UNIT 11 ENERGY RESOURCES

Structure

11.0 Introduction

11.1 Forms of Energy

11.2 Energy Consumption: Historical Patterns

11.3 Conservation

11.4 Summary

11.5 Exercises

11.6 Suggested Reading

11.0 INTRODUCTION

As we have explained in the introductory passages given at the beginning of this Block several fresh possibilities of appropriating environmental resources emerged as sedentary societies based on agriculture began to settle. The foremost among these related to energy resources. New forms of energy resources were discovered by the societies and energy consumption on an ever increasing scale became a uniform practice. The appropriation of energy resources depended on the availability of different forms of energy as also on the accessibility of the sources of these forms. It was also directly related with the pattern of consumption of energy by different societies which obviously showed a diversity adapted to the stratified social structure.

The historical information on energy resources for pre-industrial societies is thin and so is the case with the patterns of energy consumption. Yet we have attempted to weave a narrative based on this evidence that describes the forms of energy resources and the pattern of energy consumption as it evolved historically. In addition, details on the imperative of conservation have also been included. You will find the Unit interesting since it opens before you a relatively less explored and discussed subject. We recommend that you pay attention to the relationship that specific environmental conditions obtaining in India had with the appropriation of energy resources. It will help you understand better the next Block (5), on **Indian Philosophy and Environment** and help you place colonial policy with regard to environmental resources (discussed in **Block 6**) in the correct perspective.

11.1 FORMS OF ENERGY

Energy is generally understood to carry the meaning of the source of strength that is necessary for performing various kinds of activities. Most of the forms of energy are shapeless and not easy to be subjected to physical verification. They can be verified mostly in terms of the work performed with their support. The word energy is derived from the Greek

energeia which is made up of *en*, "in" and *ergon* meaning "work". Evidently its meaning centres around the work done by using energy. The idea of energy in the above sense goes back to Galileo in the seventeenth century. He recognised that in lifting weight the force that was applied was in fact a form of energy. The idea was further developed by Newton who suggested that the quantum of force applied on an object was associated with the acceleration gained by that object.

The forms of energy broadly range between inanimate natural forms and animate forms of energy; and when we step on the industrial societies electrical and nuclear forms add up. Humans and animals perform work with the help of their physical energy. This is the simplest form of animate energy. Similarly natural or inanimate forms of energy are located in most of the physical matters. They are available at the primary level in the form of solar energy and wind and water energy and at the secondary level in the form of thermal, mechanical and chemical energy.

It is, however, difficult to enumerate all the various kinds of energy. The sources of energy are visible, but the energy itself is transitory, recognisable through the process of activity generated by it. Therefore in our attempt to identify the forms of energy we are greatly helped if we focus our attention on the sources of energy. The forms, as we have said above, are closely connected with the sources; it is easier to recognise the sources which are more tangible in character. The sources of energy can be broadly divided into two categories more or less compatible with the two main forms of energy: first being animate sources of energy and the second, inanimate sources of energy.

For a very long span of time in history, barring the energy emitted by sun, humans have depended upon the animate sources of energy. In the initial stages of development human physical power was considered as the primary source of energy. For all those long centuries of human existence when agriculture had not developed and hunting-gathering activities were the principal mode of living the physical prowess of the humans was the principal source of energy. This prowess was augmented with the help of stone tools and implements that were manufactured under an organised method. We have read in Block 2 how stone tools and implements were continuously upgraded and diversified. The effort obviously was to sharpen the human physical energy and carefully segregate most of the work done for a differential use of energy to be applied to them. The detailed classification of stone tools into core and flake tools and into microlithic tools of various kinds bears ample testimony to this effort.

Mention may be made here of a mechanical device called spring which accumulates energy and releases it suddenly when required. Its first known use, and of continuing importance was in the bow used to shoot arrows in hunting and in battle. The first unequivocal representation of it, dating back from later Paleolithic times, is from North Africa. However, the effectiveness of the simple bow was limited by the strength of the arms of humans who would use the device.

Next to be utilised by the humans was perhaps the animal energy. The domestication of wild animals was a major advance in the field of the use of energy resource. The details on the emergence of pastoral practices have been given in Block 2. Animals as the source of energy were utilised in numerous spheres of life. They were also an important source of food for the humans. Animal power was harnessed for use as draught power to be utilised in agriculture. You have already read in Block 2 about the symbiotic relationship that had developed between the nomadic pastoralists and the settled agriculturists. The utility of animal power had become so evident to agriculturists that in peninsular India the Neolithic sites (mid-third millennium BC) from their inception exhibited a high imperative of large number of livestock maintaining (Cf. *Archaeology and Interactive Disciplines, op.cit,* p.166). Animals provided the energy for the transportation purposes right upto the beginning of the mechanised modes of haulage. One of the earliest references of this kind of energy harness is available in the rock paintings at Morhana Pahar near Mirzapur in Uttar Pradesh. There two chariots have been shown drawn by two and six horses respectively. You must have read about this pictorial evidence in Block 2 where it has been described at length. Another important area where animals supplied energy was in the field of irrigation/water lifting devices. Similarly cow also provided cow-dung, extensively used to fire the hearth. Human as well as animal excretion has been extensively used in the fields as fertiliser to increase the agricultural production.

Early humans first made controlled use of an external inanimate energy source when they discovered the use of fire. Burning dried plant matter and animal waste, they employed the energy from this biomass for heating and cooking. For the heating purposes humans were greatly dependent upon the forest resources. The forest resources were also extensively used as raw material for various other purposes such as housing, and the making of furniture, carts, agricultural tools, musical instruments and numerous other handicrafts. Wood has been an integral component of human housing since ancient times. Even in the mud houses roofs were usually made of wood. The necessity for wood was greater in the absence of technological support. The demand for forest resources for this kind of activity kept on growing with the increase in the population and material development of human societies.

In humanity's early attempt to harness inanimate, natural forms of energy, water occupies a central position. Besides being a key life sustaining resource for most of the living beings including humans, the irrigation potential of water for sustaining agriculture had also been discovered fairly early. The first civilization in India as also elsewhere in the world was riparian in character. But we shall discuss this and the other aspects of the appropriation of water as an environmental resource in the next unit. Here we are concerned with the use of water as an important energy resource. Not much early evidence on this matter has been garnered. We may however speculate that the flow of water in major streams and rivers would have been used for transporting the large tree trunks and logs from one place to the other. This practice has been in use even today. A greater use of water energy however become possible after the development of

a few mechanical devices that were energy saving by themselves. Perhaps the earliest use of water in this fashion was in driving waterwheels. In the hilly regions of India and in similar terrain elsewhere too, the flour mills are even today driven with the help of waterwheels.

It was with an increased use of contrivances and mechanical devices that the era of uncontrolled exploitation of inanimate sources of energy began. Most of the natural inanimate resources were now harnessed. The pressure on them gradually increased and the stage of exploitation began endangering the existence of most of the natural resources. All this, however, relates with the onset of modern age. We shall discuss these developments in Block 6 and Block 7.

11.2 ENERGY CONSUMPTION: HISTORICAL PATTERNS

It can be conveniently argued that the social evolution of humans has been closely tracked by developments in similar manner in the levels and patterns of energy consumption. In the early stages of human society the nature of energy consumption was more or less equal in terms of its horizontal and vertical expanse. The levels of energy consumption had remained confined to bare necessities and the possibilities of surplus retention were very limited. Most of the demands for energy by these societies were available in the form of food procurable locally. It was with the growth of agriculture on the one hand and the domestication of animals on the other hand that the need for newer sources of energy arose and the consumption of energy multiplied. The most important change was in the basic source of energy: manpower was gradually replaced, first by the power of draught animals. Donkey-driven mills were employed as early as the fifth century BC to crush ore from the silver mines at Laurion, and their use had extended to the grinding of corn in Greece by about 300 BC.

The next major development was the use of the water and wind energy. One of the most important uses of water energy was in agriculture for irrigation purposes. The distribution of water to cultivated fields through channels has been an old practice. An early evidence pertaining to irrigation of this type relates to Mesopotamia and dates back to about eighth century BC. This irrigation was helped by the proximity of the Tigris and the Euphrates, which assured a constant supply of water. As described by Seton Lloyd, “Almost the whole of the alluvial plain is capable of being prodigiously fertile agricultural land; and a great part of it has clearly at one time or another been under cultivation. Evidence of this is the profuse network of ancient irrigation canals, now abandoned, whose spoil-banks, like parallel ranges of small hills, run far out into the plain beyond the scanty farmlands of the present day” (*Foundations in the Dust, The Story of Mesopotamian Exploration,* Thames and Hudson, London, Revised 1980, p. 23).

The evidnece from Harappan settlement suggests that small **bunds** were erected across the rivers to use the flow energy of water for spreading fresh alluvial soil along the banks. This soil was then used as agricultural field. The knowledge of the Harappans about water energy is further supported by the discovery of the famous dock-yard at Lothal. It points to the fact that knowledge relating to the tidal currents was tactfully used in creating the dock so that ships could come in with flow-tides and could go out into the sea with ebb-tides (Cf. S.R. Rao, *Lothal, A Harappan Port Town*, Vol. I, A.S.I., New Delhi, 1979, pp. 123-132).

A very early use of water energy was in driving wheels. The evidence relates to about second or first century BC in Egypt. The wheel was submerged in running water which made it turn. This rotary movement was transferred via a fixed axle to a flat millstone. This type of mill was used for grinding cereals or oil-producing plants. In fact this was the stage when natural energy and mechanical contrivances were combined. This gave a remarkable boost to the use of energy as it enhanced its driving power substantially.

The early waterwheels, first used to drive mills for grinding grain, were subsequently adopted to drive sawmills and pumps, to provide the bellow action for furnaces and forces, to drive tilt hammers or trip-hammers for forging iron, and to provide direct mechanical power for industrial mills. Until the development of steam power during the industrial revolution waterwheels were the primary means of mechanical power production, rivalled only occasionally by wind mills. Thus, many industrial towns sprang up at locations where water flow was perennial. In an old reference to a watermill dating back to about 85 BC, appearing in a poem by an early Greek writer, the liberation from toil of the young women who operated the querns (primitive hand-mills) for grinding corn was celebrated. According to Greek geographer Strabo, King Mitheradates VI of Pontus in Asia used a hydraulic machine, presumably a watermill, by about 65 BC. Early vertical-shaft water mills that drove querns were known in China by first century AD, and were used throughout Europe by the end of the third century. A horizontal-shaft water mill was first described by the Roman architect and engineer Vitruvius about 27 BC. The Roman mills were adopted throughout much of medieval Europe and waterwheels of increasing size were made almost entirely of wood. In addition to flowing stream water, ocean tides were also used though rarely to drive waterwheels.

Like watermills, windmills were among the original prime movers that replaced animal muscle as a source of energy. They were used for centuries in various parts of the world, converting the energy of the wind into mechanical energy for grinding grain, pumping water, and draining lowland areas. The first known wind device was described by Hero of Alexendria (c. first century AD). The earliest known references to wind-driven grain mills, found in Arabic writings of the ninth century AD, refer to a Persian millwright of AD 644, although windmills may actually have been used earlier.

One of the limitations of both the waterwheel and the windmills was that it was usually necessary for the power they generated to be utilised on the spot. There were, nevertheless, systems for transmitting power over land, often for considerable distance, but the power-loss must have been much.

As with waterwheel, it is difficult to estimate the power output of windmills. A large Dutch windmill of the eighteenth century, with a 100 feet (approx. 30 metres) sail-span, probably generated about 10 horse power (h.p.) in a 20 miles per hour wind speed. Smaller mills, with a 24 ft (approximately 7 m.) span, probably yielded about 5 h.p. Theoretical considerations show that the windmill in its traditional form could not, at best, yield more than 30 h.p. It was not, therefore, a powerful prime-mover by modern standards, and a substantial proportion of such power as it did develop must have been dissipated in the clumsy transmission system, even after iron gearing had been introduced.

The foundations for the use of steam power are often traced to the experimental work of the French physicist Denis Papin. In 1679 Papin invented a type of pressure cooker, a closed vessel with a tightly fitting lid that confined steam until high pressure was generated. It was given more efficient and workable form by a Scottish instrument maker James Watt in 1765 who developed a steam engine. Although far more difficult to build, Watt's rotative engine opened up an entirely new field of applications; it enabled the steam engine to be used to operate rotary machines in factories and cotton mills.

Other important development with regard to energy utilisation had been the discovery of a device by Michael Faraday who converted mechanical energy into electric energy. This led to the development of electric generators whereby thermal energy was used to power the mechanical energy and in turn generate electric energy. The greatest advantage with the electric energy has been the possibility of transmission of energy to distant places from the source of its generation. Similarly another major energy resource has been the nuclear energy which has a great potential.

11.3 CONSERVATION

The concept of energy conservation is related with the theory that the energy remains constant and it only changes its form. The conservation of energy is not a description of any process going on in nature, but rather it is a statement that the quantity called energy remains constant regardless of when it is evaluated. The law of conservation of energy can be applied not only with regard to nature, but to any isolated system as well. Energy exists in various forms and is convertible to one-another within the constraints of conservation law. These different forms of energy include thermal, kinetic, gravitational, chemical, nuclear, radiant, electric, mass energy, etc. It is the universal applicability of the concept of energy, as well as the completeness of the law of its conservation within different forms, that makes it so attractive and useful. However, one must remember

that all the forms of energy are still not in control of the humans. Most of the energy we consume has led to increase in the other unwarranted forms of energy. The most visible example can be the uncontrolled consumption of combustion energy which has led to increase in the chemical energy causing Ozone depletion. Therefore it is necessary to realise the spirit of the law of conservation of energy and either control over-consumption of energy or develop other non-conventional sources of energy.

Most of the energy resources consumed by humanity are exhaustible and non-renewable therefore it is necessary to be prudent in one's consumption of finite sources of energy. At the same time, we must realise that there are several renewable sources of energy and it is suggested to develop the technology to harness the potential that is going waste.

11.4 SUMMARY

The analysis of energy resources attempted here suggests a possible relationship between social stratification and the pattern of consumption. Along with the changes in the patterns of consumption of energy we can also trace the changes in the source of energy. In the beginning, the primary source of energy had been the plants, animals and humans themselves. Subsequently the inert potential of the land energy was harnessed by the humans and soon the potential of various minerals as sources of energy was also harnessed. The trend of greater energy consumption continued with the growth of urbanisation witnessed during the emergence of civilisations across the world. This phase onwards, crystallisation of social stratification led to a variation in the energy consumption across the different sections of the society. Hereafter and until the advent of industrial revolution the consumption of energy varied vertically, whereas it remained more or less similar horizontally. The pattern of energy consumption witnessed, radical changes with the emergence and growth of industrial revolution. Industrial revolution provides a paradigm shift in the nature of energy sources, and the process of appropriation and distribution of energy resources. The changes introduced during and after the industrial revolution have been very rapid and have resulted into a serious deterioration of our environment. The loss of forests, pollution of water and air are some of the manifestations of the change in the sources of energy.

11.5 EXERCISES

1) How do you distinguish between animate and inanimate forms of energy? Discuss briefly their historical evolution.

2) Write a note on the historical patterns of energy consumption.

11.6 SUGGESTED READING

T.K. Derry & Trevor I Williams, *A Short History of Technology*, Oxford, 1960.

Maurice Daumas, ed. (tr. Eilean B. Hennessy), *A History of Technology & Invention*, Vol I: 'The Origins of Technological Civilization', Bombay, Eng. Tr. 1969.

S.R. Rao, *Lothal, A Harappan Port Town*, Vol. I, A.S.I., New Delhi, 1979.