequate financial resources but also other inputs such as trained manpower, appropriate and adequate institutional arrangements and other supportive measures.

Basically each country has to harmonise its energy plan with its economic development objectives and develop national capabilities for the preparation and implementation of such a plan.

*National Energy Plan: Role of Oil in the Integrated Approach*

High energy cost in general and that of oil in particular is therefore a major inhibiting factor in the economic development of the country, calling for efficient energy demand management. There is an urgent need therefore for an integrated National Energy Plan. This necessarily will have to cover a timeframe of 20/25 years due to the long gestation period of some of the energy projects, the very probabilistic nature of oil exploration and the long time required for pursuing R & D programmes. The long term plan will have to be suitably divided into five year plans to fall in line with the national plans.

Recent demand projections for petroleum products indicate a rapid increase in demand for petroleum products. Demand management, conservation and interfuel substitution could play a significant role in sustaining this picture or, perhaps, even in improving it.

The main objective being reduction of oil consumption, energy transition should emerge as the immediate option and will have to be achieved through technical adjustments, interfuel substitution and structural adjustments.

The rising real cost of energy input should lead to innovation to raise the efficiency of processes that use it. An increase in fuel efficiency often requires a change in the design and construction materials of the equipment.

Substitution among fuels is perhaps the commonest reaction to a change in the relative scarcity of fuels.

It may also be possible to change the pattern of production and consumption so as to increase or decrease the energy intensity.

In any case, preparation of energy balances would be necessary for energy policy analysis as well as for the formulation of long-term plans. Ideally, the National Energy Balance of the country must cover all fuel forms and bring out a total picture of energy used in different sectors of economic activity. The resultant balance-sheet of term named as a "Reference Energy System" indicates the resources utilised, the conversion, distribution and transmission losses, and provides the total balance between the forms of energy resources available and the total energy consumed. An analysis of this type brings out the most appropriate course of effecting an energy transition.

The energy requirements of a society should be planned with due recognition to its heritage, social background, climatic conditions, culture and aspirations. Our aim should be to control the energy demand of the society consistent with the quality of life.

The National Energy Plan should therefore take into consideration the state of the economy as well as the major objectives of the National Economic plan. The main objectives of the National Energy Plan should be:

- a) Development of an integrated total demand model of the country.
- b) Examination of such a reference energy system with a view to identifying energy transition options.
- c) Developing low-cost energy alternatives.
- d) Developing efficient energy processes to reduce energy intensities for specific use.
- e) Maximising indigenous energy sources and their optimal utilisation.
- f) Developing a diversified energy supply system to reduce dependence on imports of oil by switching to renewable sources, when it is possible.
- g) Developing new and renewable energy sources and providing adequate energy inputs for sustaining industrial growth.
- h) Introducing effective energy conservation and demand management systems by the use of appropriate application/appliances, industrial processes, etc.

- i) Energy demand management would have to be engineered by resorting to appropriate pricing and other fiscal measures.
- j) To achieve efficient use of energy and, therefore energy conservation by providing incentives for it.

The Government of India has set up a National Energy Board. The Board should consider the above points while revising its national energy policy.

The issues which require careful consideration are:

1. Restricting the growth of energy demand and trying to evolve suitable measures to curb demand.
2. Planning and evolving a more appropriate mix of energy demand and supply in a more comprehensive manner.
3. Developing our technology to fulfil the needs of society.
4. Planning for a smaller widely scattered system with a view to conserving our energy resources.
5. Since 50 per cent of our population is living below the poverty line we should plan for cheap non-commercial fuels instead of talking in terms of providing them with gas or electricity.

#### *Energy Planning in Indian Plans*

Increasing share of energy in total Plan outlays: In successive Five Year Plans, the share of energy in the total Plan outlay has steadily risen from 11.8 per cent in the Second Plan (1956-61) to 30.6 per cent in the Seventh Plan (1980-85) (Table 5). The share of energy in the proposed outlay for the Eighth Plan should be no less as demand for energy is growing at a fairly rapid pace.

#### *Energy Strategy for Eighth Plan*

Amulya K.N. Reddy of the Indian Institute of Science, Bangalore, has demonstrated that energy consumption of a little higher than 1 KW per capital per day should provide a satisfactory quality of life for all citizens merely by opting for energy-efficient methods of energy use through the modification of consumption habits and cooking and similar devices. The Planning Commission therefore envisaged that the Eighth Plan should:

1. initiate a shift from the extant non-renewable sources of energy to renewable sources and provide wider access for the rural and urban poor to adequate energy supplies at affordable costs.

Table 9.7: Energy Outlay (Share of Energy Sum in percentage)

Plan	Average GDP Growth 80-81 Sum %	Total Plan outlay in crores	Power	Petro- leum	Coal	Non- com- mercial	Total
I	3.6	1960	19.7	-	-	-	19.7
II	4.21	4672	9.7	0.8	1.9	-	11.8
III	2.77	8577	14.6	2.6	1.3	-	18.5
Annual							
Plan	3.32	6625	14.2	2.7	1.1	-	17.9
IV	4.83	15779	18.6	1.9	0.7	-	21.2
V	4.28	39426	18.7	3.6	2.9	-	25.2
Annual							
Plan	4.97	12177	18.4	4.2	0.2	-	22.8
VI	5.67	109292	16.7	7.8	3.5	0.1	28.1
VII	5	180000	19.0	7.2	4.1	0.3	30.6

Source: *Economic Survey, 1989-90.*

2. ensure efficiency in the use of energy in production.
3. review the use of all energy intensive materials and provide for substitution of less energy intensive materials through R and D.
4. Ensure efficiency in the use of equipment in the energy sector. This applies especially to capacity utilisation in thermal and nuclear power generation through improved plant availability.
5. Initiate measures aimed at reducing energy intensity in different sectors through changes in technology processes.
6. Optimise interfuel substitution. In particular, this would involve the substitution of oil by coal wherever feasible. Within the oil sector, substitution of oil products like diesel and furnace oil by natural gas.
7. Propagate renewable resources based on decentralised and environmentally benign non-conventional technologies.
8. Discourage the use of energy for conspicuous consumption.



9. Maximise the availability of indigenous energy resources such as oil, natural gas, coal and hydroelectric power as well as non-conventional energy by way of biogas, solar energy and wind energy.
10. In sum, promote self-reliance, security and environmental safety in the energy sector.

*Steps Towards energy Planning*

A new financial agency, the Indian Research Energy Development Agency (IREDA), was set up during the Seventh Plan for providing financial support to indigenous technology development efforts and dissemination of non-conventional energy technologies. But IREDA is generally not a widely known or recognised agency because its efforts so far have been halting and wholly inadequate. It is an agency which, unfortunately, has functioned as an adjunct of the Department of Non-conventional Energy Supply.

Even prior to the Gulf crisis, the erstwhile Planning Commission had drawn up a plan which involved a judicious mix of conservation, interfuel substitution and indigenous production of oil and natural gas which would make the management of the demand and supply of oil products a feasible one.

The focus was to be on:

- (a) Promoting conservation measure including improvement of efficiency in the use of petroleum products by all sectors, so as to bring down the use of energy per unit of output;
- (b) Promoting interfuel substitution by the use of coal and electricity (in lieu of oil products), where possible, and replacement of oil products by natural gas, where the latter is available, if necessary by adaptation/modification of the equipment currently in use.
- (c) Increasing the productions of both crude oil and natural gas, consistent with reasonable reserves to production ratio for both;
- (d) Minimising the flaring of associated natural gas by installing facilities for compression and conveyance of the gas currently being flared; and
- (e) Exchanging views with other countries of the region, exploring "make or buy" options in regard to both surplus gas or products thereof.

The last mentioned would also increase South-South cooperation a need which is becoming more imperative with every passing day. Equally, with our available skilled manpower we should increasingly participate in oil exploration abroad, in other countries of the South, especially where these countries are dependent on multinational companies for exploration and drilling for oil. This would be another facet of South-South cooperation and would inter alia also give us an option on part of the potential oil output in these countries. This would call for investment by India abroad, at some risk but we should take that risk.

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## THE THREE OIL CRISES OF THE WORLD

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Oil is a boon for many industries. In view of its greater efficiency of transformation and cleanliness in handling it is the most sought after source of energy. This has brought about a rapid growth in the demand for oil. Developing countries like India preferred to import crude oil for meeting their energy requirements instead of developing their indigenous sources of energy. The second half of the present century may well be called an oil age. In 1950 the world oil consumption was 650 million tonnes whereas by 1973 it had increased to nearly 3,000 million tonnes. This trend in oil consumption was reversed in 1973 following an upward revision of crude prices by the oil-producing countries. The demand for crude oil being inelastic but persistently increasing a rise in its prices blew up what came to be known as an international oil crisis. India was also affected by it. Since then oil exploration work in India has been stepped up and an aggressive campaign mounted to discover oil and gas in its onshore as well as offshore areas.

### Formation of OPEC

On September 5, 1960, the Iraqi Government under general Kassem convened a conference of oil-producing countries in the City Hall of Baghdad. It opened on September 10, and despite the short notice it was well attended. Saudi Arabia was represented by Sheikh Abdulla Fariki, an expert in oil affairs, the Kuwait delegation was led by Faisal Mezidi, one of the government directors of the newly established Kuwait Oil Company. Perez Alfonso, Venezuela's Oil Minister also joined the meeting. Fand Routhani, the author of the *History of OPEC* and director of the National Iranian Oil Company represented his country. Iraq,

Iran, Kuwait, Saudi Arabia and Venezuela were the founders of OPEC. Qatar joined the organisation in 1961, Indonesia and Libya in 1962, Abu Dhabi in 1967, Algeria in 1969, Nigeria in 1971 and Ecuador in 1973. OPEC comprises five non-Arab states—Iran, Venezuela, Nigeria and Ecuador. The aims of OPEC are to establish a uniform policy, ironing out the differences that exist among various oil producing countries over issues involved in international oil industry prices, royalty production programme participation in the vertical operation at industry level and other problems.

### **The Middle East War**

President Sadat sent an Egyptian army across the Suez Canal in coordination with Syria's assault on Golan Heights. The declared aim of the war was recovery of the land occupied by Israel in the 1967 war. Dr. Henry Kissinger, US Secretary of State, talked to the Israeli and Egyptian Foreign Ministers who were at New York for the General Assembly meeting and appealed to them to end the war. He also sent a personal message to King Faisal of Saudi Arabia asking him to use his good offices to bring about a ceasefire. UN observers reported that Egypt and Syria were the first to cross the ceasefire line. Kissinger also assumed that Syria and Egypt had launched the attack. Visibly annoyed by the USA suggestion that Syria and Egypt had started the war, King Faisal observed: "If the USA does not act to deter Israel from continuing her aggression, the volcano which has been quiet in the Middle East will become active again and its holocaust will not be confined to this region alone. The USA should force Israel to withdraw from Arab territories and to grant the Palestinian people the right to occupy their territory and homeland." Few countries have justified the just cause of the Arab nations for a political settlement of the Arab-Israeli conflict on the basis of Security Council and General Assembly decisions. Michael Jubert, French Foreign Minister told the National Assembly that the USA and the USSR had manipulated the Middle East war and its settlement using the US Security Council as a rubber stamp. The exchange of missions between Egypt and Israel, which had begun on November 15, ended. On November 25th, the cabinet announced that it would agree in principle to attend the peace talks scheduled for December 18, in Geneva.

### **The Oil War**

As rightly pointed out by *The Economist* the first thing that should be understood about the oil business is that it is more a political than an economic activity. The renewal of hostilities in the Middle East immediately reduced the flow of oil by about one million barrels a day because of the closure of the pipeline from Iraq and Saudi Arabia to the Eastern Mediterranean both of which pass through Syria. On October 8, Aramco announced that it had cut the oil flow through its pipeline from Saudi Arabia to the Mediterranean by 50 per cent to minimise losses in the event of any damage to the pipeline. On the fourth day of the war, Kuwait, with the assent of its friendly neighbour Saudi Arabia, called for an emergency meeting of the Arab Oil Ministers. The Gulf oil state members of OPEC on October 17, announced that the oil battle would be fought on twin fronts' production and prices. The oil states would reduce their oil production by 5 per cent every month until Israel withdrew from the occupied Arab soil and restored the rights of the Palestinians.

### *Escalating Prices*

The year 1973 will go down in the history of the oil industry as a year of escalating prices. That year oil prices went up very high and very fast. The revised Geneva agreement negotiated in June 1973 meant an increase in oil posting of over 11.8 per cent compared in posted prices of those prevalent at the beginning of the year. On October 16th when the war entered the 10th day, OPEC decided to increase the posted prices of oil by 70 per cent. This unilateral decision was taken after the failure of talks with the international oil companies. It was the first time that the governments of the oil producing countries had themselves chosen the posted prices. According to OPEC, in future the cost of oil to the producing companies would not be a matter of negotiation but would be determined by market prices.

### *Posted price 1975 October*

Arabian light crude	\$3.011 to	\$5.119	a	barrel
Kuwait	\$2584 to	\$4904	a	barrel
Abu Dhabi	\$3084 to	\$6045	a	barrel

The Arabs, as if not satisfied with the 70 per cent increases, announced on December 23, a 130 per cent like in the Gulf oil prices. The Gulf countries' decision put up the posted price of

light Arabian crude from November 5, from \$5,173 a barrel to \$ 11,651 a barrel. In a new surprise move OPEC announced a world record posted price of \$18,768 a barrel for its oil effective from January 1974.

#### *First Oil Crisis and Developed Countries*

All the developed countries are oil-based economies and not oil-producing economies. They have to import oil from OPEC. With rapid industrial progress and accelerated growth of population, the requirement of energy is rising steadily. This clearly indicates that the requirements of energy will always increase.

It has been estimated that mankind has consumed about  $20 \times 10^{14}$  kwh of energy from the beginning of the Christian era till about the middle of the last century. In the last century we consumed about  $100 \times 10^{14}$  kwh of energy. It is estimated that we would need about  $250 \times 10^{14}$  kwh of energy in the next century.

The oil producing Arab states of the organisation of petroleum export countries, with their control and ownership of nearly two-thirds of world oil production, announced their decision to cut back progressively their oil production at the rate of 5 per cent every month from November 1973. Simultaneously, they also imposed an embargo on the supply of Arab petroleum to the USA, Holland and Japan which had supported Israel. This created a worse oil crisis in these countries. Japan was forced to abandon its pro-Israel policy.

The Arab countries of the OPEC hiked the oil prices in early 1973. The price of crude oil was doubled. During Arab-Israel conflict they increased the crude oil prices many times more. A barrel of crude which used to cost a little over a dollar now touched a much higher price. The Arab oil monopolists stated that this price rise was a temporary one and that it would go up further. Iran, at the same time, disclosed its decision to sell its crude in open auction to the highest bidder directly, encouraging Russia and China to secure oil supplies and resell them to western countries by dictating their economic and political terms. Thus the year 1974 started with the worst ever energy crisis in the world.

The oil exporting countries may continue the policy of rising prices to curb production and exports, perpetuating world fuel shortages for ever. In short, the present fuel crisis is not a temporary one, but a permanent feature. This fantastic increase in

oil prices and the positive threat of future increases have adversely affected the industrial production and development all over the world. The developed countries are facing increasing oil bills posing a serious problem to their balance of payments position. It is estimated that the developed countries may have to pay 50 billion dollars more due to these increases in the prices of oil. The developing countries cannot face this situation and they fear an industrial recession. Japan, fearing the worst, has announced devaluation of her currency to step up exports in order to meet her oil bill. The energy crisis has also affected the UK which is experiencing the worst years in its industrial production. It has adopted a three-day week and imposed heavy restrictions on the use of oil. The UDCS are relatively better off than the advanced countries.

#### *The Oil Crisis in USA*

With half the world's coal reserves, billions of barrels of oil and oil share deposits, vast natural gas reserves, the largest installed modest capacity in the world, and with half of the world's hydroelectric plants, not to mention the largest pool of scientific talent and managerial skills in the world, the USA has been badly affected. Energy was a great help in its post-war development. The USA is both the largest consumer and potentially among the richest sources of energy of all kinds. Furthermore, it has declared itself committed to sharing its resources, with other nations.

At its prevailing rate of oil consumption the US would have exhausted its domestic petroleum stock by the mid-1980s. In fact the oil crisis had been developing in the country long before the 1973 Middle East war broke out. It pointed to the necessity for the US to import more oil from the OPECs. The prime source of oil imports, certainly for the near future, was the Middle East where 75 per cent of world's proven resources lie along the shores of the Persian Gulf. There was a possibility of exercising pressure against Israel through consultation, imposition of restriction and price inflation of Arab oil supplies. The implicit threat to the entire industrialised world through the international money markets was foreseen as a chastening experience. The federal budget expenditure on energy research and development reflected the traditional low priority accorded to energy questions in the Federal Government's planning. In 1973, the US

Government expenditure on energy was expected to reach 722 million. The 1974 projection represented a mere 25 per cent of the total estimated federal budget or about one-fourth of the space programme budget for the same year.

#### *Steps to Control Oil Crisis*

On April 18, 1973, President Nixon delivered to the Congress his long awaited measures to deal with the nation's growing energy shortages. Among the steps announced by the President were: (1) Termination of the old oil import system; (2) partial decontrol of natural gas prices; (3) intensified offshore exploration of oil and gas resources; (4) construction of deep-water ports capable of handling giant oil tankers; (5) a 130 million increase in funds for R & D of future energy resources and (6) a shift to coal.

President Nixon's response can be summarised in a five-point action programme having the following objectives: (1) Raise domestic production of all forms of energy; (2) act to conserve energy more effectively; (3) strive to meet the country's energy needs at the lowest cost consistent with national security and national environment; (4) act in concert with other nations to conduct research in the energy field and to find ways to prevent serious shortages; (5) apply the country's vast scientific and technical capacity, both public and private, so that the nation might utilise its current energy resources more wisely and develop new sources and forms of energy.

On October 10, President Nixon called on US scientists to develop new domestic sources of energy. At the same time, he set a goal of 5 per cent reduction of energy consumption in the private sector. Private cars and homes heating, industry, commerce, and transport, account for more than 70 per cent of US energy consumption.

#### *The European Economic Community*

The Washington Energy Conference held in 1974 under the auspices of the energy cooperation group served to highlight the spirit not only between eight members of the European community and France, also between France and the US, Japan, Canada, and Norway, on how to cope with the world energy problem.

By November 1974 the Energy Cooperation group had come to the conclusion that the urgent task of the group was to formulate an oil sharing programme which as the Netherlands



example had illustrated, stressed the aspect of economic survival as distinct from national self-interest. The US formally pledged its own oil reserves for any future embargo. Despite diplomatic denials to the contrary, the international energy agency was in effect a countervailing force to OPEC.

*Pre-1973 EEC Energy Policy*

The EEC community had serious differences before 1973 on the question of evolving a common energy policy. Not only because responsibility for energy had historically been divided but also because the different sources of energy were not of equal importance for the various countries. Whatever the long-term national interest of West Germany, France, and Belgium might have been, the switchover from coal to oil continued to progress. As early as the 1956 crisis when oil supplies were temporarily suspended it was clear that oil had come to play a vital role in the 1960s energy supply pattern. By 1964 it had overtaken coal as the chief source of energy and by 1966 it was providing more than half the 1960s energy requirement. Indeed, oil accounted for almost all the additional demand for energy that arose between 1960 and 1970. All of this took place not because of any direct intervention of the community in the shape of a common policy, but because oil was available in almost unlimited quantities and at very low prices. For a decade at least the Community benefited from the cheap petroleum provided by the multinational oil companies, this could not last forever. In October 1973 it suddenly came to an end. The end had long been anticipated but never its severity.

*Japan*

Japan has always been short of energy and is almost totally without any indigenous sources of petroleum. Its strategy to meet the crisis was based on three main priority responses: (1) To build new enlarged reserves of oil; (2) To economise on oil consumption immediately and (3) to seek fresh sources of crude oil.

By November 1973 the Japanese government had imposed a 9.1 per cent cut in the consumption of both oil and electric power, passed two major pieces of legislation to distribute oil supplies equitably among the consumers and others. The Government directed a raise on the price of oil in each phase of distribution. By August this policy showed results and the Government price

freeze was lifted in an attempt to reduce demand. However, the crisis was not all over. The Government announced its intention of cutting consumption in 1975 by a further 10 per cent. By using these methods Japan reduced 23 per cent of its oil dependence, which had ranged from 13 to 74 per cent.

### Second Oil Crisis in India

Industrial development in England and in other countries of the world in the 18th and 19th centuries was based on coal. As the leading source of energy towards the end of the 19th century, however, oil replaced coal as the chief energy source. Industries everywhere in the 20th century are based on low-cost oil. After independence India followed the example of other leading industrialised countries and imported Arab oil to accelerate her industrial development. So long as oil flowed cheaply there was no problem. In 1973, OPEC hiked the oil price by more than four times. Since then oil prices have been mounting, creating a global cost push inflation and huge adverse balances of payment for all countries, specially developing countries like India. While the developing countries were taking painful steps to adjust themselves to the rising oil prices there was yet another massive hike in oil prices in 1980 by as much as 130 per cent and thus emerged the second oil crisis. The movement of oil prices is shown in the table below:

**Table 10.1: Weighted Average Price of Petroleum Crude**

	<i>Price Per Barrel (US) \$</i>	<i>Price Index</i>
1973	2.09	100
1974	9.09	435
1976	11.14	533
1978	12.29	588
1980	27.30	1306

Between 1973 and 1980 oil prices rose 13 times. As a consequence the value of oil imports rose sharply, from Rs. 1,110 crores in 1973-74 to Rs. 2,500 crores in 1978-79 and to nearly Rs. 5,120 crores in 1980-81. In relative terms, oil imports, which accounted for 13 per cent of India's exports in the 1960s and 12 per cent in 1970-71, shot up to 44 per cent in 1973-74 and nearly 76 per cent in 1980-81. A lot of effort has gone into export promotion in India but the advantages of increased export earnings have been

counter-balanced by the higher oil import bill on account of persistent price hikes of crude oil. In quantitative terms, oil imports to India had grown at the rate of 8.5 per cent annually before 1970 but after 1970 the growth rate was only 2.5 per cent. But our oil imports bill has increased astronomically in recent years because of the hike in oil price.

#### **Energy Imports of India and Balance of Payments Problem**

India's plans of economic development had greatly influenced its imports. During the First Plan period, the average level of imports was Rs. 723 crores a year. It was much higher during the Second Plan period when it averaged Rs. 976 crores a year.

During the Third Plan period, except in the first year, imports rose progressively reaching a level of Rs. 1,409 crores in 1965-66. Imports averaged nearly Rs. 2,000 crores during the three annual plans.

*Fourth Plan Period:* The first year of the Fourth Plan (i.e., 1969-70) witnessed a steep fall in imports from Rs. 1,910 crores in 1968-69 to Rs. 1,582 crores in 1969-70.

*Fifth Plan Period:* The trend towards rising imports was further aggravated during the Fifth Plan. In its first year (1974-75) imports totalled Rs. 4,519 crores, as against Rs. 2,955 crores in 1973-74, a spurt of 53 per cent, due to the increase in international prices and the consequent higher cost of imports of foodgrains. Petroleum products imports alone were estimated to have cost about Rs. 1,130 crores in 1974-75.

*Sixth Plan:* In 1984-85 the terminal year of the Sixth Plan, the total imports were in the vicinity of Rs. 17,134 crores as against Rs. 12,523 crores in 1980-81.

*Seventh Plan:* In 1985-86 the first year of the Seventh Plan, total imports were to the tune of Rs. 19,658 crores. In terms of growth rate the imports registered a rise of 22 per cent in 1985-86. Imports rose further to the levels of Rs. 20,201 crores and Rs. 22,399 crores in 1986-87 and 1987-88, respectively.

#### **Commodity Structure of Energy Imports**

Commodity imports in India in 1981-82 totalled Rs. 13,560 crores (provisional) as against Rs. 12,523 crores a year earlier (in 1980-81).

**Table. 10.2: India's Imports by Major Commodity Groups, 1986-87 to 1987-88**

*Rs. in crores.*

<i>Commodity</i>	<i>1986-87</i>	<i>1987-88</i>	<i>Percentage change in 1987-88 over 1986-87</i>
Petroleum, oil and lubricants (POL)	2796.7	4082.8	46.0

*Petroleum, Oil and Lubricants (POL)*

The second bigger commodity group in Indian energy imports comprises crude oil, petroleum, and petroleum products, which cost the country Rs. 4,082 crores or 18.2 per cent of total imports in 1987-88. In 1972-73, i.e., before (OPEC) had started raising oil prices once or twice a year, imports into India of POL were valued at Rs. 204 crores. In other words, the value of oil imports rose over 20 times between 1972-73 and 1987-88, i.e., in 15 years. It is significant to note that in the first nine months of 1988-89 financial year POL imports rose in value at a slower rate—1.4 per cent as compared to 75.6 per cent in the corresponding period of 1987-88. It was mainly due to depressed international oil prices.

*Rising Petroleum, Oil and Lubricants (POL)*

An outstanding recent trend is a steep rise in imports of POL. Their share in imports rose from 13 per cent in 1972-73 to 25 per cent in 1985-86. It declined to 13.8 per cent in 1986-87 due to the crash in international oil prices. This share, however, increased to 18.2 per cent in 1987-88. In absolute terms, imports of POL have increased from Rs. 2,796 crores in 1986-87 to Rs. 4,082 crores in 1987-88.

*Direction of Imports*

The following are some of the important aspects of the direction of imports:

- (1) The OECD countries are the major sources of our imports. In 1987-88, 59.8 per cent of our total imports were from these countries. Within this group the EEC countries are the main source of our imports. Their share in our imports rose from 19.6 per cent in 1970-71 to 33.2 per cent in 1987-88.

- (2) The OPEC countries have assumed a strategic position in our imports trade due to our increasing reliance on them for crude oil. These countries had a 7.7 per cent share in our imports in 1970-71. It rose to 14.8 per cent in 1987-88, because imports from Iraq, Kuwait, and Saudi Arabia increased as a reaction to international oil prices.
- (3) Amongst the leading developed countries West Germany is the single largest source of India's imports. It is imperative to see this in terms of growth rates in imports. Imports from Japan declined by 17.2 per cent in 1987-88, and over the same period, imports from the USSR and the USA registered an increase of 26 and 3.3 per cent respectively.
- (4) The share of developing countries (Non-OPEC) in our total imports declined from 18.5 per cent in 1986-87 to 17.3 per cent in 1987-88 due to a decline in imports from Africa by 22.7 per cent.

*Imports of Oil into India*

During the period, 1960-61, 1980-81, oil imports, in quantitative terms, increased by 5.2 per cent per annum from 8.58 MTOE to 23.5 MTOE, whereas the value of oil imports increased by 22.7 per cent per annum from Rs. 87 crores in 1960-61 to Rs. 5,258 crores in 1980-81. Thus the exorbitant hikes in oil prices during the 1970s compelled the country to expend higher amounts of foreign exchange on oil imports.

Oil imports of India may be discussed in terms of total imports of crude oil and petroleum products and imports of main petroleum products, which form a part of petroleum products.

Imports of crude oil and petroleum products have recorded an increasing trend, the crude oil imports rising from 5.71 million tonnes in 1960-61 to about 17.00 million tonnes in 1982-83, followed by a decline to about 13.6 million tonnes in 1984-85. Thus imported oil recorded an annual average growth rate of 3.7 per cent during 1960-61, 1984-85. Imports of petroleum products increased from 3.62 million tonnes in 1953-54 to 6.09 million tonnes in 1984-85. During the entire period, imports of total petroleum products ranged between 2 and 6 million tonnes with an average annual growth rate of 4.2 per cent during the period 1960-61 to 1984-85.

Imports of crude oil increased by 6.4 per cent during period 1960-61, 1972-73 while those of petroleum products rose by 4.0 per cent. This indicates the non-availability of crude oil and availability of refining capacity in India during 1960-61, 1972-73. However, the growth rate of imported oil and petroleum products slumped to 3.2 per cent and 1.5 per cent, respectively, in the period 1972-73, 1978-79. This happened due to the hike in oil prices. The growth rate of crude oil imports was negative during the period 1978-79, 1984-85, while that of petroleum product, it was 7.7 per cent. During the period 1960-61, 1984-85 the former increased by an average annual growth rate of 3.9 per cent as against the latter's growth rate of 22.7 per cent.

The main petroleum products which were imported were motor gas (petrol), naphtha, kerosene, ATF, diesel oil, heavy stock and furnace oil.

Kerosene imports had a major share in total imports (30 per cent) in 1953-54. It declined to 19.2 per cent in 1972-73 but went on to increase to about 43 per cent in 1984-85. Motor gas was the second important product. It had a share of 25 per cent in 1953-54 and 4 per cent in 1960-61. The third important import product was furnace oil with a share of 23.0 per cent in 1953-54 which declined to 3.3 per cent in 1960-61 but increased to 55.0 per cent in 1972-73.

Thus, kerosene, diesel oil, and furnace oil constituted a major portion of imports up to 1980-81. Kerosene, diesel oil and ATF consumers are still dependent on imports.

### *Mounting Imports*

In recent years, India's import bill has been going up by leaps and bounds, from Rs. 1,634 crores in 1970-71 to Rs. 6,025 crores in 1977-78, Rs. 9,022 crores in 1979-80, Rs. 12,523 crores in 1980-81 and Rs. 22,399 crores in 1987-88.

### *Problems of Balance of Payments*

One of the most serious problems that face all developing economies is balance of payments. With the execution of plans of rapid economic development, there emerges a wide gap between exports and imports, both visible and invisible.

Inflation which is a consequence of mounting investment expenditure attracts imports and checks exports. It is an important cause of the balance of payment difficulties in a developing economy.

Payments for services or 'invisible items' is another important cause of balance of payments difficulties of the developing countries. According to a compilation made recently by IMF, receipts for services amounted to some 40 per cent of the value of merchandise imports over the period 1963-64.

India cannot escape from the balance of payments difficulties. But it must be regarded primarily as a problem of development rather than as a balance of payments problem. Wisdom demands that earnest efforts should constantly be made to bridge the gap between deficits and credits. Otherwise, the situation will go out of hand and all efforts at economic development will be nullified.

#### *Emerging Balance of Payments Crisis*

Thus there are prospects of a serious balance of payments crisis emerging in the coming years. The Tandon Committee had recommended that India's exports would have to grow at a rate of at least 11.2 per cent per annum during the 1980s, to achieve even one per cent share in world exports. India's share in world exports, it should be noted, went down from 1.0 per cent in 1965 to 0.4 per cent in 1987. This would call for a vigorous export drive.

#### *Gulf War and Third Oil Crisis*

The Gulf war affected the world very severely. Kuwait violated, the OPEC agreement, of exceeding its target oil production. This resulted in a fall in oil prices.

Iraq warned Kuwait against its oil activities. Iraq owed more than a thousand million dollars to Kuwait. Kuwait refused to write off Iraq's debt.

President Saddam of Iraq got angry and invaded Kuwait and declared it to be as Iraq's 19th state in August 1990.

The United Nation condemned the invasion of Kuwait and called for Iraq's immediate withdrawal from Kuwait. Iraq refused to do so. The UN passed a resolution to use force against Iraq. An attack was launched on Iraq by the Allied forces led by the USA on January 17, 1991.

#### *Third Oil Crisis in India*

The energy crisis triggered by Iraq and the disclosure that India had only about five weeks of oil reserves once again exposed its vulnerability to external sources. The shadow of a fuel famine came upon the country, demanding that all possible ways must

be explored to conserve energy and to keep oil consumption to the absolute minimum. Petrol pumps went dry temporarily and there was panic buying of essential commodities. Warnings were used to hoarders and profiteers. The Gulf war had serious implications on the world economy in general and on India's economy in particular.

A major factor contributing to inflation has been the international oil scenario. World crude prices, after crashing by \$ 8-10 a barrel at the end of the first day of the Gulf war, started firming up five days later as the prospects of a prolonged conflagration became real. Still, crude should sell at an average of less than \$ 25 a barrel unless oilfields and refineries suffer major damage. The production loss of 4 million barrels a day from Kuwait and Iraq since August 2 has been more than made up by other countries.

India's total oil reserves when the war began could last about 45 days. Facing a worsening balance of payments position, heavy dependence on foreign exchange reserves, a low international credit rating and a sudden rise in oil prices to \$ 40 per barrel, as immediate steps were taken by the Government. India is expected to succeed in importing some quantity of crude from Venezuela and Malaysia on a deferred payments basis. It has already tied up term contracts and spot purchases for one million tonnes of crude during the current year out of which 4.5 million tonnes is to be imported from the Soviet Union and one million tonnes from Malaysia. Thus there should be no cause for panic.

Another important aspect of the Gulf is that there would be a substantial reduction in India's import bill for oil purchases. India was anticipating its import bill of oil to shoot up from Rs. 6,500 crores to Rs. 12,500 crores ever since the Gulf crisis began on August 2 and oil prices shot up to \$ 40 per barrel.

India should build up higher reserves of oil at current prices, particularly now that it has got an IMF loan of about 1.8 million and has generated surpluses following the Gulf surcharge of 25 per cent on oil and oil products in the domestic market imposed on October 14, 1990, to contain the exorbitant rise in international prices in the pre-war era.

A significant step in our quest to save energy is to curtail extravagant use of official vehicles, as also personal cars; instead, encouragement must be given to public transport buses and



rail-based Mass Rapid Transit Systems (MRTS) at least in our major million plus cities.

*Prices*

Prices of consumables have shown a sudden rise since the Gulf war, particularly because of panic buying. There does not seem to be any justifiable reason for prices to go up especially when we have sufficient stocks of foodgrains and other essential commodities. As a matter of fact, our stock of foodgrains as on July 1990 were as high as 22 million tonnes compared to 9.5 million tonnes three years earlier.

*Foreign Exchange*

It is feared that besides factors other than the Gulf war, there could be a foreign exchange crisis for the following reasons:

- (1) Reduction in remittances from Indians working in West Asia and the Gulf countries.
- (2) Reduction in exports to West Asia and the Gulf countries.
- (3) Stoppage of work on ongoing projects of Indian firms in some of the Gulf countries.

As India's balance of payments deficit is increasing at an alarming rate and its foreign exchange reserves are dwindling, the country will face a serious setback. It is anticipated that there will be a substantial rise in India's exports to the Gulf country and West Asia for non-conventional items of exports. Some of the countries involved in the war may also be interested in shifting their investments, which are estimated to be more than \$ 100 billion, to other countries. India can provide a viable alternative to some of these economies.

*Environmental Effects*

Most reports about the ecological impact of the Gulf war over that as the oil wells were torched, a huge amount from 3 to 10 million barrels of crude burnt every day. This, says a new scientist report quoting Richard Turco of the University of California, released three million tonnes of black smoke into the upper atmosphere, shading up to 100 million square kilometres, more than a fifth of the planet's surface. John Cox, Vice-President of the Campaign for Nuclear Disarmament, estimates about 5,00,000 tonnes of smoke were generated per month.

More than the Gulf fires, it is the oil spilt in the sea that is causing concern. Environmentalists fear that the large oil slick,

which has already moved southwards, may move towards India gradually.

Assuming that 10 million barrels of oil are burnt daily in an area of about 1,000 sq. km. Indian scientists predict the following fall-out of the Gulf fires:

Smoke that rises up to 3 km. will stay in the neighbourhood, extending to a radius of 500 km. This is because winds at this level are low, that is of a magnitude of up to 15 knots and (20 to 30 kmph) and more within the area.

Smoke between heights of 3 and 12 km. will be transported very quickly towards the east. In January-March, when the winds blow from west to east they will cross over to north India. Wind speeds at this height can go as high as 150 knots (300 kmph). Hence, the smoke will come over India, and even blow further east quickly, thus dissipating the mass of smoke.

If however, the oil fire storm also raises vast quantities of dust, it is likely to remain in the atmosphere and could cut off some amount of sunlight and marginally reduce temperatures over north India.

Dr. N.K. Jaswal, Director of the Institute for Systems Studies and Analysis, says the loss of sunlight in the western parts of India will be about 11 per cent and similar to cloudy days. Temperatures may go down by two or three degrees.

Dr. S.K. Sinha, a specialist on global climatic changes at the Indian Agricultural Research Institute, estimates that the winter crops of wheat and barley may actually benefit from these changes. He says, "The grain development period will be extended. The crop may take a longer time to ripen but it will be good. The presence of oil near tropical islands like the Lakshadweep and the Maldives has a harmful impact on the corals, sponges and other marine life. This could cause damage to the economic system in the region."

The share of high speed diesel (HSD) in the total of petroleum products consumed in India at 35.6 per cent is the highest. Its consumption has risen rapidly. The rate of growth in HSD consumption between 1980 and 1986 was of the orders of 5.7 per cent. In 1987 this jumped to over 100 per cent. For kerosene, the corresponding figures are 5.8 and 9.0 per cent and for Mo-gas (petrol) they are 6.0 and 10.0 per cent respectively. While part of the increase in HSD consumption is related to the 19.1 per cent

growth in the production of commercial vehicles between 1984-85 and 1988-89, the main reasons for the sudden spurt in the trend of growth rate of its consumption from 6 per cent to over 14 per cent in agriculture, from 10 per cent to nearly 20 per cent in industry and from 6 per cent to nearly 10 per cent in transport in recent years, have to be found in the failure of the country's infrastructural sectors, viz., coal, power and railways.

India is now experiencing the third oil shock and an urgent response has become necessary. Its import bill will rise not only because of oil prices but also because of the expected rise in the prices of a variety of goods. Crude oil is an input for several chemicals which need to be imported. Their prices are bound to rise with the rise in the prices of imports. Not only will there be an increased outflow of foreign exchange but also an increase in the inflationary potential in the Indian economy. This would tend to reduce exports unless export subsidies are raised. The choices are indeed difficult.

If the balance of payments, position worsens as a result of the rise in the import bill, decline in remittances and the rate of rise in exports, then the rupee may have to be devalued. This could increase the flight of capital from the country and further worsen the balance of payments. Increased commercial borrowings may only be possible at stiffer terms and lead to a higher debt servicing requirement in the coming years.

The grave balance of payments problem facing the country cannot be solved by either rising petroleum product prices or increasing taxes on it. Energy is an essential input and an increase in its price would be highly inflationary. In the short run, if economic growth is not to be sacrificed, expenditures on luxury consumption and associated imports need to be cut to tackle the foreign exchange crunch. This is not possible simply through an increase in indirect taxes since they do not affect property incomes. The black economy and the margins of profit need to be checked and for this the form of corporate taxation has to be changed. This needs to be supplemented through appropriate changes in income, wealth and property taxes.

Finally, a long-term solution, and that is the only one available, demands that the planned transition from oil dependence to the indigenous energy sources will require taking an integrated view in planning India's economic development.

In India, as observed above, some of these opportunities have been precluded by the mismanagement and inadequate development of its infrastructure. Clearly, in the light of the resource crunch, the time has come for the government to withdraw itself from all other sectors where the private sector has the expertise and wherewithal to invest, and concentrate its efforts exclusively on infrastructure development.

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## ENERGY PROGRAMMES OF THE INTERNATIONAL ORGANISATIONS

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### Role of UNDP

The total expenditure on the energy programmes of the multilateral and bilateral aid agencies since 1972 has been approximately \$ 14 billion. The bulk of this expenditure has come from the large development banks; bilateral aid has accounted for 30 per cent of the total.

Most of the present energy aid programmes were established under the general umbrella of the United Nations and were designed specifically to protect developing countries from encroachment of industrialised countries trying to enlarge their markets or to otherwise advance their national interests. The UNDP (United Nations Development Programmes) has funded hundreds of projects with special emphasis on assistance for energy planning but has no funding for the execution of projects. The United Nations Centre for Natural Resources, Energy and Transport (CNRET) is another small UN agency working in assistance for energy planning.

By far the most important agency engaged in multilateral aid is the World Bank. This is the largest of the international development banks. The Inter-American Development Bank, (IDB), The Asian Development Bank, the European Development Fund, the African Development Bank, the OPEC Fund are others.

The very large sums of money lent by the World Bank (\$ 12.2 billion in 1980 in all areas)—two-thirds of which was below commercial rates (approximately 8 per cent interest and a 15-20 years' payback period)—make this source of money very attractive. Or the remainder, one-third of the loans are

concessional with practically no interest and at least a 40-year payback period.

#### *Bilateral Energy Aid Programmes*

1. Canada (Canadian International Development Agency, CIDA) concentrates activities in energy production and distribution, evaluation of resources and energy management. Invested approximately \$ 160 million, 1972-1982.

2. French aid for Africa and Francophone countries is administered by the Ministry of Cooperation Aid for East Asia and Latin America is handled by the Foreign Ministry. Emphasis was always given in the aid programmes to solar energy (biomass, solar cookers, refrigeration, wind, photovoltaics, etc.) The aid is well coordinated with French industry (mainly the French Company Sofretes).

Between 1976 and 1979 approximately \$ 280 million was committed to energy programmes, with an emphasis on hydro-power and rural electrification; non-conventional sources accounted for less than 10 per cent of the total.

3. West Germany (Ministry of Economic Cooperation, DMZ). In the past most of the energy programmes were handled by capital loans for large projects. More recently, the Agency for Technical Cooperation (GTZ), which handles technical assistance had established a German Appropriate Technology Exchange (GATE). From 1970 onwards approximately \$2.1 billion has invested, mainly in power generation and distribution.

4. Kuwait established in 1962 a fund which is the largest Arab agency. From 1973 to 1978, approximately \$ 340 million was invested, mainly in conventional power projects. Almost 50 per cent was spent outside the Arab world.

5. Holland (Directorate General in International Cooperation (DGIC), Ministry of Foreign Affairs). Emphasis of the programme is on training, assessment and investments in hydro-power although work in forestry is on the rise. From 1970-1980 approximately \$ 200 millions was invested in energy programmes.

6. United Kingdom (Overseas Development Administration - ODA) ODA has provided foreign exchange for energy projects and more recently has shown interest in the 'basic needs approach' to energy. From 1973 onward it has spent almost \$ 150 million on energy projects.

7. United States (Agency for International Development - AID) USAID's energy budget has been approximately \$ 150 million per year with an increasing emphasis on renewables, which in 1980 accounted for 25 per cent of the budget. Large scale power generation is being downgraded in USAID funds but not rural electrification. Main areas of concern in renewables are energy production (charcoal, village woodlots, etc.), energy resource evaluation, and energy policy studies and sector management.

8. Sweden (Swedish International Development Authority - SIDA) SIDA has concentrated its efforts in a few countries in order to achieve maximum impact. In the past, it has been active in large hydro projects, primarily in Botswana, Kenya, Tanzania, Tunisia, and Turkey. From 1979 onwards four areas of priority were established: hydroelectric projects (conventional and mini-hydro), forestry, energy planning, and others (biogas, geothermal, etc.).

9. Venezuela (Venezuelan Investment Fund VIF) VIF has large assets coming from petroleum revenues; in 1975 VIF resources were already of the order of \$ 5 billion. It acts through regional and national development banks, such as the Inter-American Development Bank, the Andean Development Corporation, the Caribbean Development Bank, the National Bank of Panama and others. The charter of VIF prohibits grants.

#### *The Role of the World Bank*

The World Bank has accorded high priority to energy in its overall programme because of the critical impact of adjustments in this sector on the overall structural adjustment and growth prospects for most developing countries. The contributions of the Bank to these countries are to extend financial and technical assistance to complete the process of adjustment in the energy sector, policy advice, institutional strengthening technology transfer and improved project selection, design and implementation.

The energy sector in developing countries absorbed a large and growing share of total investments doubling from about 2 to 3 per cent of DGP in the late 1970s to an average of 4 per cent of GDP in the 1980s. These investments, combined with a vigorous effort to improve the efficiency of energy use, enabled the oil importing developing countries to reduce their expensive dependence on oil imports which absorbed a quarter of their

aggregate merchandise export earnings and much more in many countries.

An analysis of the World Bank report has demonstrated that the developing countries' adjustment to higher commercial energy costs is far from complete. Despite the major shifts in pricing structures, investment programmes and economic policies that have already been accomplished in many of these countries, much more remains to be done to ensure that energy is used efficiently and to develop and utilise cheaper alternatives to imported oil.

To complete the adjustment process in the energy sector will primarily require a major increase in the allocation of investible funds to the sector, both for energy production projects and for retrofitting programmes to conserve energy. Generating the resources needed would be a challenging task under any circumstances, but it will be particularly difficult in the present international economic environment.

A second prerequisite will be to strengthen the planning and management capability in the sector.

This twin emphasis on resource mobilisation and strengthened sector management will also need to be reflected in the energy assistance programmes of bilateral and multilateral agencies, including the bank, which have an important contribution to make in these areas.

The principal objective of the World Bank's energy programme is to assist developing countries to define and implement an appropriate development strategy for the energy sector. In response to the developing countries' changing priorities during the 1970s, the Bank significantly increased and diversified its energy activities. The energy lending increased and the Bank began to support the development of petroleum, coal and other primary energy resources which it had not previously financed (Table 11.1). This process was supported by a substantial strengthening of the Bank's technical and economic staff with energy expertise. It also led to growing emphasis on the better management of energy demand and on providing technical assistance to developing countries in the evaluation of major energy issues and options. In collaboration with UNDP, the Bank embarked upon a 60 country programme of energy sector assessments designed to diagnose the main energy issues in the



**Table 11.1: World Bank Lending for Energy (1979-82)**

<i>Particulars</i>	<i>1979</i>		<i>1980</i>		<i>1981</i>		<i>1982</i>	
	<i>No. of projects</i>	<i>Million of dollars</i>	<i>No. of projects</i>	<i>Million of dollars</i>	<i>No. of projects</i>	<i>Million of dollars</i>	<i>No. of projects</i>	<i>Million of dollars</i>
Power	18	1,355	24	2,392	17	1,323	21	2,131
Coal	-	-	1	72	1	10	3	227
Oil and gas	4	112	13	385	12	650	14	539
Exploration								
promotion	-	-	5	36	6	33	8	36
Exploration	-	-	3	96	3	70	1	20
Oil development	1	3	2	60	2	462	3	303
Gas development	3	110	3	194	1	85	2	180
Energy related industry	-	-	-	-	1	250	6	460
<b>Total</b>	<b>22</b>	<b>1,464</b>	<b>38</b>	<b>2,849</b>	<b>31</b>	<b>2,233</b>	<b>44</b>	<b>3,357</b>

countries studied and to serve as a framework for investment and policy decisions by government and external aid agencies. As part of its project financing activities, the Bank stepped up its efforts to function as a catalyst in mobilising additional funds for energy development from private and public capital sources.

#### *Resource Mobilisation*

The Bank's direct contribution to mobilising resources has been a substantial increase in its own lending for energy projects. This has grown substantially, doubling from \$ 1.5 billion in fiscal 1979 to \$ 3.4 billion in fiscal 1982.

#### *Energy Lending*

In the poorer developing countries which have limited access to commercial finance the \$ 2.3 billion of highly concessional IDA financing provided during 1979-82 has made a major contribution to underwriting the process of structural change in the energy sector. As well as participating directly in energy financing, the Bank has made a major effort to mobilise resources from other sources.

A special effort has also been made in the energy sector to mobilise additional external resources through co-financing and through the identification of opportunities for direct private investment.

#### *Co-Financing*

The emphasis placed by the Bank on the co-financing of its energy projects stems from three factors:

1. The substantial investments needed for energy development in the developing countries require a major effort to mobilise funds from all potential sources.
2. Projects in the energy sector are more likely to attract co-financing than those in many other sectors because of the wide interest in energy development by both private and official financing agencies.
3. Projects supported by the Bank are attractive to other lenders because they are assured that the project is carefully appraised from the technical, financial and economic angles and because the presence of the Bank is seen to diminish risk.

During the period fiscal 1979-82, the \$ 89.9 billion of Bank lending for energy was associated with another \$11.2 billion of

co-financing from bilateral and other multilateral agencies, export and suppliers' credit as well as commercial banks and private sources. The average Bank energy project over this period had a total cost of \$ 322.6 million with a foreign exchange component of 48 per cent.

Table 11.2 shows that the Bank financed an average of 22 per cent of the total cost while external co-financing covered another 25 per cent.

**Table 11.2: Financing of World Bank Energy Projects 1979-82**

Particulars	Number of projects	Percentage of total project cost		Percentage of foreign ex- change cost	
		Bank/ IDA	Other exter- nal sources	Bank/ IDA	Other external sources
Oil and gas	43	30	45	38	57
Pre-development	26	65	8	88	11
Development	17	27	48	34	61
Power	80	23	24	53	54
Coal	5	20	25	32	42
All Energy Projects	135	22	25	46	51

From the above table it is clear that the highest degree of co-financing has been in oil and gas development projects where every \$1 of Bank financing was matched by \$ 1.78 from other external co-financers. The co-financing for the other energy sub-sectors were 1.28 : 1 for coal projects, 1.03 : 1 for power projects and 0.95 : 1 for other energy projects. Thus, co-financing will continue to be an important feature of bank projects. An example is the Bombay High Project for oil development offshore, India. The Bank's role here in technology transfer, reservoir engineering, institution building and infrastructure development materially benefits potential investors and lenders who might be interested in the same field or in other parts of the programme.

#### *Direct Private Investment*

The Bank also promotes direct equity investments by the international energy industry in developing countries' energy supplies. The greatest potential for this is, of course, in oil and gas

where the international petroleum industry has traditionally made an important technical and financial contribution. A variety of instruments are used by the Bank to pursue this objective. The Bank's exploration promotion projects are expressly designed to rekindle the interest of private companies in exploration and development by providing a better geological data base, rationalised and clearer incentive and contractual frameworks, and a stronger legal and institutional capability in the sector.

In addition to the activities undertaken directly by the Bank, its affiliate, the International Finance Corporation (IFC) is playing an expanding role in energy investments in developing countries. IFC was created to encourage the mobilisation of productive private investment, both foreign and domestic. In this capacity, IFC not only makes loans for energy ventures, but has the unique ability to make equity investments directly in private sector projects. IFC has invested equity and loans in oil and gas field developments, in enhanced oil recovery, the mining of coal, in power transmission, gas pipelines, ethanol facilities and in domestic refineries. In addition, it has invested in gas utilisation projects and has been instrumental in assisting the negotiation of geothermal power contracts and gas pipeline tariffs. IFC's continued expansion in the energy sector and its future strategy are an integral part of its new five-year plan for fiscal 1984-88, already under discussion. These activities are viewed as an important complement to those of the Banks itself.

#### *Energy Sector Management*

Along with its financial involvement, the Bank has made a major effort to assist the member countries in strengthening their management of the energy sector. In doing this, it has built upon its traditional strengths:

- a) Competent project selection, formulation and implementation.
- b) Strengthening indgeneous institutions and developing an effective sector planning and management capability.
- c) Analysing key sector issues and helping the country formulate an appropriate overall sector development strategy.

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*Of allied interest*

## **DEVELOPMENT POLICY** **A Study of Indian Perspective**

*B. Krishnarao*

While references have been made in this book to recent changes in the economic conditions of developing countries, it considers at length the various facets of the Indian economy, and the long-term trends of change and the resilience that have developed in it. The policy approaches needed to develop a diversified multisectoral economy in which technological diffusion plays a vital role are pointed out. The evolution of monetary and fiscal policies is discussed showing how changes have been emerging in India and other developing countries. The basic facts involved in planning and the economic patterns towards which these may lead are examined while stressing the Indian context.

The role of the agricultural sector and the importance of rural development policies are also dealt with, as also the need for laying emphasis on industrial growth. The problem of poverty eradication, with special reference to India and the need for promoting work, wealth and justice are discussed. The role of the state in promoting the public sector is outlined.

*Prof. B. Krishnarao is Head of the Department of Economics at Bharathiar University, Coimbatore.*

## **ENVIRONMENTAL PROTECTION AND LEGAL DEFENCE**

*V.R. Krishna Iyer*

This collection of essays and speeches by Justice V.R. Krishna Iyer reflects a unitive commitment to conservation viewed in holistic perspective of Nature, Development and Humanity.

The author expresses his concern over the drain of India's ecological resources and degradation of its environmental virginity. He believes that only a resistance movement by the masses can save the situation. The battle for survival of man, he observes, has a material-spiritual dimension. It is a struggle in which everyone with compassion must join. Law is the means, the tool, to achieve environmental justice.

*V.R. Krishna Iyer is a former Judge of the Supreme Court of India.*

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