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SOLAR ENERGY: A RESOURCE FOR DEVELOPMENT IN AFRICA

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Many African countries lack rain for the development of their plant life. On the other hand, these same countries receive heat from the sun in abundance; their soil is often dried out by the intense solar radiation; the result is daily ruination of vast cultivable areas. This phenomenon of soil degradation leads to laterization, desertification and so on.

However, it is possible to transform this destructive sun into an ally to harness the heat it so widely distributes and to use it to remedy the scourges of drought and under-development.

Each square metre of surface perpendicular to the rays of the sun receives power of the order of one kilowatt (kW). This power is equivalent to 1.36 horsepower, that is to say, power sufficient to raise a weight of 75 kilograms vertically one metre in one second. It is also known that the power of the average tractor is of the order of 30 to 35 horsepower. In other words, a surface of 1,000 square metres under the sun, that is, the surface of a square with sides of about 31 metres, receives at noon solar energy equivalent to the energy of 40 average tractors.

The profusion of solar energy could also be illustrated by the following fact: the roof of a building 10 metres square receives some 500,000 kilocalories during a sunny day, or the amount of energy produced by the combustion of about 80 kilograms of coal or 55 litres of petrol.

The solar energy whose abundance has been illustrated is produced by a nuclear reaction. This reaction transforms hydrogen into helium inside the sun which behaves like a continuously exploding hydrogen bomb. This reaction gives rise to intense heat. Temperatures inside the sun can reach several million degrees. Although the surface of the sun is much colder since its temperature is only 6,000 degrees, it radiates enormous energy into space. Of this colossal energy, the earth receives only an infinitesimal part, but this infinitesimal part is more than 30,000 times greater than the total consumption of the population of the world.

The figures set out can lead to a dream that, even when petroleum and nuclear fuels are exhausted, it will still be possible to meet mankind's appetite for energy by replacing them progressively with solar energy.

Analysis of the facts, while it promots a believe that such a development is possible in the developing countries, also shows that this progressive replacement is probably utopian in the industrialized countries. These countries, precisely because of their economic power, the complexity of their industrial systems and resistance to the adaptation of these systems have no alternative but to consume a greater and greater proportion of petroleum, uranium and torium produced in the world.

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ECONOMIC COMMISSION FOR AFRICA

Even if a very strong political commitment emerged in favour of the intense exploitation of solar energy in the industrialized countries, a series of physical constraints would necessarily limit the scope of such action. The unfavourable climatic conditions prevailing between the poles and the 45th parallel, the obvious difficulty in using the surface of the oceans, limit the areas capable of accommodating solar energy receptors to about 10 per cent of the earth's surface, or about 50 million square kilometres.

The sun offers three kilowatt hours (kWh) per square metre per day on average and it is difficult to convert these three kilowatt hours into energy useful to man with average efficiency greater than 10 per cent. The result is that, in order to meet in full the present needs of the four billion people who live on earth (per capita needs which are annually equivalent to two tonnes of coal or about 16,300 kWh), it would be necessary to cover with solar receptors one per cent of the total land surface between the 45th parallel north and south. It is difficult to envisage translating such a theory into practice without changing the environment unacceptably.

If now the fact is taken into account that the industrialized countries alone consume about 80 per cent of the world's energy and occupy areas much smaller than those of all the countries of the third world, the industrialized countries, in order to meet their energy needs from solar energy, should cover much more than one per cent of their area with solar receptors. As a result, solar energy cannot represent a satisfactory solution to cover all the energy needs of the developed countries.

On the other hand, the situation is radically different in the case of the developing countries, more particularly in Africa. Africa, because of its favourable geographical position, its relatively low population density, can advantageously benefit from intensive and planned exploitation of solar energy and its derivatives; energy from rivers, wood and plants, the wind and, to a lesser extent, from the tides and the heat gradient of the oceans. Such a policy, undertaken rapidly and with adequate resources might perhaps avert for the African, non-oil-producing countries, almost inevitable economic extinction, which will in time be caused by the financial burden imposed on them by their imports of fossil fuels which they will no longer be able to pay for it present trends are maintained.

The density of the population of Africa is of the order of 11 inhabitants per square kilometre; annual average consumption of commercial energy in Africa is of the order of 2,700 kWh per head. Africa receives solar energy of the order of four kWh per day per square metre. As a result, it would suffice to use 1/5,00 of the surface of the continent in order to meet its needs for commercial energy using converters with average efficiency of 10 per cent.

Commercial energy is that energy which passes through the commercial circuits. In general, it is petrol, paraffin, coal, charcoal and electricity.

A simple calculation shows that covering 1/5,00th of the surface of the continent with solar converters calls for a huge investment effort. In order to have an order of magnitude of this investment, it may be considered that the installation of one square metre of collector, linked to possible best storage, in some cases a motor, calls for investment varying from US$ 150 to US$ 450. In other words, on the basis of the above assumptions, African countries to meet their present commercial energy requirements, should invest from $3,000 to $9,000 per head.

Such investment appears formidable and in fact represents from 10 to 30 years for an average African. But, in all the countries of the world, the investment required to supply energy useful to man is enormous. For example, it is calculated that, if the United States was now to acquire a sufficient number of coal or nuclear stations to cover all its requirements, it would have to invest the equivalent of four to eight years of its gross national product.

In this calculation, the following assumptions were made: an American consumes

30 times more than an African and his annual income is 20 times higher. Moreover, according to Lowins [1] it costs him from US$ 2,250 to US$ 4,500 of investment per kW produced from coal or nuclear station delivered to the house of the user.

Commercial energies have been referred to above. In fact, this type of energy represents only 25 per cent of consumption, in the countries south of the Sahara. In this area, the proportion of energy obtained from firewood is assessed at about 75 per cent. Firewood is the most practical and least expensive form of storing solar energy, thanks to the well-known phenomenon of photosynthesis; its use should be specially recommended in areas where the technological level is low, such as, for example, in African rural areas, not only at the individual level (rural people have been burning wood since prehistoric times), but also at the level of handicrafts and the small-scale industries.

Assuming a reasonable rate of production of 10 tonnes of dry firewood per hectare per year and an average calorific value of 4,000 kilocalories per kilo of dry wood, with efficiency in use of 10 per cent, it may be observed that all African needs for commercial and traditional energy could be met through the exploitation of a forest covering 26 per cent of Africa. As a comparison, it might be mentioned that forests today cover 25 per cent of the area of France, for instance.

The above calculation shows that wood could, in theory, meet all Africa's energy requirements. Therefore, care should be taken in the selection of the technologies to be applied for the exploitation of solar energy is envisaged. This leads to the following question: is it advisable to surround African huts with solar collectors with the aim of meeting <u>all</u> energy needs, or would it be better to plant trees and exploit biomass to the maximum and use solar receptors only when their use is much more rational and viable than the exploitation of biomass.

The various numerical data set forth in the preceding pages suffer from being only general averages but they appear to be sufficiently meaningful to assert without risk of error that:

1. it is practically impossible to meet the energy requirements of the developed countries using solar energy and its available derivatives on their own territory, without causing unacceptable deterioration of the environment;

2. the theoretical possibility of meeting African energy needs using solar energy and its derivatives exists and that the application of this assumption will not produce harmful effects which the environment cannot tolerate;

3. it is unlikely that the types of energy consumption in the developed countries will change much before the fossil deposits are totally exhausted, in other words, the exploitation of non-conventional energies will remain marginal in these countries as long as this result is inevitable.

4. as a result of the industrial level reached in the developed countries, incomparably higher than that reached in the African countries, the former are necessarily the ideal place for the recycling of petro and urano-dollars. As a result, the developed countries are in a position to pay a higher price for fossil fuels extracted from less and less accessible deposits. Correlatively, the African countries, if they base their development on the use of fossil energies, will have to devote an ever-larger share of their incomes to this section of the budget to the detriment of investment in development, which will ineluctably lead them to economic extinction.

On the basis of this analysis, the United Nations Economic Commission for Africa has recommended that African countries should, as soon as possible, explore and exploit the sources of renewable energy, such as the sun, wind, biomass and waterfalls. This strategy calls for an immense effort in the following fields:

- reforestation and sound forest management;
- construction of hydro-electric stations of all sizes and, as far as possible

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- interconnexion of electricity grids;
- installation of all kinds of equipment for the conversion of energy from the rays of the sun, the wind and biomass into energy easily usable by man;
- study, as part of the north-south dialogue, of the question of the huge investment required for the implementation of this strategy.

This last point is obviously fundamental and decisive for the development of the proposed strategy. But, for the sake of clarity, this aspect of the problem will be left aside and only the purely technical aspect of possible exploitation of solar energy to Africa will be discussed.

Also, the problems raised by reforestation, forest management and the construction of hydro-electric stations will not be discussed, as these are relatively well-known and thoroughly covered in more specialized works.

Strictly as regards solar energy and its derivatives, wind energy and energy obtained from biomass, apart from wood, recent progress in laboratory work gives grounds for thinking that, in technical terms, these energies can meet most of the energy needs.

Nevertheless, the following question must be asked:

- what technologies are immediately available?
- to what extent and through what efforts will these technologies enable solar energy to be converted, in order to place it at the daily service of the peoples of Africa?

The already available technologies can produce:

- warm water at 50-70 degrees Centigrade;
- drinking water from brackish or sea water;
- mechanical energy by thermal processes;
- electricity from photoelectric cells;
- thermal, mechanical and electrical energy from organic wastes
- ethylene, the basis for the manufacture of plastics from alcohol of sugar-cane, sorghum and corn.

Solar water heaters are made in Africa (Kenya, Mali, Niger, Rwanda, Senegal and Tunisia), or can also be imported. Solar warm water is at present produced almost exclusively for household use. It is not impossible that, in the near future, this water heating technology will be used by certain food industries, such as in breweries, soft drinks plants and dairies. ECA recommends the use of this technology when it makes it possible to economize on wood in regions threatened with serious deforestation, or to economize on imported fuel oil in regions where electricity is produced from thermal power stations.

<u>Solar distillation</u>

In some countries, such as Chile, Egypt and Greece, solar green house stills have been used for many years to supply villages with drinking water. These distillers are installations which cover several thousand square metres. In Africa, only Egypt, Mali and Somalia are beginning to take an interest in solar stills of this size. The Onersol Centre in Niger has embarked on the popularization of small distillers with a surface of a few square metres. Several Niamey firms are at present equipped with such stills which supply service stations and the perfumery industry. Rwanda is planning to do likewise.

This rudimentary technology permits the production of drinking water from brackish water only in limited quantities because the hothouse-effect solar still is a rather bulky piece of equipment. In practice, one hectare of land is needed to produce 25 to 30 cubic metres of drinking water per day, which is barely enough water to supply a village of 200-300 inhabitants and about 500 head of livestock.

It is, nevertheless, possible to use solar energy to supply drinking water to a

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small urban community, providing that a solar motor or a wind-driven generator, if the winds are favourable, is coupled with a desalination unit using inverse osmosis or electrolialysis; in this case, the thousands of cubic metres of water required for a small town can be obtained.

Thermal production of mechanical energy

This is a dream which man has cherished for a very long time. History teaches that a solar engine and a parabolic solar cooker were already operating in 1870 in France. These inventions were developed by Mouchot and Pifre at the request of Napoleon III who wished to equip his colonial army in Africa with them. In 1930, an American engineer named Shuman installed and operated near Cairo in Egypt a 60 horse-power solar engine; this engine was linked to 1,200 square metres of cylindro-parabolic mirrors. The engine was coupled to irrigation pumps. Shuman's system worked for only three years; it was, unfortunately, destroyed by the fellaheen during a demonstration in 1913.

It was necessary wait until the 1960s for a new experiment; this one took place at the University of Dakar in Senegal, where Professor Masson assisted by the engineer Girardier developed a solar engine. This engine draws its energy from medium-temperature collectors (about 70°C). The collectors heat a liquid which is usually water. This heated liquid transmits its heat in an evaporator to either liquid butane, liquid propane or liquid freon. The liquid gas vaporizes; its pressure increases and it activates a motor which can be coupled to a water pump or an electrical generator. The gas then liquidifies in a sealed condenser and is again injected into the evaporator. Apart from solar energy, nothing is thus consumed in the system.

These solar engines are at present manufactured by the SOFRETES firm headed by Mr. Girardier. More than 30 of these engines have been or are being installed in Africa where they are rapidly increasing in numbers. There are many other engines of this type in the rest of the world, particularly in Mexico. Their capacity varies from 0.5 kW to 25 kW, as is the case at San Luis la Paz. A 75 kW unit is being installed at Diré in Mali. Since 1970, many American, Israeli, Japanese and German firms have been trying to develop solar engines with higher thermal efficiency, using more complicated technologies which require more careful maintenance. These new prototypes generally use cylindro-parabolic focussing systems.

Production of electricity solar cells

This technology originated in space research. It has made spectacular progress in the past 20 years because it has proved the most practical technology to supply energy to satellites and space craft in balistic trakectory. The use of photo-electric cells on the ground, where they are subject to the permanent assault of bad weather, is more difficult than in space. The only photoelectric cells at present developed for use on the ground are made of ultra-pure silicum. These are cells which are very expensive to buy. The electrical energy they produce costs from $12 to $20 per watt when they are under maximum natural insolation. From $50 to $150 per watt when a storage system makes it possible to obtain continuous power over 24 hours in very sunny countries. Nevertheless, there are very serious hopes of seeing these costs tumble shortly since many laboratories throughout the world are working to produce cheap cells. Because the cells produce electricity directly, the uses that can be made of them are as varied and numerous as the types of electrical equipment existing on the market. But, at the moment, as the cost of investing in cells is very high, much of the production is limited to small-capacity equipment located in isolated places. Photoelectric cells are, for example, used in Niger to supply sets for educational television. The other uses of this equipment in Africa are as follows:

- microwave links in Zaire;
- small absorption refrigerators in which to keep vaccines;
- portable insecticide atomizers;
- water pumps in Mali, Cameroon, Rwanda.

The following four uses of solar energy, namely: water heating, distillation, thermo-solar engines and photoelectric cells, are the only fields, to the writer's knowledge, in which installations have been operating in Africa for several years.

For centuries, Africans have been using solar energy to dry food products, especially fish, fruits and cereals. This practice is traditional and does not call for the use of any equipment. Various research centres are currently applying themselves to the development of solar dryers for fish, vegetables and fruit. The purpose of these efforts is to reduce the drawbacks of traditional drying, i.e. poor control and lack of hygiene inherent in traditional drying, which provides no protection against insects and dust.

Unfortunately, the value of the solar dryer has not yet been seriously tested in a market study. The "identikits" of solar dryers useful and acceptable to African socio-economic circles have yet to be drawn up.

The problem is the same for solar cookers. Several research centres in Niamey (Niger) and in Bamako (Mali) and technical assistance groups like VITA or even certain individuals, such as Mr. Fillippini in Ethiopia, have dealt with the development of cookers, using direct heating in Africa. Elsewhere attempts have been made to introduce this equipment in Mexico, the West Indies and Morocco. The general opinion seems to suggest the rejection of this equipment by rural peoples but it should be pointed out that there is no long-term and realistically-based study in this field. In 1977, a Danish organization embarked on such a study. It provided 250 parabolic solar cookers in Upper Volta, but the results of this undertaking are not yet known. The Ethiopian Ministry of Education is at present undertaking a similar study.

Much is said about solar air conditioning and refrigeration. Several firms are at present marketing solar absorption conditioners but because of the temperature of 85° to 90° C, which the solar collectors must supply, these apparatus are very expensive. Meanwhile, dozens of researchers are working on solar refrigerators, larger than one cubic metre, in Rwanda, the Sudan and Egypt. For the time being, no equipment is available on the market and there is little hope that a moderate price will be attained for several years.

Large-capacity thermal solar power plant (from 1 to 10 megawatt) are just beginning to be tested in Europe, the United States, the USSR and Japan. Installation of such solar plants in small towns should be technically possible after 1980.

Wind energy

Although this form of energy has been used for a very long time in Europe, it is not commonly exploited in Africa. Despite the various attempts to introduce wind energy on this continent, particularly in Algeria and in the Sahel, this form of energy has not yet met with success; many operating tests have failed because servicing of the equipment was not properly organized. A few experiments with irrigation using windmills which seem to have succeeded may be noted, particularly along the Omo River in Ethiopia.

In the Republic of Cape Verde, dozens of multibladed windmills, 2 to 3 metres in diameter, locally manufactured, are irrigating fields of flowers in the Island of San Vincente. The Cape Verde Islands are particularly windy and the Government there is planning to use wind energy on an extensive scale.

Biomass energy

Biomass energy is also a form of non-conventional energy. Using chemistry and knowledge of microbiological processes, man can make from plants, fuels such as alcohol, biological methane gas which are used either directly as fuels, or as engine fuels, or to manufacture plastics materials.

During the second world war, petrol was scarce in Europe. Cars, lorries and buses were driven through the use of gas generators, which permitted distillation of wood;

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the gases thus produced supplied energy to the engines of the vehicles.

The generators are rather impractical and somewhat dangerous to use but it is possible to replace them by fixed industrial units in which liquid and gaseous fuels are extracted, not only from wood but also from sugar and cassava. The liquid fuels obtained in this way could replace petrol in vehicles, or petroleum in plastics chemistry. Brazil has fully understood the importance of biomass as a source of energy and is introducing a policy for the progressive replacement of petroleum by biological alcohol. The industrial chemical firm, Rhône-Poulenc, and the engineering company Litwin have established a plant capable of producing 260,000 tonnes of polyvinyl chloride a year from alcohol produced from the fermentation of sugar cane liquor. According to the senior officials of Rhône-Poulenc, one of the inestimable advantages of the agrochemistry of plastics materials is that the size of the processing units can be adapted to the local production of alcohol, while units producing ethylene in petrochemistry reach viability only with production above 400,000 tonnes a year.

Nevertheless, it seems that the economic production of biological alcohol should be an industrial process, even if that does not necessitate huge installations. On the other hand, it is possible to produce biological methane gas using small units of the family or community type.

Biological methane gas is produced from a mixture of cellulose plant matter (non-lignous) with animal or human wastes in anaerobic fermentation, that is, excluding oxygen from the air. This mixture is made in an apparatus known as a methane fermenter; it produces a mixture of methane gas and carbon dioxide as well as an excellent fertilizer for agriculture. The gas thus produced is in fact no different from the "marsh gas", produced naturally at the bottom of ponds. The technology for the production of biological methane gas is already extensively used in China where more than 2.8 million methane digesters are reported to be in operation in the province of Szechwan, in the north. In Europe, many fermenters were used during the Second World War by farmers but they later abandoned this technology because the prices of petroleum products were very low.

In Africa, only a few small private firms are at present using this technology; there is one example at Fort Ternan in Kenya. A number of research centres are also studying the use of this technology in Rwanda, Malawi and Upper Volta but the process has yet to be popularized.

In the introduction, an endeavour has been made to illustrate the full extent of the benefit which African could draw from rapid and intensive exploitation of non-conventional energies. It would seem that numerous technologies exist for the exploitation of these energies. However, genuine exploitation on a large-scale will encounter many difficulties and African countries will need to acquire certain administrative and technical facilities in order to make real progress in this field.

Pre-conditions for extensive use of solar energy in Africa

Throughout the world, planners and technicians tend to neglect, or even systematically reject, the proper large-scale use of non-conventional, renewable sources of energy, except in the case of large waterfalls. This hesitation may be explained by the often decentralized nature of these sources and the novelty of the technologies and equipment required for the exploitation, as well as by the magnitude of the investment for which they call. The railways, air transport and other important technological innovations suffered from the same hesitation at the outset. Apart from this human reaction, which is initially unfavourable to any change, the preceding pages show clearly that solar energy and its derivatives -- wind energy and biomass energy -- represent major resources in the service of development in Africa. If African countries seek to draw maximum benefit from the resources they have in this field, it is a matter of urgency that they should take the following steps:

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- draw up a policy for the development of energy sources placing firm emphasis on the promotion of national sources of renewable energy and the progressive substitution for imported petroleum products;
- set up a national technical body specifically responsible for assessing and exploiting the renewable sources of energy. This body should be of similar structure and have a similar role to the national body reponsible for the production of electricity. It should not only deal with the exploitation of the non-conventional energies but should also endeavour to identify the real needs of the population, and determine to what extent these needs might be met. A list of priorities is given below:
- train skilled technical personnel capable of installing and maintaining the equipment needed for the exploitation of the non-conventional forms of energy;
- set up a centre for technological research and development and for the adaptation of techniques to exploit renewable energies, if the country has adequate human and financial resources, or machinery for co-operation with other African countries, which already have such centres,should be negotiated;
- establish a network of stations to measure solar radiation, direct and diffuse, and wind speed. The recording stations should be suited to the requirements of the solar and wind energy exploitation technologies. It is of vital importance that the processing and analysis of the data should be ensured. This task is greatly facilitated at the moment by the marketing of completely self-sufficient stations, storing on magnetic cassettes data for a six-month period. These data are subsequently analysed by mini-computers.

If an African country acquires the administrative and technical facilities mentioned above and if it clearly sets out its determination to develop the exploitation of non-conventional energies, it should be easy for that country to secure the support of the international financing agencies. The country in question will, thus, be able to suggest to the various sources of bilateral or multilateral assistance with development projects on its territory that provision should be made for the inclusion in these projects of equipment and technologies for the exploitation of renewable sources of energy such as solar water heaters, solar distillers, wind-driven generators, solar pumps, methane digesters.

At the African regional level, the United Nations Economic Commission for Africa is active in the field of the promotion of renewable sources of energy. Eca makes available to Member States the services of a regional adviser in solar energy and it is working on the organization of an annual regional seminar dealing with the application of renewable energies, the first of which covered solar energy in October 1978. The Commission is promoting the training of technicians, engineers and research workers in solar energy through the allocation of scholarships and it is at present seeking resources to enable it to instal demonstration equipment with the aim of creating awareness among African leaders and the African public of the possibilities offered by the exploitation of solar, wind and biomass energy.

1/ <u>The road not taken</u> by Lowins, Foreign Affairs, October 1976.

<u>Note:</u>

The original of this article was in the French language.