Renewable Sources of Energy

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RENEWABLE sources of energy, as the term implies, are those sources which nature continuously renews on its own. They include direct energy from the sun (solar energy), wind energy, biomass energy (including fuelwood and charcoal), draught animal power, geothermal energy, and hydro energy. Mankind has used these sources from ancient times for its various needs like drying, cooking, heating, lighting, mechanical power and transportation. However, when the industrial revolution started in the nineteenth century, it was based on more concentrated forms of energy such as coal and later, oil. Of the renewable sources, only hydro-energy (from falling water) and to a lesser extent, geothermal energy started being used for electric power generation in a substantial way. This is a form in which energy can greatly assist in modern development.

The other renewable sources continue to be used, where they are used, largely in traditional ways. These are not adequate for meeting the growing energy needs of the world, particularly in the developing countries; and for providing energy in forms that can help to improve material prosperity and the quality of life. Furthermore one of these resources, fuelwood is presently being used in a way which, overall, is depleting the resource. The rate of cutting of fuelwood is in excess of the rate of growth—the difference being quite alarming in many developing countries and serious in others, including India. In fact the denudation of forests, to which this is contributing, is leading to many adverse effects on soil fertility, climate, flooding and silting of rivers, to have become a major global problem in itself. Thus the challenge before us is to harness the renewable forms of energy in such a way that they can contribute to modern development, improved standards of living, and the preservation of the environment and the ecological balance.

The need for doing this is now obvious. The conventional hydrocarbon fossil fuels are oil, coal and natural gas, on which development has been primarily based since the mid nineteenth century. These are finite on the earth, and steadily depleting. In particular oil, which has been the backbone of development in this century and the particularly spectacular technological and industrial growth since the second world war, is depleting at a fairly rapid rate compared to the world reserves. Until the sharp rise in oil prices in 1973, when the world as a whole first became aware of the 'energy crisis', the increase in oil consumption was proceeding at a galloping pace. By 1970 it amounted to over 2,300 million tons per annum, constituting more than 46 per cent of the total primary commercial energy consumption from all commercial sources (oil, coal, natural gas and electricity) in the world. Even after 1973, in spite of conservation and substitution measures, world oil consumption increased, so that by 1980 it reached 3,067 million tons per year or 45.5 per cent of the total. The rate of growth in oil consumption in the decade 1970-80 came to an average of 2.9 per cent per year. In 1979-80 there was another steep oil price hike, followed by a recession.

A combination of factors, including a low demand caused by recession, increased energy conservation and the substitution by other fuels caused world oil consumption to drop slightly between 1980 and 1982. Oil prices have also declined slightly, due to the factors mentioned above and due to the increase in oil supply from non-traditional producers. However, the overall demand for oil is rising again, as economies come out of the recession. The potential demand for energy in the developing countries is enormous; and the growth in *their* oil consumption in the decade 1970-80 was at a rate of about 6 per cent or double the world average. Thus the global pressure on oil supplies will continue to rise on the whole, in spite of temporary fluctuations. Studies based on even 1980-81 trends indicate that the bulk of economically recoverable oil reserves could face exhaustion by about the year 2040, less than 60 years from now. This comes remarkably close to estimates made by some scientists as early as 1960, well before the oil crisis.[1]

Apart from pressure on total resources and availability, one has to consider the question of costs. Even at today's prices, oil consumption is a considerable economic burden, particularly severe for the oil-importing developing countries. Although prices declined in the past year, they remain substantially higher then the prices of even 1979 and five times higher in real terms, as compared to ten years ago. For the reasons mentioned earlier they are likely to rise again in real terms during this decade, even though there may be unpredictable fluctuations in the short term. Hence the urgency of measures to reduce dependence on imported oil remains acute. The magnitude of this problem can be seen from the fact that in 1980, the net oil imports of the oil importing developing countries were 295 million tons (up from 160 million tons in 1970) or 44 per cent of their total commercial energy consumption.[2] Even if the growth in their indigenous production of oil goes up from 0.3 per cent per year in the period 1970-80 to 5.5 per cent per year in the period 1980-95, and growth of consumption is reduced from 4.9 per cent per year in 1970-80 to 2.6 per cent per year in 1980-95, the oil imports of the OIDCs will need to increase from 295 million tons in 1980 to 386 million tons in 1995 – if we have even a modest 5 per cent per year growth in total energy consumption.

While oil may constitute the largest single problem area in fossil fuels, the difficulties with coal and natural gas are also going to increase with time. These reserves cannot supply the growing energy needs in the long term; and even in the short term the difficulties in mining, and transporting these fuels and in the environmental consequences of using them, are becoming more and more pronounced. The imperatives of a limited hydrocarbon fuel supply cannot be changed; nor should there be a reduction in the tempo of energy supply for the developing countries, since their very economic and even social growth, depends on making available increasing amounts of energy. The required demand increase is substantial even at present levels of per capita consumption, simply to meet the needs of rising populations. It becomes massive, when we realize the imperative to supply much higher levels of energy per capita to the developing countries. (The average present consumption of commercial energy in these countries is only about 450 kg coal equivalent per capita per year compared to a world average of over 2000 kg, and a figure for the developed market economy countries of over 6300 kg.

Unlike the industrialized countries where there was considerable wasteful consumption of energy, the developing countries need more energy for their new industries; and for improving agriculture, transport, social and cultural services. While they should ensure maximum possible efficiency in the use of energy, this will help to keep demand *increases* reasonable. At the same time there are vast resources of renewable energy available; e.g. the incident direct energy from the sun itself is more than twenty times the entire reserves of fossil fuels. It is therefore both logical and indeed essential to harness the renewable sources of energy. As the 1980 United Nations General Assembly put it:[3]

> The international community will have to make substantial and rapid progress in the transition from the present international economy based primarily on hydrocarbons. It will have to rely increasingly on new and renewable sources of energy, seeking to reserve hydrocarbons for non energy and non substitutable uses.

The need for such an energy transition was emphasized by the nations of the world, who gathered for the United Nations Conference on New and Renewable Sources of Energy at Nairobi in August 1981. The sense of urgency recommended there may have declined in some quarters, due to the subsequent easing of the oil crunch. However as discussed earlier, this would be an extremely short-sighted view—particularly for the oil importing developing countries, and specifically for India which has vast requirements, vast resources of renewable energy, and a majority rural base where supply of conventional energy is increasingly difficult or costly.

World-wide development in technology and the know-how to harness renewable energy sources in a modern way is progressing steadily. Many technologies have reached what is known as a 'mature' stage, that is, they can be applied on a large scale and in a commercial manner. Several of them are also now economically competitive or nearing that stage, for certain applications particularly in remote and rural areas. Several other technologies look promising from the point of view of research, large-scale field demonstration and trial programmes. Still others offer a longer term development potential which justifies increased attention to longer term research. Some of the renewable resources and technologies are discussed below.

Fuelwood

Recent studies have further served to confirm that the situation regarding fuelwood is indeed at a crisis level and would be disastrous for many developing countries. The need for fuelwood for supplying rural energy needs is one of the major reasons for deforestation, which it is now estimated is reducing the forest cover in the developing world by about 10 million hectares a year. The effects of this are numerous. They include soil erosion, reduced productivity of the land, increased siltation of waterways and increased flooding. Almost each of these subsidiary effects itself causes major problems which could be very serious.

Thus, reduction in agricultural productivity negates the already serious food situation in many developing countries, with all its attendant ills of hunger and malnutrition. Similarly, siltation leads to reduced water availability which further contributes to reduced agricultural productivity, as well as reduction in water supply for drinking and other human uses. It has also been seen that in many parts of the world, the desertification of arid regions is expanding in large areas, as the little biomass cover in those regions is used by people in search of fuelwood. There is scientific evidence that reduction of the forest cover is leading to longer term climatic changes and reduction in rainfall precipitation—which will further compound the existing problems of inadequate water and inadequate land productivity. Many poor rural and even poor urban households do not have at present adequate alternatives to fuelwood.

From the point of view of ecology, as well as for meeting rural needs, a massive programme of fuel forestation and wood plantation has to be undertaken. It has been estimated that at least 50 million hectares have to be planted in the developing countries, between now and the end of the century—necessitating a five-fold increase over current planting levels world-wide. This was also recommended in a resolution sponsored by India and some other countries, and unanimously passed at the United Nations Conference on New and Renewable Sources of Energy, 1981.[4] The resolution, however, also recognized that simultaneous action is needed to start reducing pressure on the fuelwood supplies—by the acceleration of programmes for the development and widespread utilization of other new renewable energy sources, which can supply energy in a manner that will improve standards of living and the quality of life in the rural areas.

The twin-pronged strategy requires application and development across the whole spectrum of disciplines and technologies, including the development of fast-growing varieties of trees and biomass; the plantation of de-forested areas in a rigorous fashion with all that it entails in terms of infrastructure, organization and financial support; the development of more efficient and low cost means of burning wood and producing charcoal; the introduction of methods for converting fuelwood wastes to modern forms of energy such as through gasification or pelletization etc.

In India the National Committee on Fuel Wood has analysed this matter recently, and the report[5] indicates the action is of specific relevance to Indian conditions. Similar studies have been carried out for other areas, several derive support from the United Nations and it does appear that the means are available for dealing with this problem in an increasingly effective fashion. Energy plantations could also be used for supplying modern energy at a lower investment than energy from conventional fuel, such as coal-based systems. Thus, according to one estimate, the cost per million BTU in the case of energy plantations may come to only about Rs. 14.50 as against Rs. 18 for coal. The investment on energy plantation could be only about Rs. 5 lakhs per megawatt as against Rs. 18 lakhs to Rs. 31 lakhs for mining and transport facilities required to support 1 megawatt of coal based power generation.

The growth of knowledge in respect of improved and faster growing species is also increasing steadily. The application of more modern scientific technologies, including tissue culture and genetic engineering, will further accelerate its pace.

Hydropower

Electricity from hydro-energy is the form of commercial energy from renewable sources that is perhaps most conventional in the sense that it is well developed, and widely applied. There is every reason to expand the utilization of the hydro-potential, particularly by giving greater stress to small hydropower systems located on streams or canals. Attention is now being given to developing lower cost technology, for such mini and micro hydro systems. It is clear however, that already the costs have come down sufficiently for such systems to compete economically with the larger conventional hydro-plants—for application to regions which are far from the electrical grid. For such application, the investment requirement has to be compared with the investment plus transmission requirement in respect of conventional large hydros. The latter figure has come often in the order of $2,000 per kilowatt, a cost which can now be met even by the smaller of the mini hydros (less than 1 megawatt). Several manufacturers are now available who can produce such equipment.

A further advantage of such installations is their greater speed of manufacture and erection. This translates into direct economic benefits, as the early completion keeps interest during construction and escalation at a low rate, and furthermore, the early benefits mean early economic returns for the use of the power. If these two benefits are used in comparison with the long gestation of the large conventional hydro, the comparison in favour of the former becomes even more marked. Finally, small hydros do not have the adverse environmental impact of the larger hydros, resulting in the flooding and submergence of large areas and the effects on the river flora and fauna. For all these reasons, attention in the world has accelerated in favour of small hydro installations which can now be readily commercialized.

Wind Energy

Wind energy for small-scale application, even for mechanical purposes, was widely used until 1930. In the 1920s there were over 6 million wind pumps in the USA alone. Australia, Argentina and South Africa are other countries which used wind pumps in large numbers. While the use of wind pumping declined in the 1930s and subsequently due to the advent of cheap oil, it is estimated that even today more than 700,000 wind pumps are in regular use over the world. Due to the resurgent interest in renewable energy, over 50 manufacturing units are producing wind pumps.

For wind pumping to be economical, a basic requirement is found to be the availability of a mean wind speed of about 3 metres per second, at the time where the demand for water is greatest. This requirement could drop substantially as the cost of wind pumping declines with increased production. The energy costs from modern wind pump system range from about $0.5 per hydraulic KWH to about $4 per hydraulic KWH. This compares to costs of $0.9 to $2.4 per hydraulic KWH for average diesel engine pumps. In fact, since the economics of wind energy systems are very sensitive to mean wind speed, in the higher wind areas the costs can be substantially competitive. The other application of wind energy which is already at the level of commercialization is electricity generation for small-scale purposes. Small wind generators today can supply electrical energy, including battery storage, for between $1 per electrical KWH at wind speeds of 3 to 5 metres per second; which again can be quite competitive with diesel generators without battery storage in several locations.

Much more work needs to be done to map the specific wind energy possibilities in different parts of the world. Yet enough is known to conclude that many developing countries have adequate wind speeds, to use wind energy technology in an economical fashion—even with the present day technology. Development in this technology is, of course, resulting in improving efficiencies and reducing costs. In several countries, with the provision of physical incentives, the installation of wind energy devices for both pumping and low power production is proceeding quite rapidly. Thus, for example, in California several wind farms are in operation. More are being installed which are able to provide power to the grid at costs lower than or at the same rate as their normal grid costs particularly for peaking power. Such wind farms have in some cases several hundred individual units of say 25 kilowatts each, which can be owned by a small group or by individuals, binding together in a group and each receiving revenue for his particular machine or machines. Thus more than 75 wind electric generator manufacturers are now in production world-wide. Developing countries can start using this resource in many areas. In India, the coastal areas as well as mountains, hilly and valley areas are potentially very good, for the large-scale application of wind energy technology; for pumping water as well as for electric generation on a smaller scale.

Geothermal Energy

Geothermal energy is energy deriving from heat in the centre of the earth. This can be used both as a source of heat for space heating, industry, crop drying; or even providing cooling by using the heat for a vapour absorption or other cooling systems. This energy can also be used to generate electricity. The latter is its major use today, and almost 2000 megawatts of power is already installed on this basis. Of this total about 700 megawatts are installed in the developing countries already by 1980, notably in the Philippines and China, which are proceeding with installation of more geothermal capacity. Other developing countries which have geothermal projects in operation or under construction include Mexico, Indonesia, Kenya, and Turkey. Work is proceeding in several other developing countries, for evaluating geothermal potential and identifying the projects which could avail of it.

Since the costs of developing geothermal resources by drilling are relatively high, there has been perhaps insufficient action in this area. Only a fraction of the known areas with potential have been scientifically investigated, or developed. There is every likelihood therefore that with greater effort in investigation and evaluation, geothermal energy could play a more significant part in meeting the needs of total energy.

Direct Solar Energy

The direct energy from the sun, as mentioned earlier, is enormous in its total quantity. The major problem in harnessing it is only the rather dispersed form in which it arrives on the surface of the earth. Thus the average insolation rate in India, a high incident tropical country, is only 5-8 kilowatt hours per square metre per day. However, there are several modern uses where energy is required in the form of heat at low or medium temperatures. For such applications, concentration and conversion of solar energy are not required; and it becomes more economically competitive. It is for this reason that the largest modern application of solar energy today is for water-heating using flat plate collectors for residential and industrial uses. For such applications it is now possible to have pay-back periods of between $1\frac{1}{2}$ to 6 years, depending on the conventional fuel being considered. Apart from the industrialized countries using this application where adequate sunshine prevails including several parts of the United States, Spain, parts of Japan etc., several developing countries have large solar water heating programmes under way. These include Cyprus, Brazil and Mexico.

A major constraint in further spreading the use of this technology which is commercially available on a large scale today is the higher initial cost; and secondly, the lack of adequate numbers of installations which have been run for long enough periods. Measures could be developed to help consumers overcome these constraints, through large-scale government sponsored or internationally sponsored demonstration programmes. Methods of recovering the initial cost in easy instalments, or by leasing, will permit the technologies to spread fast and the costs will also decline. This is indeed required across the spectrum of renewable energy technologies.

As the cost of conventional fuels increases, concentrator type solar collectors will become increasingly competitive. These can supply energy at somewhat higher temperatures, as for example for industrial processes which need steam or high temperature fluids. Parabolic line focusing collectors have already started being used for such purposes on a fairly large scale. With the help of economic incentives to meet initial costs, several such systems are being installed for meeting industrial steam needs in different parts of the world, for example, for solar generated process steam for textile mills, chemical plants, sugar and agro industry plants etc. In this case also there appears to be considerable potential for meeting the needs of developing countries for both rural industries, as well as small urban industries.

It may be pointed out that in India, 20 per cent of the total commercial energy is required in the form of heat at temperatures of

200° C or below. This is an illustration of the potential that can be met from concentrating and flat plate collectors. In several industrial countries also a large percentage of the energy used in factories and processing plants is for producing industrial processing heat which can be technically met from such solar technology today. Solar crop-drying through simple or concentrating collectors also appears very promising for developing countries.

Solar energy is also being used to produce electric power, both through conversion of the heat through an intermediate fluid such as steam or organic vapour; as also from direct conversion through the photovoltaic effect. In the former category line, focusing collectors, point focusing collectors and central tower focusing systems have all been used on a pilot basis. For smaller power outputs, the line and point focusing collectors are more economic; whereas for larger power outputs the tower type concept gives more promising results. The largest solar power station based on this principle has been operating now for almost a year at Barstow in California, producing 10 megawatts steadily. The technical performance of this plant has been rather satisfactory. The cost of this particular plant including research and development has been quoted at about $140 million. However, the cost of similar plant built now should be only 60 per cent or less of this amount.

Photovoltaics

This is a technology which has excited a great deal of interest, because of its simplicity and ease of maintenance during operation. There are no moving parts in the conversion process. However, very high purity silicon and high quality processing is required, which puts up the price. Ideally the technology can be used in a variety of ways, for stand alone power systems, for power packs used on individual pieces of equipment such as pumps, refrigerators, telecommunication equipment, lighting systems etc. or for other small or large electrical uses.

The cost of these technologies is steadily declining, with development in techniques and the rate of production. Costs have already come down to about $5 a peak watt for modules and $10 per peak watt for installed systems. At these prices it is now economically viable to use photovoltaics for several remote area applications of small size lighting and telecommunications systems in offshore platforms, defence outposts, railways, post and telegraphs etc. They are also nearing economical competitiveness for applications for remote area pumping of water, a requirement that is of predominant interest in developing countries including India. As technology develops and production increases, the costs will decline so that larger and larger applications nearer electrical networks are coming within range. Exciting developments in this area are taking place in ribbon development of high purity silicon (which requires less than half of the material needed in present day technology using wafers, and could come down to about 1/5 to 1/6 of this requirement) and in the use of amorphous and other thin film techniques.

An interesting example of the application of photovoltaics for fairly substantial electrical generation is found in California, in the U.S. A one-megawatt plant is already operating there, supplying power to the local utility. A 16-megawatt plant has also been announced for the same state. Another project in the same state but with a different utility (Sacramento Municipal Utility District) foresees construction of a 100 megawatt photovoltaic plant in stages. The first megawatt is currently under construction and the Utility expects that the average cost of this installation built over the next eight years or so will be about $3 per peak watt. The cost of the units installed in the latter half of this period will be considerably lower than this figure and down to about $1.00 per peak watt (Rs. 10 per peak watt). At this price, this technology will be economically competitive in vast areas of the developing countries where there is adequate solar insolation.

Bio-energy

Apart from fuelwood which has been discussed earlier, there is enormous potential energy in other biological material, including animal and human wastes, industrial and municipal wastes, and agricultural residues. The best known and perhaps most exploited technology here is biogas. A great deal has been written about the potential and the programme of biogas, which is proceeding, if somewhat controversially, in India also. It may be noted however, that in this area also developments are taking place throughout the world, in technology, feed material, efficiency, cost and numbers of installations. Efforts need to be continued to reduce the costs and improve yields of gas throughout the year (including low temperature winter periods) to ensure that the programme meets the needs of rural people without adverse effects on the poorer sections of the rural population.

The potential for biogas is very large in India, and in many developing countries, if the technical, social and economic aspects are properly handled. The inputs of modern techniques such as uses of immobilized cells and enzymes, of higher temperature digestion wherever applicable, of temperature control etc. can give very useful results. Biogas can also be produced from sewage and distillery effluents to provide valuable energy *and* a simultaneous method of cleaning the environment; and it would be useful to take up major programmes in these areas also. Municipal waste use techniques include direct incineration, gasification or pyrolisis of wastes; and bold programmes in this area are also needed.

Finally, mention may be made of using agricultural residues through gasification and pelletization. One such technology, for pelletizing waste rice husks, has already been developed and commercialized. Other promising work is under way. Draught animal power is another renewable energy resource, widely used in the developing countries. In India the bulk of ploughing and transportation is based on this resource. However, newer techniques, particularly for using this resource for mechanical work such as pumping or small machines in a more efficient way, need to be promoted.

Ocean Energy

While feasibility studies and the use of tidal energy are under way, a project has been envisaged for the Lakshadweep island area for using the thermal gradient of the sea for generating power and using the cold water drawn from the depth for aquaculture simultaneously. The potential for this technology looks fairly promising in several island areas in the tropics.

Conclusion

The above discussion has dealt, necessarily, with only some aspects of renewable energy sources, their development and status. Renewable energy units involve no fuel cost as the energy itself is free. It is clear however, that these sources can meet a growing part of the modern energy needs of the developing countries—in an environmentally acceptable fashion. It has been estimated that in India in the next twenty years, almost half the total energy could come from new and renewable sources including fuelwood, biomass and hydro power. Over 20 per cent will be from modern solar, wind and other technologies provided adequate push is given to the programme from now on.

Similarly in many developing countries, renewable energies could play a significant, in fact decisive role, in the pursuit of economic and social advance. National efforts got off to a good start about two years ago, but then somewhat slowed. It is to be hoped that now, and with international support and stimulus, it will be accelerated to make this a reality in India and in the world as a whole.

REFERENCES

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