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SOLAR ENERGY IN AFRICA

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I. INTRODUCTION

1. The earth receives almost all its energy from the sun, in the form of electromagnetic radiation made up of 3 per cent ultra-violet, 42 per cent visible and 55 per cent infra-red rays. This "Fuel" is remarkable for the fact that it is free, abundant, and does not depend on men, animals or plants. It is not thermal but of electromagnetic origin: in theory, then, it is completely transformable into mechanical energy.

2. Wood, coal, oil and natural gas are solar energy transformed, as are the winds and water. It is the sun which keeps the earth close to the temperature required for human existence. Agriculture is made possible by the sun, and by the rain, a natural form of irrigation which derives its existence from the sun.

3. In human terms the sun is inexhaustible, although its mass is decreasing by about five million tonnes a second. The earth receives about one ten-billionth of the sun's energy, which yearly, represents five to ten times the total fossil reserves known in the world (uranium included).

4. Unlike other continents, Africa straddles the equator and is thus especially blessed since it is exposed to solar radiation throughout the year. The African countries which have areas with a desert or Sudan- type climate enjoy excellent conditions of insolation and intense solar radiation. The potential importance of solar energy varies according to the climatic zone:

- In the Saharan zone, the annual insolation (the duration in which the intensity of direct solar radiation has a maximum value in the order of 60 per cent of its daily maximum value) varies between 3,600 hours and 4,000 hours; the mean intensity of total radiation (the sum of direct radiation, diffused radiation and almost negligible atmospheric radiation on a horizontal surface) amounts to 1 KW/m^2 and more.

- In the Sudano-Sahelian zones, the annual insolation varies between 2,700 and 3,400 hours, while the mean intensity of over all radiation ranges between 0.3 and 0.6 KW/m2.

- In Guinean or equatorial climatic zones, annual insolation varies between 1,500 and 2,000 hours, and total radiation intensity varies between 0.3 and 0.6 KW/m2.

5. In the first two groups of countries, which are particularly well endowed, the highly scattered population, the severe water problem in the dry season away from permanent water cources and certain river valleys with seasonal intermittent discharges, and the relatively heavy dependence of food, industrial and export crops and livestock on climatic variations together point to the need to take advantage of the various advantages of solar energy and its applications:

6. Although the third group of countries are less well endowed from the point of view of availability of solar energy, they are blessed with hydroelectric energy and perhaps also with other energy sources, conventional or otherwise (solid, liquid, gaseous or ligneous fuels and tidal energy or thermal power derived from the sea). However, in view of their large rural population, their communications difficulties and other problems confronting them, such advantages should not induce those countries to neglect the use of solar energy, especially in its thermal applications based on greenhouse effects (solar water heaters, stills and dryers), and the photovoltaic, thermoelectric and even thermodynamic conversion of this form of energy (direct production of electricity and solar energy and their various applications).

7. The steady rise in the price of petroleum and its derivatives and the onset of a worldwide energy crisis which is expected to occur in the years to come are undoubtedly behind the renewed interest in solar energy in the developed as well as the developing countries. The fact that all Governments are rapidly becoming aware of the enormous possibilities offered by the use of direct solar radiation to meet their future energy needs and that scientists all over the world, even in countries with relatively limited solar energy potential, are putting more and more efforts into harnessing this source of energy, can be explained by its chief attributes and advantages.

8. Solar energy is a universal source of energy in that sufficient quantities exist almost everywhere on the earth's surface and it can be captured <u>locally</u> to satisfy numerous needs and therefore there is no need to transport it. It is an <u>inexhaustible</u> source of energy. Life itself is governed by the sun, so that as long as there is life on earth, solar energy will be found in abundance. It is <u>clean</u>. Its use does not result in smoke, odour, noisor waste. This is a considerable advantage in that it cuts down pollution at a time when the world is investing substantial amounts of money in the struggle against pollution and in the effort to safeguard the human environment. Another advantage which cannot be overlooked is that the use of solar energy can make a great contribution in the campaign against deforestation, which results in the deterioration of the ecosystem, desertification and drought.

9. As an important local source of energy, solar radiation guarantees greater independence from foreign energy sources. Many countries are therefore coming to view the use of solar energy as an important national objective since their economic development in the years to come will undoubtedly be accompanied by an ever increasing demand for energy. However, solar energy presents some drawbacks, or rather inadequacies, which should be minimized as much as possible. It is an intermittent source of energy owing to the succession of day and night and to seasonal variations and it is widely dispersed, meaning that large areas of land are needed for a large-scale industrial operation. Consequently, a heavy initial investment may be necessary, but the operating costs of solar energy are insignificant, even nonexistent, compared to those associated with traditional energy sources.

10. Although it is hard to assess exactly the contribution which solar energy could make within the framework of a global approach to the economics of energy in different countries, it is reasonable to think that, while its contribution will be uneven, it will have a significant effect on the economic and social development of the African countries. The present status of technological development and the economic viability in the traditional sense of this notion vary immensely depending on the kinds of use envisaged. It would, however, be risky, in the context of African developing countries, to insist only on the traditional rate of return criteria, for the indirect advantages are legion and often unquantifiable. In many cases, Research and Development are still needed before installations which are satisfactory from the point of view of conversion output and economic competitiveness are available.

11. However, the effort required must not cause African countries to adopt a passive attitude in that they sit back and wait for foreign countries to do everything at the scientific and technical level. The independence of African countries and their future in the field of energy will to a great extent depend on their ability to organize, execute and develop their own scientific and technical potential both in the limited field of solar energy and new energy sources and in the broader field comprising the total body of energy resources. This highlights the urgent need for greater co-operation at the regional and international levels, and in this respect institutions such as OAU and ECA have a leading role to play.

II. APPLICATIONS OR USES OF SOLAR ENERGY IN AFRICA

12. If Africa's aim is to make rapid and significant progress in its national and regional development within the framework of collective self-reliance, it must give high priority to rural development with a view to forestalling any concentration of population in urban areas. In future it will therefore be necessary to devote the lion's share of the development effort to energy infrastructure in the countryside. This infrastructure will necessarily comprise apparatus and installations which make use of solar and wind energy and methane fermentation. The exploitation of energy sources depends on the demand for energy, which is at present very low and shows very little concentration owing to the dispersal of the population over vast areas. The distribution of energy over long distances is not a viable solution because of the obvious problems presented by the shipment of fuel or of the prohibitive cost of transporting electric power, even that of hydro-origin.

13. In rural areas the problem will be one not so much of determining the kind of general scientific research carried out at the international level as of finding ways of adapting the findings of this research to specific needs. It is in this connexion too that the greatest socio-psychological problems are encountered since development is not what is attained merely by installing the right equipment or applying the right technology, no matter how advanced. Its true measure may be most accurately taken by the way people concerned accept it and the value they attach to its results.

14. It seems possible that the use of simple techniques with low capital intensity would, at least in sofar as some applications of solar energy are concerned, go a long way toward meeting urgent needs in the rural areas. Other applications will still require a great Research and Development effort. African countries and intergovernmental and multinational bodies, whose objectives is to ensure that the economic and social development of the continent progresses as rapidly as possible within the framework of a global strategy of collective self-sufficiency, must pay particular attention to the following sectors:

(a) Production and use of low, medium and high-heat potential

15. For common household purpose (heating and cooking) and some industrial or collective uses of low-heat (heating water or air for drying certain products), solar devices which act as greenhouses may very economically replace conventional devices. The necessary technologies have been perfected and are available, even in Africa. Before their use can become generalized, however, there must be a policy to establish collective facilities in rural areas and maybe also a credit policy in urban agglomerations because of the low income of the inhabitants and the magnitude of the initial investment required.

16. Some industrial uses of wood for the production of high-temperature heat (baking bricks and various ceramics, etc.) are aggravating deforestation in certain areas where the practice is already causing alarm because of the use of wood for household purposes. The substitution of solar energy through the use of medium-performance and medium-power kilns would help to limit environmental hazards (deforestation and its consequences, atmospheric pollution and ecological imbalances) and would make it possible to decentralize production. The technology required for this type of facility is still at the Research and Development stage, but some tests are to be carried out in the Niger.

17. The production of cold (air conditioning and refrigeration) from solar energy is worth investigating because cold temperatures could be used collectively in rural areas (in health establishments and for the preservation of vaccines and perishable foods) and in urban agglomerations (for central air conditioning of buildings or multi-family dwellings). Such schemes are still at the Research and Development stage although much work has already been carried out on them.

(b) <u>Production of mechanical or electrical energy for various low-or medium-power devices</u>

18. Solar engines and turbines operating at temperatures of between 70°C and 120°C on various kinds of organic vapour may be fueled from flat-plate collectors, those operating at temperatures higher than 120°C may be fueled from concentrating collectors. A power range of between 1 and 5-10 KW are especially suitable for use in supplying villages and grasslands with water. Devices operated on between 10 and 50-100 KW are useful for supplying farms with water (crops watered or irrigated by surface water or underground water at varying depths). When these units are connected to alternators, they can produce electricity for various purposes. The addition of accumulator batteries would then make it possible for the units to operate at night.

19. This type of device produced in small lots is now available on the market for about $US 40,000 per kilowatt. If they were mass produced, their price could be one third to one quarter of that. They are, however, irreplaceable in outlying areas which are difficult to reach, where the problem of supplying water and electricity is acute. Research and Development is under way with a view to devising similar facilities with a performance and an adequate life span.

20. There now exist prototypes of 50 KW solar engines capable of irrigating hundreds of acres and of supplying entire farm co- operatives in areas where the maintenance of conventional pumping devices (generating sets, motor-pumps etc.) presents problems which are extremely difficult to solve. Moreover, it is possible for a solar engine to drive an alternator to meet the electricity demands of co-operatives. It is now accepted that the price of such solar equipment will be significantly reduced when high-power facilities begin to come into general use. With regard to the production of electricity in connexion with the establishment of 25- to 100 KW solar power stations distributing power around the clock, the price per kilowatt-hour will be about $US 0.15 to 0.20 in the near future.

21. Photovoltaic solar cells make it possible to obtain electric power directly from solar radiation, the yield varying at present from between 6 to 16 per cent. All the uses to which electric and/or mechanical power may be put may thus be contemplated, including the pumping of water, the treatment of grain, refrigeration and air conditioning and supplying radios, educational television and other communications apparatus (transmitter-receiver sets, microwave relays, etc.). Panels of photovoltaic components are now available on the market at prices which vary from between $US 10 to 40 per Watt installed, depending on the material used and the ability of the panel to resist various atmospheric agents. These costs are comparable with those of solar equipment for thermo-dynamic conversion, which although much more cumbersome and calling for a greater number of operations, has the advantage of being partially manufactured in Africa itself.

22. In view of the outlook for the development of technology and the production of photovoltaic cells, it may be expected in the near future that the cost will be one half to one third of what it is now, the announced objective being $US 3 to 5 per Watt installed.

23. Thermoelectric conversion of solar energy is at present less advanced than photovoltaic conversion because of the unavoidable concentration of solar energy (operating temperature varying from between 350 and 700°C) and the resultant technological problems (the resistance of semi-conductors used and the marked decline in their performance). However, the use of material in series in thermoelectric batteries offers possibilities for considerably higher conversion efficiency which have not yet been adequately explored. Moreover, a reduction in the size of the battery (components) due to a concentration factor from 100 to 200 would also help to lower the cost price of facility. Finally, since the semi-conductors used are made of polycrystalline materials, their technology is less complex and their cost could be considerably lower than in the case of photovoltaic cells despite the fact that a concentration mirror is required; in any case, this is what those who advocate the use of the thermopile believe.

24. The application of thermoelectric conversion of solar energy to the production of cold through the Peltier effect is one method of achieving solar refrigeration and air conditioning. The thermopiles available at present have an efficiency rate of from 6 to 8 per cent, and only low-power units (from 1 to a few dozen Watts) are obtainable, at prices which are still rather high because they are individually produced.

III RESEARCH AND DEVELOPMENT ACTIVITIES AND ACHIEVEMENTS IN THE USE OF SOLAR ENERGY IN AFRICA

25. Since early in the 1950s, a number of African countries have been conducting research aimed at the use of solar energy. Experimental centres have made it possible to develop prototypes of solar devices, such as water heaters, dryers, stills, cookers, refrigeration facilities and low-power solar engines for supplying water to grasslands and villages. Some of the technology developed has already made it possible to start popularizing their use, and it is now possible to bring them to the semi-industrial or industrial stage. A brief review can be made of the various activities taking place in the major solar energy research and application centres of the continent.

26. In Algeria solar energy research is being conducted primarily under the auspices of the Organisme national de la recherche scientifique (ONRS) (the National Scientific Research Agency) and universities working in close collaboration with it. Part of the research is being carried out at the solar energy station at Bouzareah, which is responsible to ONRS. The station has a parabolic collector with an automatic sun tracking system. On the basis of this station's experimental work, a technical and economic study is being done with a view to setting up an electro-solar power-station. Along with this study, insolation measurements were taken in liaison with the national meteorology office in order to establish a radiometry network throughout the country. Research has also been done on the low-temperature use of solar energy including the development of solar flat-plate collectors and the production of hot water for health purposes. The water heaters are built from local materials and operate at the station site. Other projects include a study on home heating, the use of solar energy in agriculture, a study on storing solar energy in all its forms, and the study and development of a solar cooker.

27. Research is being carried out on the manufacture of solar batteries in another research centre which is also responsible to ONRS; results have been encouraging and will be useful at the international level. A third area of research deals with the establishment of a low-temperature power-station at Oran at the Ecole nationale superieure d'enseignement polytechnique (national polytechnic institute). An integrated Socialist village using soft energy as much as possible is being planned in the context of an agreement with the United Nations University in Tokyo. A site has been chosen and feasibility studies completed. The project is being carried out under the auspices of the Centre de recherche en architecture et urbanisme (the Architecture and Town Planning Research Centre). Annaba University is primarily interested in solar pumps, concentration systems and the integrated use of solar energy.

28. As it is impossible to complete a research project without training qualified staff, a post-university level programme was scheduled for September 1979 at the University of Science and Technology at Algiers.

29. In the area of wind energy, experimental pumping stations are already operating; results are encouraging and point to their possible widespread use throughout the country.

30. Some of the activities mentioned are being carried out by Algeria alone, whereas others are part of bilateral agreements with countries such as the Federal Republic of Germany and France or with international agencies. In defining and implementing its programme, Algeria has at all times been concerned with integrating Algeria production with solar energy research as fully as possible.

31. Communications difficulties have arisen between African States with respect to research problems, Algeria is eager to see the development of subregional or even regional co-operation with a view to integrating the use of African materials in the solar industry, which will no doubt continue to grow.

32. In Egypt a research programme was established in 1957 on the utilization of solar energy including solar water heating, water distillation, solar energy concentration for power generators, solar cooling, cooking and recently thermoelectric generators and hydrogen production.

33. Studies were done on the performance and upgrading of solar water heaters. Research and evaluation work was carried out on selective coatings, the dust precipitation effect, concave glass covers, the optimization of flow rates and tilt angles. Economic research was also done on the national needs for hot water, available technology and production costs.

34. Since 1957 the solar energy laboratory of the national research centre at Dokki, Cairo has been carrying out surveys and doing research on the basis of technology and economic forecasts with a view to using solar energy in various areas. The aim of the programme is to find the solar energy system suitable for use in conjunction with existing energy sources, to save fossile fuel and reduce the effects of atmospheric pollution.

35. The programme started with the thermal use of solar energy in different areas such as water heating for home needs, water desalination, cooling, cooking and power generation.

(a) Reliability and economics of solar water heating

36. Approximately 75 per cent of home energy needs are related to heating, particularly water heating. The study of solar water heating was therefore chosen as a priority area in the research programme. Various studies were done on the performance of various types of solar water heaters.

37. An economic analysis was then made of solar water heating and focused in particular on the average annual consumption of an Egyptian family. Based on Egyptian solar conditions, it was found that a solar water heater with a 2 m^2 surface was adequate to satisfy the hot water needs of a family of 5 persons (about 160 litres per day at an average temperature of 50 to 55°C).

38. The economic analysis was based on a comparison of the costs of solar heating with the costs of three other methods. It was found that solar heating was less expensive than heating with kerosene, butane gas or electricity.

39. In the area of distillation, the programme included research on the performance and productivity of greenhouse-type stills and on improved designs of evaporation and condensation circuits.

(b) Solar water desalination

40. The laboratory started its work in this field in 1958. Significant efforts have been made in this area of research since much of Egypt suffers from a shortage of fresh water. At the outset, a simple greenhouse-type still was used. An increase in productivity led to some improvements with an analysis being done of the parameters affecting the efficiency coefficient. The distillation process is complex consisting of an evaporation operation and a condensation operation. The two phases take place simultaneously in a dual chamber still. Evaporation increases as a larger amount of solar energy penetrates the wall seeing that the possibility of condensation on the collector is reduced. Condensation is improved through the presence of fresh water in the condenser which acts as a vapour trap and through the cooling caused by the condenser's being insulated from the sun's rays.

41. The evaporation phase could also be improved by increasing the temperature of the salt water. It has been proved that the evaporation rate is a function of the water temperature. The process could be improved therefore by orienting the evaporation surface so that it will collect a larger amount of energy. To this end, a semi-concentration still was built and an 8 per cent increase has been obtained.

42. An economic study of a greenhouse-type solar water still has been done. The total cost of the still increases as the still's capacity increases. However, the unit cost (per cubic metre) decreases with the increase in the still's capacity, then increases sharply and drops once again following a jagged curve. This can be attributed to an increase in operating costs.

43. In 1976 an economic research and evaluation programme was carried out on the above-mentioned designs. The surface area of each still was 30 m^2. The aim of the study was to determine the following:

- manufacturing ease
- possibility of using materials available near the site of the still
- production costs
- durability, servicing, repairs, etc.
- efficiency coefficient
- length of programme (two to three years)

(c) Production of cold from solar energy

44. A study was carried out on the use of solar energy for refrigeration. The factors affecting the operation of a refrigerator using absorbed solar energy were studied. A co-operative programme with the Federal Republic of Germany on the use of solar energy for the cold storage of vegetables is in progress and a prototype is being tested.

45. The experimental equipment is a domestic refrigerator operating on the absorption principle and using an aqueous ammonia solution; it has a capacity of 27 litres and runs on butane gas. It has been converted to run on solar energy. A solar energy heating loop in which glycerine is the heat-transfer fluid has been fitted. Its boiling point at atmospheric pressure is 186°C while the working temperature is 120°C.

(d) Power generation

46. The power generation programme started in 1963 with calorimetric studies of a cylindrical parabolic collector made of plane segment mirrors. It has been extended since 1975 through a NSF/USA (Nuffield Foundation) grant for power generation using a thermodynamic cycle. Solar thermoelectric generators and solar cells are currently being tested.

47. A model of a cylindrical parabolic mirror with a focal length of 1 m and an aperture of 2 m has been constructed. Calorimetric tests have been carried out to investigate its energy distribution in the focal plane. It was found that it behaves as if it were made in one piece. The maximum temperature at the focus was about 400°C.

48. New Mexico State University and the Egyptian Solar Energy Laboratory are undertaking a joint programme on power generation by the Rankine cycle using a 5 m^2 collector for generating steam which is then passed to a steam turbine. The collector is constructed on the same principle.

(e) Solar cookers

49. An elliptical paraboloid cooker of 1.5 m diameter has been constructed from aluminium strips. The focus must be located in a horizontal plane so that the cooking pot can be placed at that point. The existing cooker is designed so as to make this possible. The results of the investigation were as follows:

- it takes 20 minutes to boil two litres of water at 200°C.
- it takes about 2 hours, starting from 11 o'oclock, to cook a meal consisting of vegetables, rice and kebab for five persons.

50. At the present time, research in Egypt is oriented towards the industrial scale production of solar equipment, as well as research. Some fundamental research has been started on heat transfer, absorbant coatings, dust precipitation and measurement of solar parameters.

51. The programme for the next few years will include research on subjects such as water and air heating, water desalination, solar distillation, solar drying, biomethane, wind power for small-scale power generation and mechanical use, solar cells, solar pumps (thermodynamic and photovoltaic), use of biomass by direct combustion and solar refrigeration.

52. Certain types of solar equipment are already available on the Egyptian market; these include solar water heaters, solar stills, solar dryers, and lower-power wind generators. Production of solar pumps and wind pumps, solar cells, etc., is expected to begin in the near future.

53. In Mali, the Solar Energy Laboratory in Bamako, established in 1964, is the main national institution involved in solar energy research. However, it was five years before a workshop was equipped with the necessary mechanical equipment and a few laboratory instruments. In 1969, when effective work began, the staff consisted of the department head and one other employee. There are now approximately 30 employees, all Malians, working in four sections. They include five senior research workers, one senior administrator, three technicians, foremen and so on.

54. Activities are concentrated mainly on the study of the means of using solar radiation without prior conversion. In thsi respect Mali can now be regarded as having some experience in the following five fields:

(a) Water heating

55. Models of water heaters, well adopted to national requirements and climatic conditions, have been developed.

(b) Domestic water heating

56. After three years of research and experimentation a campaign was organized to attract the attention of the authorities and the general population. For this purpose the solar energy laboratory gave practical demonstrations in Mali of the equipment which had been developed.

57. Since 1972 investment has made it possible to manufacture almost 300 water heaters, of which more than 200 are already or will be installed in hospitals, maternity homes, hotels, private houses or administrative buildings all over the country. Some of these water heaters were installed in the homes of members of the CMLM (Comite militaire de liberation nationale), of the Government and of other high-ranking officials with the aim of reducing the amount of electricity consumed by the Government itself. In this manner official recognition of the role which the use of solar energy is already playing in the social and economic development of the country is being sought. Ohter users of water heating equipment include: the maternity homes at Mopti and Sevare (200 litres), Markala (400 litres), and particularly Bamako, where a 2,000 litre capacity heater is operating at the Hospital du Point G, and another at Gabriel Toure; 2,000 litre capacity heaters are also installed at the Hamdall-Laye maternity home and at l'Hôtel du Rail.

58. Although this part of the programme has been successful it would have enjoyed greater success if it had been supported by a publicity campaign. Such support is now possible as an industrial and commercial institution has been established which will collaborate with the Laboratory in marketing water heaters and other solar equipment. This institution, called the "Fonds energie solaire", is now meeting local demand and exporting as well. Upper-Volta, for example, has ordered several dozen water heaters. The Fund is proposing to build a distillation unit made of bricks to produce 500 litres of distilled water per day. Under these circumstances there can be little doubt that Mali will soon stop importing electric water heaters and will stop using wood or charcoal to heat water in the future, or use less of them. This is the ultimate aim, which seems to be understood by the authorities.

(c) Industrial heating

59. The study of water heating for industrial purposes as well as for other uses has not been limited to traditional methods. All sectors of the economy were examined for possible applications. One example is the investigation of the possible use of flat solar collectors for the preheating of fuel oil for the kiln at the SOCIMA cement factory in Diamou. First results indicate a saving of nearly 60 million F.M./year on an investment amortizable in one to two years. This project is of great interest as it will be the first attempt to use solar energy industrially and one that SOCIMA considers to be essential. Once this has been started it will then be possible to consider using this process systematically for other applications, such as steam generation, heating or drying, and where other fluids are heated.

(d) Solar distillation and steam generation

60. At the present time distilled water is not produced commercially in Mali although there are many uses for it: car batteries, pharmaceutical products, and toilet preparations. Distillation can also be used to produce drinking water from polluted or blackish water, although chemical treatment is still required.

61. Public services (State undertakings in particular) need distilled water badly. Since 1970 the Solar Energy Laboratory has been regularly supplying such important services as the Genie militaire de Regie des chemins de fer, the Garage Administratif and a large number of garages and private individuals.

62. The problem of the shortage of distilled water and its high price is expected to be overcome by the construction of a large still (surface area 1,000 m^2) with a capacity of between 3,000 and 5,000 litres per day. This project has already been financed and will soon be started. Construction of additional still is included in the current five year plan. These will have a surface area of 200 to 300 m^2 and will be located in five important towns in the other regions of the country. In this way the whole of mali will have distilled water in sufficient quantity and at low cost. In spite of the low selling price it is hoped that the investment will be amortized in one year.

63. One advantage of having distilled water available locally relates to the distribution of pharmaceutical products. The Pharmacie d'approvisionnement du Mali of the Department des medicaments, located in Bamako, currently supplies the whole of Mali with medicines of all kinds. A high proportion of these are solutions in glass containers which are easily broken during transport. If distilled water was available on the spot only the freeze-dried drugs would have to be transported. This would reduce transportation costs, shorten delivery times and prevent breakages. Another advantage of locally available distilled water is that it can be used for drinking purposes. In regions such as Taoudenit (northern Mali), where well water is brackish, this is of considerable importance.

64. At the present time it is necessary to transport drinking water, at considerable cost, over long distances. The production of distilled water on the spot, as can now be done by the Solar Energy Laboratory, would be of considerable benefit to the economy.

(e) Combined still and water heater

65. A combined still and water heater has been developed which combines the operations of distillation and heating. The quantity of distilled water obtained as a percentage of the volume of water in the apparatus is 2 to 3 per cent when the temperature of the water in the tank is 60°C, and 5 to 6 per cent when it is 80°C. This equipment costs only slightly more than a simple water heater and since distilled water finds a ready sale the initial investment is soon amortized and the equipment then becomes a source of income.

(f) Cylindrical parabolic collector

66. Work has also been done on a cylindrical parabolic concentrating collector (length 4m., aperture 1.5 m). The quantity and physical characteristics of the steam produced are being studied with a view to application to distillation processes, motors, etc.

(g) Solar drying

67. Extensive experience has been acquired in drying food products such as meat, fish, mangoes, etc. Samples of these dried products have been kept for years without any deterioration. The same cannot be said of traditionally dried foods, which become infested with insects.

68. The advantages of solar drying have been demonstrated; processing is fully hygienic, and it has been shown to be economic when used in the following Malian undertakings:

- SOCOMA (fruit canning plant);: drying mangoes;
- SOMBEPEC and OMBEV: drying meat;
- La Tannerie (shoe factory) : drying hides;
- La Briquetterie (factory for making refractory bricks).

69. A meeting of directors of these undertakings was held in 1970 to discuss the introduction of solar drying process. From their point of view, solar drying has many advantages in particular, it provides a cheap method of preserving and also increases production. An example is the production of mangoes. During the season, mangoes are picked everywhere and although some are consumed locally and others exported, a great deal of waste occurs. Outside the season SOCOMA has to suspend operations because of lack of stocks. This situation causes selling difficulties as consumers hesitate to buy a product which is available only during part of the year. If, however, SOCOMA and other producers of mango products were to adopt the solar drying process the surplus of mangoes during the season could be dried and sold all year round at a low price. This would prevent waste, increase production, eliminate the need to import other dried fruits at considerable cost and, in general, be of benefit to the economy of the country.

70. The use of solar drying would also increase the production of building bricks and thus reduce the requirements for cement. The drying of fresh fish and meat when these are freely available would prevent waste. These considerations are of great importance to the economic and social development of the country.

(h) Solar cookers

71. Although the technical problems of solar cookers have been solved, their use has encountered psychological problems. It is contrary to the habits of the population and careful preparation and an educational campaign are therefore necessary before they are introduced. This introduction must not be hurried if the principle of the solar cooker is not to be rejected by the population.

72. The method of introduction has already been decided. By means of a government subsidy, the equipment will be supplied free of charge in rural areas in exchange for forestry work. In this way the introduction of the solar cooker will contribute in several ways to the economic development of the country. Its use will reduce dependence on conventional fuels and consequently reduce atmospheric pollution; it could also be a determining factor in the success of the reafforestation programme.

(i) Solar pumps

73. Interest in solar pumps first developed in 1969 but it was only in February 1975 that the first pump was installed. A KW thermodynamic cycle pump made by SOFRETES (France) was installed at Dioila, 175 km from Bamako, where water is available. The pump draws water from a well for use in a dispensary, maternity home, a secondary school, a number of water fountains, and cattle troughs. The solar collectors form the roof of the dispensary.

74. A pump of the same kind is installed at the Rural Polytechnic School of Katibougou, 50 km from Bamako. It supplies water for the school and is a means of irrigating a field where the students work on agriculture.

75. The Ministry of the Interior has also asked the Solar Energy Laboratory to study what equipment will be needed for a large-scale programme of fitting pumps in wells, including wells in the recently drought stricken Sahel region. Finance is available for installing two pumps at Dyli and Kerbane in the Nara department. One of them could be of the photocell kind.

76. A solar station financed entirely by a French Government grant was inaugurated at Dire in November 1979 at a total cost of something like 800 million Mali francs. The Dire solar thermodynamic station, with a rated capacity of 65 KW, is reckoned to be the most powerful of its kind in the world. It is required to perform the following duties:

- Pumping an average of 8,500 m^3 of water daily from the river Niger to irrigate 110 hectares for the Dire "wheat action";
- Pumping an average of 600 m^3 of water daily from a borehole to supply Dire village with drinking water;
- Running a refrigeration unit producing 30,000 negative kilo-calories daily to maintain a temperature of $4^{\circ}C$ for the conservation of perishable foods;
- Supplying an average 5 KWh of electricity daily for evening lighting;
- Generating an average of 450 KWh daily.

77. The Dire station consists of a machine hall in which there are three Diesel sets beside three solar generating sets called Dire I, Dire II and Dire III, a grid of flat solar collectors of a total area of 3,248 m^2 in 28 banks, eight of which are used as roof elements, a heat storage basin of 425 m^3 capacity providing night power, connecting piping, a water intake and network of irrigation channels.

78. The Dire I and Dire II sets each have a 22 KW capacity and drive the irrigation pumps directly. The Dire III set, also of 22 KW capacity, drives a 30 KVA alternator supplying the submersed borehole pump, the refrigeration unit, the lighting system and control, automation and safety features. Incidentally, the station is designed for automatic operation but can, if necessary be operated manually.

79. Malians were involved in the project throughout from the design stage through to the civil and hydro engineering work and all the installations were assembled by a locally recruited team under the guidance of French engineers. For the purposes of this project, which is the first integrated programme using solar energy, two engineers of the Bamako Solar Energy Laboratory attended a training course in France on thermodynamic cycle pumps.

80. Simultaneously with these practical aspects of the work, research continues on improving techniques and attaining new targets. Research activities are mainly concentrated on:

- Improving collector performances;
- Industrial heating and drying;
- Large-scale water distillation;
- Improving the dimensions, performances and transportability of solar cookers;
- Solar air conditioning;
- Electricity generation (photocells);
- Steam raising to supply engines.

81. Substantial infrastructure is required for successful implementation of these various projects. In addition to the personnel referred to, there are three buildings for offices, laboratories, workshops and stores. It is planned to expand the station by the construction of a new laboratory, a new solar station and a 100 m^2 concrete distilling plant. They will be built on two large open spaces provided by the Government. New Laboratory equipment for the solar station worth more than 60 million Mali francs will be installed shortly over and above additional equipment purchased recently for 330 Mali francs. A general and specialized scientific library contains more than 800 volumes.

82. For these activities to be ongoing financing must be reasonably constant. As a token of its interest in the development of solar energy in Mali, the Government agreed to the setting up of an industrial and commercial organization whose function will be to make and sell solar energy devices. This body will be called the "Solar Energy Fund". Some if not all of the profits will go towards self-financing of the Laboratory's various programmes.

83. The idea of using solar energy commercially is just starting to make headway in Mali and solar energy projects should be given a high priority. Solar energy is a local resource and its enormous potential makes it the answer to the country's future energy requirements, despite the existence of hydroelectric potential. However, other conventional energy resources are limited.

84. In the Niger, tests in the field of solar energy utilization for water heating and cooking have been undertaken in the Niger ever since the 1960s, and the interest aroused by the implementation of these pioneering projects has encouraged the Niger Government to establish by a decree of 5 May 1965, adopted on 15 May 1965 a Solar Energy Board.

85. ONERSOL is a State organization with legal status and financial autonomy, of an industrial and commercial nature, under the Head of State or a minister appointed by him.

86. Its terms of reference, as laid down by the above-mentioned decree, were further specified by the Ordinance dated May 15, 1975. The purpose of ONERSOL is:

- On the one hand, to carry out research and development on the design, testing and perfecting of prototypes of installations or devices operated on solar energy,
- On the other hand, to popularize such installation or devices, manufacture them industrially and market them, in the country as well as abroad.

87. In accordance with these provisions, ONERSOL has carried out research in the field of solar energy and popularized some devices which can be mass-produced as from now.

88. During the period 1966-1975, solar water heaters with capacities ranging from 100 l to 1,000 l, and solar distillers with capacities of 10 l/day and 25 l/day were studied, tested and perfected.

89. Since 1971, about 30 water heaters have been installed in private dwellings as well as in schools or public health buildings and about ten solar distillers have also been installed. They have been so popular that mass-production of these devices is planned for widespread use.

90. Following a market research and feasibility study of a factory to cover the local, as well as regional, demand, that was carried out jointly with ILO, an industrial-scale plant was built (between September 1975 and July 1976) and has just started production in the Niamey industrial area.

91. This plant was designed to be the manufacturing and difussion branch for solar energy devices designed by the ONERSOL Research Department, and will allow ONERSOL to divide their work more effectively in two distinct, although complementary, difficult fields of activity because towards the end of 1974, it had become increasingly difficult for a centre with only four research physicists, one engineer, two technicians and a score of workers to deal with both research and marketing.

92. The buildings of the industrial plant for the manufacture of solar energy equipment at Niamey cover a surface area of 850 m^2 and are equipped with modern machines. It is the first of its kind in West Africa. Its aim is to work the raw materials in their simplest form (sheets or tubes) into the profiles and sizes required. Current production capacity is around 400 water heaters per year (consisting of a 200 l thank with an insulated reservoir, a cover, a 2 m^2 collector and supports) and 1,000 to 1,200 m^2/flat plate collectors for pumping stations. Productions can easily be increased to 500 water heaters and 3,000 m^2 of collectors without any major change in the production line.

93. The range of products made and available on the market in the Niger includes the following:

200, 400, 600 and 1,000 l solar water heaters;

10 and 25 l/day solar stills (high capacity distillation units can be made to order);

single or double glass flat plate collectors with an active surface area of 1.72 m^2 and a 60 per cent yield at 70°C.

94. The following ex-factory prices are quoted for ONERSOL products

(CFA francs as at 1 January 1979)

Solar water heaters	Single glass	Double glass
200 litres	176 700	188 200
400 litres	251 500	
600 litres	296 200	356 000
1000 litres	546 400	613 000
Solar collectors per m^2	36 250	42 000
Solar stills		
10 litres/day	83 400	
25 litres/day	180 000	

Solar pump blocks (order of magnitude) 10 000 000/KW.

95. In the near future, the factory will be in a position to offer cylindro-parabolic collectors with an active surface of 12 m^2. This kind of collector was developed by the ONERSOL research department some years back. Similarly, ONERSOL is already able to offer a wide range of thermodynamic pumping stations on a turnkey basis.

96. The Research Department is now in a position to concentrate exclusively on basic and/or applied research, which is already under way in the following areas:

(a) Solar energy thermodynamic conversion. Experimental study on the hot source of a freon gas solar motor has been carried out since July 1973 and has already yielded conclusive data on the the thermal efficiency of the plant, so that actual construction of a first prototype is being considered which will produce around a 1KW from a 24 m^2 collector surface area. ONERSOL is at present engaged in negotiations with a foreign company on a draft co-operation agreement to bring this prototype into operation. Other interesting applications could be derived from the success of this project such as refrigeration based on a compression system, and power generation with alternators. Theoretical calculations and the test results would indicate that the motor could run on 2 to 10 V/CV according to the collector surface.

(b) Solar-energy flat plate collectors and water heating. Prior to marketing solar water heaters, numerous tests were carried out on various absorbant coatings covering the flat collector heating plate. Studies are under way to improve the energy output of collectors which are fully competitive with anything produced elsewhere in the world.

(c) Solar kiln. A research programme on concentration collection has been undertaken at ONERSOL; this programme aims at equipping the country with a 40 to 50 KW solar kiln, an operating temperature of 1,500°C, for building material processing (burnt bricks, lime, cement). A kiln temperature of 1,500°C will make it very versatile: for example it could be adapted for ore-processing tests. The installation includes:

- One parabolic mirror which was entirely designed at ONERSOL - data were subsequently forwarded to CNRS (Odeillo, France) for checking and further information;

- two 8 m x 15 m heliostats to follow the sun;

- the kiln proper.

A 21 million CFA Francs contract has been signed with SNRA (local firm) for the manufacture of orientators. The mirrors for the orientator-panels were ordered from the Miroiterie CASTRAISE (Mirror factory in Casters, France) in April 1975 and have arrived in Niamey.

(d) Solar air-conditioning

(e) Thermo-electric and photovoltaic conversion. These two fields of activity are still forward-looking projects, although for the very short term, since basic naterial has been ordered and even installed at CNERSOL. With regard to solar air-conditioning, there are plans to test in the climatic conditioning, there are plans to test in the climatic conditons of the Sahel brine-based refrigeration systems (lighium bromide) within the framework of the laboratory-complex scheduled for installation in implementation of the solar kiln project.

Concerning thermo-electric and photovoltaic conversion, two research projects are planned:

- Study of thermo-electric generators to supply receivers used as heat pumps, for refrigeration or air-conditioning.
- Study of photocell specifications (an order has already been placed for these photocells, at a cost of 2 million CFA francs).

(f) Water pumps for irrigation. In a joint venture with the relevant department of the Ministry of Rural Development, ONERSOL has just obtained EDF support to finance water pumping plants for irrgation purposes. Thus over the next three years, two SOFRETES-type solar pumps with 5 KW capacity each will be tested in the Niger river valley, and one 2 KW capacity pump up country. Solar pumping equipemt currently sold by SFRETES costs 40 million CFA francs for 5 KW developed at Rouen port, with shipping and related works, the installed KW would cost 12 million CFA francs in the Niger at least. International financing organizations have already withdrawn from such an investment, which would cover the irrigation of four hectares of rice field only, with a head of 5 m. That is why ONERSOL is going to import part of the equipment only, i.e. the motor and its essential fittings; it will then manufacture flat-plate collectors locally. ONERSOL thus expects to save at least 2 million CFA francs per installed KW.

Staff recruitment and training

97. An expatriate civil engineer managed the Centre at its beginning with limited staff, and attempted to popularise solar water heaters, and rudimentary cookers. Materials used in the construction of these devices (wood, iron, groundnut husks as insulators) had the disadvantage of deteriorating rapidly in the climatic conditions of the country: cracks in wood, iron rust....

98. From 1969 on, a high-level physicist from the Niger specializing in solar energy, was recruited; tests were consequently resumed and manufacturing standards were improved. The raw material selected for metal devices is aluminium, the insulator being fibre-glass. Their cost is higher of course, but their energy output is higher and they should last at least ten years.

99. From 1967 to 1973 the number of staff did not change much (one expatriate research worker, one expatriate engineer and one expatriate overseer, two technicians for recording instrument maintenance, seven workers). After 1973 three physicists with an M.Sc. or B.Sc. in physics were recruited. Two of them took a solar energy training course in Perpignan (France) in 1975. The engineer is still an expatriate. There are two technicians and 16 workers from the Niger. Six are assigned to the Research Department and ten to the Manufacturing Department. A staff increase is scheduled in the next three years; however, there are imponderable factors in this respect, relating to the educational achievements of present staff. Up to now, senior staff have come from the Ministry of Education (on voluntary basis). Technicians are trained on-the-job and may take refresher courses abroad. The same applies to workers who generally come from the Niamey Vocational School.

Research issues and financing

100. ONERSOL initially received foreign financial support (FAC, UNDP, Libyan Aid, UNESCO) for the construction and equipment of the Research Department offices and workshop, as well as the purchase from abroad of the necessary insolation and temperature measuring instruments. From 1966 to 1973 the annual grant from the national budget was increased from 3 to 10 million CFA francs, and reached 22 million in 1976. The Niger Government decided to donate 300 million CFA francs to ONERSOL for various activities.

101. The premises of the newly-built factory, which was entirely Government financed, cost 75 million CFA francs. The machinery, which was mostly imported from France and the Federal Republic of Germany and financed in part by UNESCO (Saudi Arabian Fund for the Sahel countries) to the extent of 10,5000,000 CFA francs, cost 27,250,000 CFA francs; 13 million were spent on factory inputs (aluminium sheets, tubes, extruded sections, fibre-glass, glass sheets, etc.).

102. These figures show that the Government is more and more committed to the encouragement of both solar energy research and public acceptance of its applications. Nevertheless management and administrative duties, trips and other commitments in pursuit of financial backing, often bring research to at least a temporary halt.

103. Moreover, given the sophisticated tehcniques of some current or planned projects, ONERSOL will have to approach foreign countries, and European ones in particular, for assistance in carrying out some of these projects. It has already done so on behalf of the solar motor since there is no thermal motor manufacturing plant in Africa.

104. ONERSOL is also dependent on foreign suppliers for measuring instruments and for factory inputs (semi-finished products). However, the raw material is extracted initially from mines within the country, and only poor organization and lack of trade among African countries oblige ONERSOL to deal with third parties. There is no aluminium industry in Africa (extruded sections are particularly needed) nor is glass manufacture, hence the necessity to import tons of glass from Europe, a good deal of which is wasted through breakage or fibre- glass is imported, the best thermal insulator at this time.

105. Scientific co-operation between African States is negligible, and opportunities for African scientists to meet, generally occur within the framework of international conferences and seminars outside Africa.

106. However, in the particular field of solar energy research there have been some attempts to co-ordinate the activities of existing centres, with emphasis, at least for scientists, on data exchange and in-service courses for staff at different centres. This year, for instance, a Mali research student engaged in similar thermo-electric and photovoltaic conversion studies was brought by ONERSOL to Niamey for a two-week course. Since he left, however, this kind of co-operative shceme has suffered, there being no legislation to provide for such schemes despite their clear value to both countries concerned. Nevertheless, ONERSOL has just received a trainee from Chad, and has been asked by Senegal to take one.

107. Following the UNESCO General Conference in Nairobi in 1976, ONERSOL was asked to set up special post-graduate courses in solar technology for African research workers. These courses were held in Niamey, from 3 to 24 April and from 1 July to 31 August, 1977, for 22 trainees from nine African countries (Senegal, Mali, the Upper Volta, the Ivory Coast, Togo, Nigeria, Sierra Leone, Algeria and the Niger). Subsequent programmes are being considered, and the Niger is eager to make more training courses in solar energy techniques, available to African researchers and qualified staff.

Use of solar energy in telecommunications in the Niger

108. Up to 1973 all postal and telecommunications installations were powered by energy from conventional sources: that is, electric power from the city grid, and power from post and telecommunications generating sets and batteries in the villages.

109. In 1974 OPTN, (Niger Post and Telecommunications Administration), for the first time equipped a radio relay station with turbo-generators. Their performance is satisfactory but the cost is high. Therefore OPTN has turned to solar energy and have asked manufactures for information.

110. Meanwhile the Malagasy Postal Administration approached OPTN for information on the use of solar energy in the Niger telecommunications network. Before answering this request OPTN forwarded it to ONERSOL. On 18 July 1975 data concerning telecommunications(capacities from 1 w to 1 KW) was supplied. Since then OPTN has studied this question in depth.

111. In October 1975, the first photocell-based self-contained power pack was ordered for the Boukanda radio-relay station which is 60 miles north of Niamey.

- Latitude 14° 00'N
- Longitude 02° 09'E
- Altitude 280 m.
- Declination 5° 10'
- Solar collector tilt angle 14°

112. The power equipment comprises a solar collector, an electrical current charge controller and a battery. When there is no sunshine the collector stops supplying energy and the battery takes over.

113. The Boukanda relay station has a 35 watt average consumption and a 40 watt peak consumption. This supply system lasts on average for ten years. The project costs 5,385,266 CFA francs. 538,526,6 CFA francs is the average operating cost per year.

114. Before the commissioning of the solar collector the Boukanda relay station operated AD 608 type large capacity power batteries. In 1975, 160 batteries of this type were used in this station. The batteries' average cost in Niamey, being 20,000 CFA francs, the operating expenditure for the relay station amounted to 3,200 000 CFA francs.

115. The collector is made up of 33 modules with an 8.1 watt nominal capacity, and a total supply of 267 watts. The size of each module is 1 m x 0.15 m, so that the collector's surface area is about 5 m^2. The modules are mounted on aluminium extruded sections set on a metallic frame with a tilt angle calculated for the latitude of the location (14°N). In the daytime the collector supplies power to the radio relay system and to a battery made up of 17 lead cells with a 250 A.h. capacity.

116. Solar generators of this type are now scheduled for installation in various parts of the country to supply power to low capacity radio relay stations and to small telephone exchanges in rural areas.

117. Transmission. Ouallam-Banibangou Link, Maradi-Dakoro Link, Zinder-Tanous Link. The last two are HF radio links with an average 30 minute power span.

118. Replacement. At present all unconnected districts are equipped with 1,938 type local battery exchanges. These exchanges are no longer produced and spare parts are also missing. They are scheduled for replacement by more modern equipment with electronic components operating on 6V. supply instead of 48V. which supplies the old equipment. Moreover the new exchanges will serve from 20 to 200 subscribers at a power consumption rate of 12 to 120 watts.

119. School television. Twenty-two school courses are transmitted by a system run on 10 watt average capacity photocells. This was achieved in a joint project with ONERSOL.

120. Generally solar energy has been introduced into the telecommunications network where during the course of modernisation essential to the economic and social development of the country, existing equipment has been found to be absolete or unsuitable.

121. The results of work done and being done by ONERSOL in the Niger suggest that the following projects should be undertaken subject, of course, to the availability of the necessary finance and labour.

- Popularisation on an adequate scale of tested thermal solar installations such as cookers and dryers already in use and likely to have an immediate effect on present social and economic conditions.

- Development of the activities of the Trade and Manufacturing Department, improvement in the quality of its goods, widening of the range of products (solar motors),

- Continued research on solar boilers fitted with cylindrical parabolic mirrors for use with solar motors of 2 to 10 CV and subsequent joint production with the firm Spiller, in the Federal Republic of Germany, of the first complete prototype.

- Continued research towards the creation of solar electric installations fitted with thermo-electric and photovoltaic batteries and parabolic revolving medium precision mirror. Study of thermo-electric and thermo-dynamic refrigeration.

- Experiment on solar air-conditioning. This is linked with the 5 MW oven project which will include: trial testing of cement roasting and of various clay products; the production of lime; experiments on, and eventual testing of, clinker production for cement and so forth. Moreover, as the solar oven must be constructed within a building with a laboratory and other rooms, this allows research experiments on solar central air-conditioning. In the same way the study of solar absorption refrigeration in Sahelian climatic conditions, suggests as does the study and production of solar compressor refrigerators together with the Rankine cycle colar motor, using an appropriate gas as motor fluid and cooling fluid.

- Start of a programme of experimental studies of "green-house" crops raised on minimal (salt or fresh) water consumption. This programme to be carried out with the co-operation of the public services as well as that of interested organizations and individuals.

122. Taking into account the time span of such a programme, there must be selection of immediate, short-term, medium-and long-term objectives and this must be according to various considerations: e.g. the stage of development at which a project has arrived; the complexity of the technology required; the degree to which the proposed installations will affect economic and social progress and development particularly where there are pressing energy demands and where solar energy is most suited (water-pumping, irrigation along the Niger and other water sources, water heating and distilling, process drying of agriculutural goods for export); etc.

123. <u>In Rwanda</u> solar energy research is carried out at the Energy Research and Application Centre (CEAER), which was established in 1974 in Butare, a part of the National University and responsible to the Ministry of Natural Resources, Mines and Quarries.

124. This national Centre has three main objectives:

- To study and develop simple machines powered from local energy sources and adapted to the needs and conditions of Rwanda;
- To popularise such machines and to encourage their production on a small scale from reliable prototypes which will attract the interest of the people of Rwanda;
- To contribute to the training of research and technical management staff.

125. Within this frame five main areas of research have been given priority:

- solar energy;
- low power turbines;
- peat;
- methane gas from Lake Kivu, and
- geothermal energy.

126. Since the establishment of CEAER there have been a number of solar energy research and development projects in the following areas:

(a) Solar water heating: Solar water heaters have been researched. One 1,200 litre/day prototype has been installed at Gabiro Hotel in the Rwanda National Game Park; it supplies 6 rooms with hot water at a temperature of 40 to 60°C. Prototypes of various capacities have been designed and tested in order to popularize solar water heating for several reasons:

- to reduce firewood consumption, thus alleviating deforestation effects;
- to improve rural living standards by facilitating better prophylaxis; rural dispensaries and maternity clinics could be equipped with solar water heaters;
- to use hot water as the motor power for solar pumps in order to improve rural water supply.

(b) Flat collector performance improvement. Several tests have been made. Flat collector construction has been improved and the latest collector prototypes are now fully competitive with foreign collectors. The Butare Centre is installing 50 m^2 flat collectors.

(c) Solar distillation. One solar still supplies the Butare National University chemistry laboratories with distilled water. Distilled-water supply to garages for battery charging is being studied.

(d) Solar refrigeration. A large capacity absorption solar refrigerator prototype (4 to 6 m^3 for the cold chamber) is being developed. Some technical snags, particularly the low efficiency of the 18 m^2 parabolic cylinder shaped collector, are causing delay. In the same line of thinking, farmers are being approached about the need to develop solar dryers for agricultural produce preservation and storage.

(e) Solar cooking. Rwanda is experimenting and testing a solar cooker imported from Switzerland.

(f) Sunshine recording. Insolation data have been recorded by the Institute's recording stations for about ten years. Statistical data processing is being carried out with one computer.

127. Rwanda has carried out small-scale experiments on biomethane conversion. CEAER has boosted research in this area. Larger capacity units are now being installed and consumptions for various applications (cooking, lighting, etc...) are being evaluated. One gas producer prototype based on cowdung fermentation is being tested in an agricultural college wich has a sizable cattle herd.

128. Concerning low water fall harnessing, Rwanda, being a mountainous country, is taking very careful stock of electric and mechanical power generation. Low capacity turbine integration in Rwanda has been proceeding since 1975. It is planned to instal one 20 HP rustic turbine on a low water fall near the University, with the help of a group of civil engineering students. This turbine could run a sorghum mill and serve as a prototype for future plants.

129. In Senegal, the Institut de Physique Meteorologique (IPM) (Institute of Meteorological Physics) was set up in 1955 as part of the Scinece Faculty of the University of Dakar. Several years ago a laboratory was established on the initiative of Professor Henry Masson, Dean of the Dakar Science Faculty, to meet the demands of a great many international agencies wishing to obtain information relating to the meteorology of tropical areas.

130. The work of this Institute centres around a laboratory for measuring solar radiation, which is perfectly equipped for measuring direct, global and diffuse solar radiation and the thermal balance. Radiation is measured every day, and the findings, with regard to both solar radiation and the thermal balance, have been published by courtesy of the Voeikov Central Geophysical Observatory in Leningrad for approximately the past 20 years.

131. The solar energy programme under way in Senegal has focused primarily on water, which is justified by the increase in the prices of so-called conventional energy and by a policy of environmental protection. The scientific and technical research division co-ordinates the research and implementation of programmes and ensures their financing through either domestic or external sources. IPM possesses the equipment needed to work in the four areas of research and implementation of its programmes

(a) Improving the performance of solar engines used for water pumping in villages, grasslands and agricultural areas;

(b) Water heating for domestic and collective uses;

(c) Preserving foodstuffs, especially fish, by hot air drying;

(d) Distilling water for hospitals and clinics in remote rural areas and treating brackish waters using the same process.

IPM is now being converted into Centre d'études et de recherches des énergies renouvelables (CERER)(Study and Research Centre for Renewable Energy Sources) which will have an integrated Research and Development programme. CERER was officially established in 1980.

132. The semi-conductor laboratory of the Science Faculty is particularly interested in photovoltaic conversion. Its research is aimed at promoting the use of solar batteries in the production of electricity and the pumping of water. The Institut universitaire de technologie (IUT) (University Technological Institute) has as its goal the training of technical staff in diverse fields for immediate imployment in Senegalese industry. It has high level staff including some persons interested in the use of renewable energy sources. Students have participated in applied research work on high-temperature thermodynamic conversion, the use of solar batteries in refrigeration and lighting, the study of housing in terms of local building materials, weather conditions and the country's lifestyle, and the building of windmills. The Thies Polytechnic School is responsible for training high-level engineers but also concerned with promoting the use of solar pumps and wind machines in rural areas.

133. The Government established an industrial company to implement the use of solar energy. Projects are being considered with France, Canada, the United States, the Federal Republic of Germany and other countries with a view to making more efficient use of renewable energy sources. A rural energy centre is being planned to study the most suitable way of combining the use of the sun, wind and biomass. The UNEP-assisted project is aimed at meeting the energy needs of a small village unit at the lowest cost. With the help of FAC, four 1 KW power-stations were installed and are operating to supply water to four areas. A one KW water pump has also been installed at the Centre national de la recherche agronomique (National Agronomy Research Centre) at Bomby for experiments in drip irrigation of market gardening. A 60 KW pumping station is now being installed at Bakel to irrigate a hundred hectares and in this way to promote the diversification of agricultural products in this part of the Senegal river valley.

134. Senelec, the Société national d'electricité du Senegal, (the Senegalese National Electric Company) is carrying out a rural electrification project at Diakhao. A 25 KW electrosolar power-station is nearing completion. It will provide the village of Diakhao with electricity and be associated with an experimental centre for solar materials. This power-station is to begin operating forthwith (toward mid-1980).

135. Lastly on the national level as well, the Institut de recherche et de documentation, (Research and Documentation Institute) in liaison with the national meteorology office, has installed measurement devices in most of the administrative regions in order to produce radiometric map.

136. Sudan is one of the most solar radiation-rich countries of the world. Geographically it is located between latitudes 4° & 22° north of the equator. Thus it is a suitable place for utilizing such an important source of ever-lasting type of energy. Utilization of solar energy is not a new subject in Sudan. It has been used over many ages for the drying of agricultural products, timber, mud, bricks etc.. These applications of solar power, though primitive in nature, were the first steps to enter the solar era.

137. Scientific research of Solar energy in Sudan started in 1955 at the University of Khartoum, where the Department of Physics was engaged in power generation and measurements of solar energy. In 1958 the Department of Mechanical Engineering began to conduct research on solar desalination, power generation, water heating and dehydration. The institute of Solar energy was established in 1970. In 1977 it has been renamed the institute of Energy Research (I.E.R.) The activities of this institute in Solar energy research include the following :-

i - Development of solar stills for large scale application.

ii - Low-cost water heaters

iii - Flat-plate steam generators

iv - Solar cooling systems

v - Solar drying

138. In May 1980 the National Energy Administration was created as an organ of the Ministry of Energy and Mining. Its major role is to control, coordinate, utilize, and rationalize the energy sources in Sudan. Solar power research and development lie within the scope of its activities. The National energy Administration will enable, through intensive research work, the solar energy to participate in the total share of energy needed in Sudan by the 1st quarter of the 21st century. The National Council for Research is undertaking the development of different solar power projects.

139. A brief summary about these projects is given hereunder:-

(i) Solar water heaters

Five units are installed at the Faculty of Engineering (University of Khartoum). Each unit is inclined 15° to the South and comprises of galvanized steel tubes seated on galvanized corrugated steel plates or mesh wires. The tubes are covered by glass plates. Outlet temperatures up to 75°C are reached depending upon water flow rate inside the tubes. Such units may prove suitable in residential areas, hostels. and hospitals.

(ii) Solar stills

These units produce distilled water from tap water/wells water. Each unit consists of a flat glass mounted on a basin. This basin is filled with water, and by the "green house" effect water evaporates and then condenses on the glass surface and the droplets are gathered on throughs. One gallon of distilled water is produced per meter square flat plate per day.

Four units are installed near Khartoum area :-

Place	gal/day
University of Khartoum (Institute of Energy Research)	20
Suba (Institute of Energy Research)	40
Shambat (Food Research Centre)	16
Medani (Agricultural Research Corporation)	20

Petrol stations can utilize such units to produce distilled water for cars accumulators.

(iii) Solar Cooling Unit.

This unit is a donation from Netherlands and is installed at the Faculty of Engineering. (University of Khartoum). It is composed of steel tubes filled with solid calcium chloride. Ammonia is absorbed by $CaCl_2$ during night and ejected during day. As an result of this process cooling occurs. This unit now produces about 16 kg of ice per day.

(iv) Solar Drying

Air is forced by means of fans to pass a series of cascades towards a cabinet where drying takes place. The cascades are composed of black tubes with flat glass plates mounted over them. Air absorbs heat as it passes through the cascades and the outlet temperature reaches up to 70°C (158°F). Bricks are tested in the cabinet for drying and good results are obtained.

(v) Photovoltaic solar pumps

One type of such pumps is positioned at Butri (25 Km South of Khartoum). It is composed of a pannel of solar silicon cells which converts solar energy directly into electrical energy (D.C.) The panel has a design peak power of 660 watts with an average output of 400 to 500 Watts. A D.C. motor drives a centrifugal pump to pump water from a surface well with a capacity of 18 to 23 m^3 a day. Although the capital installed cost is comparatively high, the operating condition of the pump is now under investigation and recording to come to a final judgement.

(vi) Solar Thermal pump

This unit is under erection now at Suba (15 Km South of Khartoum). It consists of flat plate collectors which contain freon 13. A diaphragm engine is pressed by heating freon and a reciprocating motion is created and transmitted to a hydraulic press which delivers water from an artesian well.

Potentials of Solar applications in Sudan

140. The potentials of harnessing solar energy in Sudan have good prospects due to more than one reason:-

(i) Sudan climate is very suitable for solar utilization especially in middle and northern areas.

(ii) Majority of population resides in rural areas which lack conventional sources of energy (mainly electricity). Solar energy can be utilized with reasonable cost to promote the development in these remote areas. Water pumping, irrigation, and cooking are suitable fields of Solar applications.

(iii) Needless to say that Solar energy environmentally is cleanest source of energy, besides that it needs less operating and maintenance costs once the equipment is erected.

141. In fact Sudan lacks the technology of Solar energy, like many other developing countries, but would like to step forward into such zone through research and by the help of other developed nations, because Sudan enjoys a lot of Solar energy and there is no reason to miss a technology that would convert the enormous amounts of heat into useful applications.

142. In Tunisia solar energy research has been going on for about twenty years, and some solar energy units have been installed, such as the water heating installation at the Kairouan High School. However, serious consideration began to be given to the use of solar energy only after 1973, the year when the world energy crisis began. To overcome the crisis the National Engineering School of Tunis (ENIT) begun research and developed a flat collector, photocells and a solar heat pump.

143. On the other hand, Tunisian Oil Enterprises (ETAP) had undertaken studies and research into the different uses of solar energy such as domestic heating and industrial water heating. The conclusions drawn from these studies were that, compared with the current price scales for oil products and electricity, solar energy was not yet competitive, Consequently ETAP had recommended that Tunisian authorities should exempt all plants using solar energy from tax. It had recommended also that subsidies be granted to users of equipment run on solar energy, and that locally manufactured machines and installations as well as locally produced material should be used as much as possible in order to reduce costs. These recommendations are still being considered.

144. Tunisia has begun, however, to put a few water-heater models on the market, and is completing research-development work on:

- small scale production of solar electricity: projects are now being developed;
- solar pumps; several prototypes are being tested and the study of their economic viability is planned;
- laboratory production of hydrogen

145. The Upper Volta has undertaken several research and development projects with special emphasis on solar water pumping and refrigeration, initially at the Inter-State Rural Development Engineering School (EIER).

146. Water pumping. Only low-temperature mechanical pumps using flat collectors have so far been tested. One of these has been in operation at EIER since 1971. Its operating features are as follows: "OUAGA" solar pump; flat collector with a surface area of 30 m^2; single-cylinder motor; heat vehicle: initially methyl chloride, now butane. The expected discharge was 2 m^3/h. The pump is installed in a reservoir without renewable subterranean water supply. In order to keep water in the reservoir, the pumped water must be returned to it. The reservoir also acts as a cold source for the condenser; the water heated in the condenser also returns to the reservoir, thus raising the temperature. This decreases the efficiency of the system.

147. Four pumps of a similar type were to be installed in 1975 under the auspices of the Hydraulics and Rural Development Department, at the rate of one per cent:

(a) One for Koupela Hospital to supply pressure water, hot water and distilled water with a cold chamber for serum and vaccine preservation;

(b) A second one to supply water to Djubo village;

(c) A third for agricultural water supply. This pump was intended for a well drilled in Markoye and to supply water for cattle and irrigation,

(d) A fourth, installed at EIER in 1975, has a collector surface area of 75 m^2 and a discharge of 3 to 5 m^3/h with a 45 m head; it operates for 5 to 6 m hours a day.

148. These four stations will make it possible <u>inter alia</u> to study operating conditions and evaluate costs. The first two projects are financed by "Catholic Life", the third by DGRCST (France) and the SOFRETES Company. The pumps will have a power of about 1 KW and the boreholes will be 18 to 25 m deep. Water will be stored in an earth-banked reservoir covered with a plastic's sheet. According to available information these pumps have already been installed. Other stations are scheduled for installation under the "Sahel Alternative Energies" project. In 1976 some ten SOFRETES MS-5 pumps were installed in the following places: Kembara, Djibasso, Kassoum, Thiou, Gorom-Gorom, Ouahobe, Banga, Tapaiko, Darka and Zinibeogo for village water supplies and water supplies for rangeland. These stations have a discharge of about 15 m^3/day. Financial support came from French bilateral aid. Under the same project two SOFRETES MS-7 pumps were installed at Kongoussi and Barsalogho, although intended for village water supply, these two pumps can deliver 250 litres of hot water a day each and provide refrigeration (they are equipped with a 150-litre refrigerator operating at 3°C). EIER is also planning to supply water to hospitals, stock-breeding centres in communities and rural villages.

149. EIER is engaged in an applied research programme for improving the components of the solar mechanical pump and reducing cost. In order to reduce flat collector costs it is investigating concrete flat collectors and trickle systems, with a view to having them 90 percent locally built. A high efficiency diaphragm motor has been designed in the school and a patent has been taken out. Research is also proceeding to improve the condenser and adapt it to local low-hydrometry climatic conditions. Evaporation condensers would help to lower the temperature of the cold source and reduce its water consumption.

150. EIER has made a "research agreement" with the solar mechanical pump manufacturer under which improvements developed by EIER are vested in the manufacturer and introduced into prototypes.

151. Water-heaters and cookers: Manufacturing solar water heaters and cookers locally would help to save firewood. Water heater prototypes made in Niamey fulfilled expectations and could be manufactured locally. Solar cookers would solve the crucial issue of wood supply and would help to check the deforestation process which is assuming alarming proportions. At present, the firewood used in Ouagadougou comes from 50 to 60 km away. In 5 to 10 years time the distance will have increased so much that supply will be out of the question.

152. Dryers: Fruit and vegetable drying is an imprtant activity in Upper Volta, and designs of operational prototypes of solar dryers would be welcome with a view to setting up local manufacture.

153. Cooling: EIER has researched refrigeration with solar pumps and windmills with a view to adding compressors to the systems.

154. Solar equipment for buildings: The Volta Valley Authority is planning to flood some onchocerciasis affected areas (a disease causing blindness). The inhabitants will be resettled in new villages. The head of Town-planning and Architecture has suggested that the new dwellings should have solar collectors as a standard feature for water heating, power generation and water pumping.

155. Power generation: At present nothing is being done in Upper Volta about solar power generation. Designs for low power (1 KW) generators would be welcome to run well pumps (3 to 6 m^3/h, from 5 to 25 m head), lighting for part of a dispensary, storage of drugs etc.

156. EIER plans to generate power from mechanical solar pumps, with capacities ranging from 2 to 5 KW. This could provide power for small rural communities. EIER puts great emphasis on reliability, since maintenance and spare-parts supply are difficult in Upper Volta.

157. Insolation and wind measurements: Since 1962 insolation measurements have been made by the Meteorological Services at 13 stations equipped with heliographs. Daily sunshine duration is recorded. It is found that annual sunshine duration ranges from 2 300 h to 3 200 h. These figures are similar to those for the South of France.

158. Wind measurement was made for one year under the WMO project for the supply of 8 windmills to Upper Volta. Measurement ought to be carried through over a five-year period in order to yield useful results for wind energy planning in the country.

159. <u>Education and training:</u> The Inter-State Rural Development Engineering (EIER) already has a thermodynamic solar pump for demonstration. A course on solar technology is feasible. Ouagadougou Technical School plans to set up a refrigerating engineering stream. Solar energy applications to air-conditioning and refrigeration could probably be introduced into the curriculum.

160. <u>New research organizations:</u> Now that the new bodies have been set up, the Ministry of Higher Education and Scientific Research and the Scientific and Technological Research Agency (DRST) are the specialist bodies jointly researching solar energy. The main functions of the DRST are co-ordination, leadership and synthesis, for the use of solar energy and applications affects different sectors which do not actually come under the DRST.

161. In the preparatory stage of data collection on ground insolation, a network for measuring total radiation and sunshine hours was set up in the Upper Volta in 1971. One team of university researchers are studying thermal conversion and another team bioenergy conversion; both teams are still in the early stages of their projects. Also, organizations not directly under the national authorities are carrying out research work in the Upper Volta.

162. The regional organizations concerned or likely to be concerned with solar energy include the Inter-State Rural Development Engineering School (EIER) at Ouagadougou, a pool of 13 States, 3 of them from the Sahel; the Inter-State Hydraulic Study Centre (CIEH) at Ouagadougou; the Inter-State Rehabilitation Commission for drought-affected areas in the Sahel (CILSS) at Ouagadougou and the Liptako-Gourma Authority. CILSS has included a solar energy project in the compendium of projects approved by the Sahel member States (project No.801).

163. CIEH deals with all aspects of water including dewatering. Research on dewatering led to experiments with some forms of energy, in the event wind power and biogas. CIEH runs projects which include experiments on pumping, windmills and principally the production of biomethane gas. Research on biomethane gas production proceeded with FAC funding for many years and two tanks were installed at the Committee's headquarters at Ouagadougou and eight more outside Ouagadougou. This experiment was in line with the two aspects - energy and agronomy - of the programme, which ran for two years and resulted <u>inter alia</u> in the construction of a small cooker running on the gas produced and in the use of biomethane gas to run a pump. Another of the programme's projects tackled the conversion of pumps to run on biomethane gas instead of petrol. The items in the second phase of the Committee's programme include a survey on biomethane gas demand and a project on the use and processing of human faeces, as well as improvements to earlier items. It is also the intention of the CIEH to improve information and documentation relating to the uses of new forms of energy.

164. CEAO. having organized jointly with CILSS the 1976 Bamako seminar on "Solar Energy and Development", the first meeting of its kind in Sahellian Africa, recently decided to set up a "regional" Solar Energy Centre on the recommendation of its Ad Hoc Committee. The Centre includes all the member countries of the Community and has its headquarters at Bamako. As yet it is not operational, but it may have a very imprtant part ot play in the harmonization of research programmes in the Sahel region and the co-ordination of work.

165. At the present time several research groups in West, Central and East Africa are researching into the practical uses of solar energy, but their means are limited.

166. A brief summary of activities carried out in other African countries (as available) may be summarized as follows:

BENIN

167. Two pumps guinard photovoltaic were installed in 1978 one of which is operating very well with outputs of about 30 cubic meters per day. A programme of experimentation with new forms of energy, especially solar, will be defined by one ONUDI expert included in the second development plan, scheduled to start in 1981.

BOTSWANA

168. Solar insolation is relatively high, while the mean annual sunshine duration is around 3300 hours.

169. The development of solar energy devices has been undertaken mainly by non-government organizations. A rural-based centre which has taken a leadership role in solar energy experimentation in Botswana is the Rural Industries Innovations Centre. This centre has developed solar cookers, ovens, stills, biogas units and windmills, some of which are now being tested in the field. Most of the work has involved adaptation of proven technology to meet local needs which is then introduced into villages through extension workers. Some of the needs of the urban population have been met by one commercial organization which fabricates solar heaters of the conventional design type. Another rural-based group is now in the process of establishing a renewable energy technology unit which will concentrate on the development of solar pumps.

BURUNDI

170. No concrete work has been undertaken in the country as yet in the field of research and development of solar energy. However, the Burundi government has made several formal requests to ECA for the assistance of one solar energy expert in order to:

- have recommendations on the practical use of solar, wind and biogas energies; and
- work out a realistic programme of priority steps to take, specifying necessary resources and implementation costs.
- establishment of a national solar energy centre.

171. The eco-climatology office within the Burundi Agronomic Science Institute (ISABU) operates a network of 14 stations all over the country recording climatic data. Five of these record sunshine duration as well as integrated radiation. Recommendations have been made whereby all 14 stations ought to be equipped with Campbell Stockes heliographs and anemometers coupled with mechanical adding machines.

CAMEROON

172. In September 1977, the Cameroon Government made a request to ECA for its assistance in working out a concrete research and development programme in the field of practical utilization of solar energy in Cameroon.

173. There are, at this stage, national institutions which could undertake research and development activities. Beside the Ministry of Energy, ther is a National Board for Scientific and Technical Research, underwhich the Technology, Industry and Mining Research Institute has an energy-research co-ordinator. Besides, research is currently undertaken by staff and students of the University and Polytechnic Institute of Yaounde, with special emphasis on biogas conversion.

The National Railway Company (Regifercam) has placed a sizeable order for 20 railway-signalling stations to be operated by solar cells. The anticipated power consumption will be about 400 wh/day.

174. An investigation report on possible contributions of solar, wind and biogas energies to the development of the United Republic of Cameroon has been submitted to the Government's consideration by a professor in the Physics Department, University of Yaounde, who is also a professor at the Polytechnic Institute. Here is a broad outline:

(i) <u>Assessment of needs:</u>

To make the necessary assessment of solar and wind resources: as a preliminary step, to gather all data recorded in the past to plant sunshine and wind data-recording stations throughout the country;

To evaluate short/middle-range needs in terms of low-temperature energy: to assess domestic power-consumption as well as in industries using low-temperature thermal power; to assess agriculture needs for the drying of agro-food produce; to assess the present level of energy consumption in water pumping for domestic use; to assess present and future needs that could be met by the use of biogas energy;

- To study transfer of technology: simultaneously with data gathering and assessment of needs, initiating possible transfer of technology for local production of alternative energy-based equipment is advisable.

(ii) Evaluation of resources to be engaged in the implementation of this Project

- Evaluation of solar, wind and biogas energy potential: to co-ordinate activities; to select measuring equipment; to make a cost evaluation of the programme;

- Assessment of needs: to determine surveys to be carried out; to co-ordinate activities; to assess required aid; to evaluate cost;

- Transfer of technology planning: to purchase flat collectors available on the international market for field-testing; to investigate local manufacture of collectors suited to local environmental conditions and to technological and economic contraints; to investigate construction of a biogas digestor;

- To provide adequate documentation facilities: library; specific journals; photostats or microfilms of scientific literature.

175. In the first place a national policy seems to be essential in the field of research and development of solar, wind and biogas energy sources. Secondly, co-ordination of activities at the national level is desirable. Concrete recommendations have been made by ECA on structures to be set up as well as on short-/middle-term projects to be carried out.

176. Regarding existing operational devices, it should be noted that a SOFRETES type water-pump was planted at Makary in 1976. With a 70 sp.m. collector surface area, this pump draws 3 cu.m./hr from a 20 m. head. Operation duration is 6 hrs/day, and daily production is 18 m.m. Besides, a low capacity biogas digestor is being constructed at the University of Yaounde.

CAPE VERDE ISLANDS

177. Several solar and wind energy devices operate in various parts of the country. The Ministry of Rural Development is engaged in experimenting and testing the efficiency of windmills of various capacities, of air-generators and of a SOFRETES MS 3 type solar pump at Praia, on the experimentations sites of San Felippe and Achada Boleria, with UNDP financial support.

178. A SOFRETES water pump was also assembled at Saint Domingos in 1977.

CHAD

179. No research and development activity has been undertaken to date; however several solar devices have been installed in the country since 1976:

- one SOFRETES thermodynamic pump at Karal. The collector surface area is 70 m2, with a duty of 3 m3/hr against a head of 20 m. with a 5 hrs/day operating time, this pumps supplies 15 m3 water per day. It was commissioned in 1976.

- two sister pumps have been planted since then, one at Ati, the other at N'Gouri.

- one SOFRETES 5 kw pump has been planted on the Ndjamena cattle-market for water-supply to the cattle.

180. The Chad Government is basically interested in water-pumping (through mechanical, electrical or wind pumps), water-processing (by solar heating and distillation), food and medicine preservation (by solar drying and by absorption or compressor-types cold-storage room refrigeration), power generation through low-capacity plants (photocells), refrigeration and air-conditioning. Such activities shall be carried out under a National Research and Development Centre to be established.

CONGO

181. The Department of Physics of the Brazzaville College of Sciences decided in October 1975 to study the possibilities offered by the use of solar energy in the Popular Republic of the Congo.

182. The first task consists of making an investigation in order to examine closely the local needs in industrial and domestic energy, the average financial and technical possibilities of the population, and the insolation conditions in the whole country.

183. In parallel to this task, the Brazzaville College of Sciences, since October 1975, has organized post University lessons of the third cycle level about solar energy. A scientific and technical library is being created.

184. The research work which could lead to doctorates is being defined; it will have to consider the economical situation of the country and the possibility of international co-operation particularly with the laboratory of Solar Engineering of Perpignan (France) and the ONERSOL of Niamey (Niger).

185. More particularly, the study of the comportment of flat captors is undertaken simultaneously in Brazzaville , and in the kinetic and electrochemical laboratory of the Perpignan University. Results will be exchanged and compared in order to adjust captors as well as possible to local conditions of use. In this aim, comparative studies of solar distillers will be made simultaneously in Brazzaville and Perpignan (distillers of the "glasshouse" and "streaming" types).

186. Later on, other applications of flat captors will be studied, as well as the possibilities given by electrosolar direct converters.

DJIBOUTI

187. According to available information, a SOFRETES TS 3 solar pump is being installed in the Republic of Djibouti for irrigation purposes by French bilateral Aid.

188. The Republic does not seem to have undertaken research in solar energy to date.

ETHIOPIA

189. The applications of solar energy in which Ethiopia is mostly interested, are:

<u>Direct use of Solar Energy</u>

(a) For mechanical drive (including flour mills and small industries);

(b) For water pumping (both for water supply and for irrigation);

(c) For food and crop drying;

(d) For water heating;

(e) For cooking;

(f) For solar distillation;

(g) For ambient air conditioning and for refrigeration (food conservation);

(h) For decentralized electric power supply to rural areas either on isolated basis or integrated basis (small hydro, wind and storage batteries).

About 100 to 120 prototype experimentation in about five years period could be of interest.

190. The country has just begun to collect the relevant radiation data to enable it to effect proper planning with respect to its development. It is intended to test some solar pumps to see what adaptive research needs to be undertaken in the Ethiopian context.

191. A limited programme of development has already started in Ethiopia in solar energy, and in the very near future the proposed acquisition of two solar pumping sets on aid basis is envisaged. A very interesting solar cooker prototype was prduced by an individual concerned.

192. Solar Energy, has been recognized- a priori - to partly satisfy the energy requirements of the country. But since Ethiopia, like many other developing countries does not possess enough trained manpower, industrial infrastructure and financial capability, aid would be required in all aspects of the development stage. Aid would be needed in the study of the potential applications of solar energy in rural energy supplies in all its aspects. This will have to be of course, preceded by the study of ways and means of collecting and processing parameters for the application of solar energy in all its forms,

193. Aid would also be required in the development of infrastructure hardware and software) for carrying out research development experimentation and testing under actual field conditions, evaluation of results, and finally, expansion of solar energy systems to reach the vast majority of the rural inhabitants. This will then be followed for the development of infrastructure for the eventual design, manufacturing and/or assembly of the whole or of parts of these solar energy systems together with the necessary manpower training and institutional development. 1-/

GABON

194. There is no administrative body as yet in Gabon in charge of research and development of solar energy. However, the Government has developed the use of solar cells for television. In 1975, four television sets were installed in rural communities. Results seem to have been very encouraging and the Government is planning large-scale extension of the system, especially in rural areas.

195. ELF-GABON Company is using a radio-telephony system running on solar cells for communication with the various off-shore oil-drilling rigs.

CAMBIA

196. In the Gambia, solar energy utilization has hardly been sutdied. However, some measurments pertinent to the solar energy potential have been carried out by the Department of Hydro-Meteorological Services.

The country experiences over 3000 hours of sunshine per year, mostly via direct radiation, except in August when the radiation flux is less than 400 Langleys per day. A significant use is already made of solar energy in the production and processing of agricultural products. For example, over 130,000 metric tons of groundnuts and over 70,000 tons of cereal, mainly millets, sorghum, and rice are dried yearly by stacking or spreading them in the sun before thrashing; and up to 20,000 tons of marine products caught locally, of which 50 per cent is exported, are usually sun-dried. Plans for economic and social development call for increased output of smoked or dried fish. Given the fact that tons of groundnuts turn mouldy each year, solar assisted crop drying techniques could be useful in this regard.

197. There can be, therefore, indentified three major areas in which solar energy development could prove to be of great benefit to the country:

1. As a solution to the environmental and ecological problems of deforestation.
2. As an operable alternative in the face of rising energy needs, especially of the rural population, and population growth.
3. As a middle level technology providing jobs and income.

Solar energy systems could be utilized in various forms:

A. Direct heat energy systems - cookers, water heating and crop and fish drying.

B. Electrical energy systems - photovoltaic and thermal systems for village lighting and water pumping.

C. Converted mechanical systems - irrigation pumps, space cooling for houses, offices and factories, and refrigeration.

198. It is believed that increased and improved inputs of energy in the country's production machinery are almost a precondition to improved economic and social status of Gambians. While it is not argued that solar energy can immediately replace conventional sources, it could on a long term basis be a viable alternative, especially as a solution to the desertification problem.

GHANA

199. A solar energy committee was recently set up under the aegis of the Council for Scientific and Industrial Research (CSIR), to co-ordinate direct solar applications. A few modern solar devices, such as solar heaters and dryers are now in varied stages of R and D at the universities and reaserch centres. Direct sunshine is also utilized for all kinds of drying processess, especially for agricultural products, meat and fish.

200. Solar refrigeration, water pumping and irrigation, by way of solar-powered thermal and photovoltaic systems, could assist on-going efforts to make clean water available and to improve agricultural productivity, especially in the northern and upper regions.

GUINEA

201. Little work on solar energy was done in the past. However, a National Centre for Heliophysics and Oceanography has now been created to initiate solar energy R and D, and the Polytechnic Institute of Conakry, under the aegis of the National Institute of Research and Documentation, has also launched a research programme in solar energy. The first phase of the programme, consisting of data collection on insolation, wind and waves, is already underway in Conakry and Kinton, with plans for extension to all the climatic regions of the country, The School of Sciences, at the Polytechnic Institute, has also produced a solar water-heater and dryer, which were tested over the past several months and were found to be satisfactory. The use of local materials and aluminium foil for the heaters is also being investigated. Encouraging results were obtained when the solar dryer was used for fish and other products like manioc, peanuts and tobacco leaves. Two other phases of the programme will be the installation of two 1.3 KW photovoltaic pumps and the introduction of digesters on a large scale.

IVORY COAST

202. The Ivory Coast National Centre for Scientific Research has not undertaken concrete work in the field of solar energy research and development to date. However work is being carried out at various levels:

(i) <u>The Boiké television complex</u>

Three television sets running on photocells have been experimented since 1975. Now, nearly 900 schools in rural areas use this system. The Government is planning to extend it to all rural villages which are not yet connected to the power network.

(ii) <u>The National University of Abidjan</u>

The Science Faculty of the Abidjan University has undertaken investigation and testing of solar air-conditioning devices. Through its staff assistance, an experimental station is being operated at Boundiali in northern Ivory-Coast: the Minister of Tourism's house is entirely air-conditioned and hot water supplied by an experimental solar water-heater. Other experiments are being carried out.

(iii) The Abidjan-Niger Railway Company (RAN)

A sizeable order has been placed with a private manufacturer for solar signalling stations to be planted all along the railway linking Abidjan with Ouagadougou. Installation work should start very shortly.

(iv) Ivory Coast Electrical Power (EECI)

The National Electrical Power Authority of Ivory Coast has established a Department in charge of investigating various utilizations of alternative energy sources. This department is destined to co-operate with all institutions in the country dealing with practical utilization of rnewable energy sources, and to work out a practical development programme.

203. The National Centre for Scientific Research is planning to establish through EECI a co-ordinating body that would cover all research and development activities in the field of renewable energy sources.

KENYA

204. The land mass of Kenya lies approximately 4.5 degrees north and south of the Equator and, as a result, much of the land receives solar radiation all year round. The Department of Physics and Meteorology of the University of Nairobi have been collecting radiation data in the past 15 to 20 years and have just released a solar map of the country. These data indicate insolation levels of 30-42 watts per square centimetre in some areas in the country. The Department of Physics and Engineering at the University of Nairobi have also been conducting basic research on materials which are locally available and would be suitable for fabrication of dryers, heaters and other solar devices. Solar water-heaters are being developed, manufactured and commercialized by five private firms in Kenya. Total sales of the heaters for 1978 were around 10,000 units, at prices ranging from 2000 to 5000 Kenya shillings for a unit with a collector surface area of 0.85 square metres. A proposal has been made to the government to legislate that a provision be made for solar water-heaters in all new buildings which are fitted to supply hot water. More efficient solar dryers are being developed by the Pyrethrum Board to Kenya for drying of pyrethrum flowers. These dryers could also be used for other crops like coffee, sisal, maize, tobacco and tea. In 1978, the Mechanical Engineering Department of the University of Nairobi fabricated a prototype of a German solar oven. This oven can attain a temperature of about 200 degrees Celsius. Work is also in progress on solar water-pumping, desalination, refrigeration and electric power generation by photovoltaic systems.

205. The solar pump unit installed at Wajir is the first of its kind in Kenya. In September 1975, the French Government offered to donate a water pump power by solar energy. In consultation with the (French) manufacturers of the pump and the French Embassy, the Ministry of Water Development selected Wajir as the site for the pump.

206. Installation and commissioning of the pump was completed by January 1978. The pump is being operated over Well No. 29, (more commonly known as "school well") near the Range Water compound in Wajir. The pump has a capacity of lifting 5 m3/hour against a head of 20 m. The solar collectors cover an area of about 90 sq.m. The collectors are made of aluminium plates covered by glass sheets. They provide the hot source by heating distilled water with anti-corrosive additive circulating through them. The well water is the cold source. Thermodynamic fluid is Freon.

207. The capital cost includes K.Shs. 340,000 (FF 200,000 CIF Mombasa) for the equipment donated by the French Government and K.Shs. 350,000 spent to accomplish civil and ancilliary works. The projected operating costs were anticipated to be of the order of K.Shs. 15 to 25 per day and obtain an average of 30 m3/day lifted from the well to the elevated service reservoir in the Range Water compound.

Mr. Paritosh C. Tyagi, Head of Design, Ministry of Water Development.

LESOTHO

208. Climatic observation is undertaken with 1 or 2 heliographs (Maseru, Roma University). Few pyranometers (no long term records), two or three anemometers (few long term records). Reasonable data are available on precipitation and temperature over the whole country.

209. Solar cooking fits into the Lesotho structure in many ways (climate is suitable, out-door cooking is common). However the main meals are taken morning and evening. Solar cooking combined with a "hay-box" could provide for the evening meal. Institutional solar cooking could be done any time. Many schools serve a midday soup. Again here a very simple and reliable back-up system is necessary even if it is a cowdung fire right under the solar cooker, (flat plate steam cooker, immobile).

210. Pumped water seldom needs treatment in Lesotho. Distillation of any water to H2O for batteries and medical purposes is necessary and will be done in the near future through the Ministry of Rural Development (Minrudev) solar workshop. The capacities will be very small, one to ten litres per day.

211. Drying of peaches is presently done on galvanised iron sheets (roofs). Solar dryers will be built and demonstrated by the Minrudev workshop to improve the quality of the products and reduce losses.

212. Water heating for domestic use is progressing. Several housing schemes have installed solar water heaters available on the local market. There are around 100 to 150 family-units installed, mostly on houses of teaching staff and civil servants. One group of approximately 30 units experienced problems in winter which were overcome by improvement of the piping. Nine units manufactured in Maseru in 1976 are in use. Their production was stopped because of "lack of capital".

213. This above mentioned production may soon re-start. If not it should definitely be assisted to this effect. Within the Minrudev solar programme a number of water heaters were tested. Two models proved suitable. One of them is being installed in five strategic places in the country. First results are encouraging. The installation of water heaters in hospitals is of high priority. Capital is scarce for this particular purpose. One hospital in the northern mountains has been equipped in 1969. This installation is still working.

214. A passive solar house scheme is in progress. Five demonstration models are to be built in the north of the country. On the basis of these five houses designs should be chosen and financially assisted to be multiplied all over the country.

215. Smallish experiments and small to medium commercial green houses are in operation, mostly in Maseru and in central mountain village. Commercial viability has been proven. Remote schools should be assisted to build attached greenhouses. This would serve several purposes:

(a) Heat the school which can not afford fuel even in sub-zero conditions.

(b) Grow fruit for either school kitchen or families.

(c) Assist horticulture and biology lessons.

(d) Condition the air of the class-rooms which is often stale when doors and windows are closed due to the cold.

216. Simple attached greenhouses for family quarters should be promoted with small capital assistance and a large educational programme.

217. While the winter in Lesotho is sunny the summer is frequently cloudy. Even light clouds can upset solar cooking. For this reason solar cookers must be integrated with another way of heating. The same applies for vegetable dryers. Three consecutive days of rain spoil a drying batch. Solar pumps should be complemented with wind-mills or designed in a way that an ordinary fire can take over the heating process.

LIBYA

218. In the Libyan Jamahiriya, the first solar-energy based device was installed in the Sidi Rhouma area in May 1973. It is a water-pump for irrigation purposes.

219. According to the Chairman of the "Djebel Akhdar" project executive committee, solar energy utilization is scheduled under this project as well as other agricultural projects in the country.

220. The Libyan Jamahiriya Government plans to set up a long-term programme of practical utilization of solar energy, particularly for irrigation and village and pastoral hydraulics. There is to date no research institution in this field in the country.

Activities are also being carried in the field of solar water distillation.

MADAGASCAR

221. Research is being currently carried out at the Antananarivo Polytechnic Institute on the practical use of solar water-heater.

222. However, it should be noted that an experimental solar wood-dryer has been in operation for some years at CTFT in Madagascar. Except in such countries as Columbia and Turkey, this technique is not publicized adequately.

223. In 1978 at the University of Antananarivo, has been established the University Delegation for New Energies with a task to collect and assess solar data, some programmes on flat plate collectors and dryers.

224. The New Energies Society, an affiliate of the National Electricity & water supply and the National Oil Company, has been established in 1979. Research and sales programmes are carried out in solar energy field.

225. The workshop of the Scientific and Technical Research Ministry constructed a solar water heater in 1980 with local materials. This apparatus is now being tested.

MALAWI

226. Preliminary analysis of available data on solar radiation shows that the solar energy potential in Malawi is enormous.

227. To fulfil the country's development programme the area of energy needs are many; the priority areas for solar energy are: boiling water, cooking food, pumping water for irrigation, drying fish, drying agricultural products, food preservation by refrigeration; use of thermo and/or photo-batteries for educational needs and operating radio receivers.

228. With limited resources research by the Staff of the University of Malawi has been undertaken in the following areas:

(a) Measurements of solar radiation using an Eppley precision radiation pyranometer. This will include spectral distribution of energy and also calculate mean daily total solar radiation.

(b) Design and construct radio receiver to be operated by solar cells and with auxilliary accumulators to be charged during the day and use at night.

(c) Design and fabricate low cost solar cooker and water and study the efficiency.

(d) Design, construct and operate a simple absorption refrigeration system. 1/

229. An evaluation of the contribution which solar energy can make to the rural development efforts of developing countries has been carried out. The work was motivated by the increasing awareness of the need for rural development schemes featuring an appropriate technology and where small-scale, rural based industrialization complements other development effort, such as improved agricultural output, etc.

230. The investigation which has been carried out includes:

(1) the evaluation of some specific areas of rural development projects where solar energy could be applicable and where its utilization would further its acceptance as an aid to development;

(2) the identification of low-cost solar energy devices applicable to rural areas and suitable for local manufacture;

(3) the assessment of factors relevant to the implementation of solar energy in rural areas, such as socio-economic considerations, technical appropriateness, development strategy and the national international co-operation required.

1/ Prof. A.K. Som, Physics Department, University of Malawi, Zomba.

231. The priorities of solar energy implementation geared to specific applied technology objectives in rural development programmes include:

Food production, preservation and processing;
rural industrialization and small-scale power system
improvement of health and other facilities.

232. The assessment of the above areas shows that solar energy by itself or complemented by other small-scale energy source(s) - wind, hydro, methane gas can make a considerable contribution to an integrated rural development programme.

233. The necessity of national backing and the international co-operation required to develop and encourage a strategy for the implementation of solar energy in rural development programmes of developing countries. 1/

MAURITANIA

234. The lack of economic development of the rural sector, which represent 95 percent of the population., and the ecological imbalance due to the geographical position of the country are causing migration to the urban centres. Solar energy development and application would make life more bearable for the rural people. The greatest needs which solar energy technologies could help satisfy involve provision of adequate fresh water, water heating, sanitary facilities and the efficient drying of agricultural products.

235. A one-kilowatt solar pump, a Rankine thermodynamic system with a capacity of 50 cubic metres per day, has been installed at Chinguetti with a second bore-hole system to be installed at Butileme, which will produce 400 cubic metres per day. A 12 KW pump, financed by a grant of $500,000 from the European Development Fund, has also been installed to provide irrigation for a rice field of 22 hectares, located along the Senegal River. This pump will have a capacity of 200 cubic metres per day. It has also been installed a one peak-kilowatt photovoltaic-powered pump with a capacity of 25-30 cubic metres per day. Finally, solar stills are being studied to help to solve the water supply problem of the rural population living on the sea coast. This project is financed by the United Nations Development Programme with feasibility studies done by Tom Lawand of the Brace Research Institute of McGill University, Canada.

1/ Dr. W.K. Kennedy, University of Malawi, the Polytechnic, Chichiri, Blantyre.

236. Mauritania is considering the creation of solar research institute to train personnel, test equipment, monitor the performance of field test units, investigate the use of local materials in the development of prototypes and conduct studies on the impact of new technologies.

MAURITIUS

237. An investigation programme into the practical application of alternative sources of energy is under consideration, be it solar, wind or shore; the main ones are firstly, Mauritius, by virtue of its favourable geographical location is in a position to capitalise on an abundant and free source of energy; mean annual solar radiation averages about 1,700Kwh/m2, and secondly implementation of a programme based on alternative source of energy will lead to a significant reduction on dependence of imported fuel.

238. Concerning direct applications of solar energy, water-heaters are in use in a few houses and hospitals. These heaters are licensed by Australian manufacturers. It is also investigated the use of small solar stills to produce distilled water for car batteries.

MOROCCO

239. Morocco is engaged in implementing a number of research and development projects, particularly on solar water heating, active and passive heating of buildings, solar water distillation, solar drying, greenhouses, and solar water pumping.

NIGERIA

240. At present, a number of groups of scientists in Nigeria are engaged in research of the practical use of solar energy although the resources at their disposal are still limited. In this connexion, the Universities of Lagos, Nsukka, Ibadan and Zaria have carried out some research in different fields involving experiments, design and cost evaluation of some solar devices.

241. In the University of Nsukka work has been carried out on the use of solar energy for cooling. Experiments are carried out in which a flat plate collector and a paraboloidal cylindrical concentrator are used for the "Solar Energy Harvest". Water is the energy absorbing fluid and the heated water is circulated by regulated thermosyphon action to a lagged collector enclosing the generator of "Type 27A1 Production No. 9230271 - Domestic Electrolux Absorption Refrigeration Unit". Thermal energy from the sun then replaces the kerosene burning process in such systems. Acqua-ammonia is the primary generator binary mixture and results obtained show that with collector areas of close to 2.0 m2, the maximum generator temperature is about 80°C and the maximum cooling in the evaporator only about 14°C below the ambient temperature of around 33°C.

242. In the University of Lagos, research and development are undertaken in the fields of solar water heating and solar distillation. The University of Zaria is testing a solar water pump of the Guinard 500 type using solar cells.

243. A Federal Agency "The National Science and Technology Development Agency" (NSTDA) has been created with a responsibility to find and initiate research and development of alternative energy technologies including solar.

SIERRA LEONE

244. Some research activities undertaken at the former Fourah Bey College, now the Sierra Leone National University in Freetown, bore on solar energy utilization for water heating and refrigeration. This has been discontinued since present activities in the field of solar energy utilization are practically insignificant.

245. One locally manufactured solar water heating was installed on the roof of the Science Faculty several years ago. This devices supplies hot water to the campus; however features and performance data are unknown.

SOMALIA

246. The Somali Government was planning to construct one large solar distiller with 2,000 m2 surface area at Khuda, with a view to supplying a fishing community with drinking water. The project was scheduled for 1978-79 with UNICEF assistance. The Somali Government's committment was expressed in a series of requests forwarded to UNICEF in 1976 for the finalization of the Khuda distiller project, to UNESCO for the working out of a solar energy utilization development project and, in 1978, to Italy for integrated projects on solar, wind and biogas energy utilization. A request to the same effect has been submitted to UNECA.

SWAZILAND

247. The Swaziland College of Technology in M'Babane is carrying out tests on solar water heating with a view to supplying all the required hot water to a hotel scheduled for construction for the Hotel training Centre located in the vicinity of the College.

248. Other experiments are undertaken with a view to extending the use of solar water heaters and other uses of solar energy to the whole country.

TANZANIA

249. The National Scientific Research Council of Tanzania has carried out a series of research investigations and studies for utilizing solar, wind and biogas energy involving location of prototypes, economic evaluation and population acceptability.

250. The activities are undertaken by some teachers and students of the National University under the supervision of the Tanzania National Scientific Research Council. Different investigations were made regarding the performance and improvement of:

- solar cookers of the Vita type,
- some windpowers generators, and
- biogas small scale equipment.

251. In the field of research and development of solar, wind and biogas energy, the Tanzanian Government is working in collaboration with the Federal Republic of Germany, the United States of America, some private donors and international organizations like UNIDO.

252. Under the sponsorship of the Tanzania National Scientific Research Council and the Board on Science and Technology for International Development of the United States National Academy of Sciences, a workshop on solar energy for the villages of Tanzania was held in Dar es Salaam in August 1977.

253. In recognition of the serious situation facing the country in the energy sector, work is in progress on the research, development and field-test of a number of solar devices. Solar stills have been tested in the laboratory in Dar es Salaam. The cost of distilled water by this process was found to be 20 per cent of the current commercial price. A solar cooker was tested in 1977 and 1978 and it was found to be adequate to cook certain Tanzanian dishes like Ugali (maize or cassava stiff porridge). Phillips Electronics of Holland has donated a photovoltaic water pumping system to Tanzania which will soon be installed for testing.

254. The installation of a solar water pump of the SOFRETES MS-7 type is expected soon for rural water supply. In the late 1977 a Solar Energy Promotion Committee was established.

TOGO

255. With over 700 watts per square metre average insolation, direct solar applications appear possible. Work is currently in progress at the University of Benin, Lome, to gather data on solar insolation, wind-regimes, humidities and temperature variations. Development work is also being done on flat-plate collectors. Laboratory studies on solar refrigeration, and the study of solar drying of agricultural products are being undertaken.

ZAIRE

256. At the present solar energy experimentation stage Zaire wishes to be assisted so as to find solutions to the following problems:

(i) solar energy utilization for power generation to run low capacity telecommunication equipment;

(ii) Power supply to rural areas, especially to public institutions;

(iii) Public water pumping installations in rural areas.

257. Ten television sets run by photocells are already in operation in Zaire and a television network was installed in 1975: the Mbanza-Ngugu receives the Kinshasa telecasts and relays them to the N'Kela station which in turn relays them to the Kongo station which covers a whole region. Transmitters and relay stations are entirely run on photocells.

ZAMBIA

258. Reliable solar radiation data are not readily available. However, there are calculated data on the intensity of solar radiation and also other meteorological data which were observed in Zambia over the last 30 years.

259. Certain research and development work is being carried out on the utilization of solar energy for such processess as water heating, air-heating and solar drying, distillation of brackish and sea water, refrigeration and air conditioning based on solar energy conversion into mechanical and electrical energy. Such applications as solar water drying of agricultural produce and other materials, solar cooling and heating of buildings, solar power systems based on heat engines, refrigeration for food preservation, etc., are very much in experimental stages.

260. Solar devices for water heating, air heating, refrigeration and energy conversion with a hot air engine, were developed in the school of Engineering of the University of Zambia. Further fields of research and development of solar plants are under consideration.

IV. MAJOR CONSTRAINTS LIMITING THE DEVELOPMENT AND USE OF SOLAR ENERGY IN AFRICA AND MEASURES AND ACTIONS SUGGESTED TO OVERCOME THEM

CONSTRAINTS	MEASURES AND ACTIONS
261. Lack of adequate information for decision makers	-Elaboration of consise and clear documentation on solar energy, covering technical, economic and social aspects of its development and utilization.
262. Lack of basic data on solar energy characteristics	-Establishment of a network of modern solar radiation measurement stations for assessment of solar energy potential taking into account possible utilization of existing meteorological stations and international specialized centres (inventory of solar energy potential).
263. Lack of information flow between scientists, engineers and technicians involved in solar energy activities in Africa.	-Periodical organization of study tours, workshops, seminars, and exhibitions of solar energy equipment; establishment of institutions at all levels and encouragement of those established.
264. Social constraints related to tradition and habits of African rural population in satisfying its energy needs	-Carrying out studies on social and economic impacts of solar energy utilization in rural areas; popularization of solar equipment and its utilization through demonstration centres, itinerant exhibitions, lectures and initiation ofrural population in using the equipment.
265. Financial constraints related to high cost of equipment and its installation	-Government's participation in granting preferential tarrifs for equipment acquisition; revision of financial practices related to investment in solar energy equipment; government's support for R & D programmes.

266. Prohibitive costs of imported materials	-Increased use of locally available materials and expansion of local manufacturing of solar equipment
267. Lack or weakness of R & D programmes for solar energy utilization in Africa	-Concentration of efforts and elaboration of R & D programmes at national level and co-operation with subregional, regional and global specialized institutions; co-ordination of the existing R & D programmes with a view to avoid duplication and/or useless competition.
268. Lack of qualified manpower	-Increase of scholarships number for training of personnel at all levels; introduction of courses on solar energy in high school and Universities curricula; organization of on-the-job training; initiation of short-term specialized post-graduate training sessions.
269. Hazardous character of solar energy	-Increasing efforts to find out reliable storage methods and utilization, where it is possible of integrated energy system.
270. Transportation of materials used for solar energy equipment from one country to another in Africa	-Improvement of packing methods and of transportation conditions; initiation of local production of equipment elements in co-operation with national industrial sectors
271. Natural inhibition to invest in solar energy	-Testing by standardized procedures of solar equipment before launching it on the market; undertaking of demonstration programmes with a view to convince the consumers on reliability and effeciency of solar equipment.
272. Lack of national energy policies related to the availability of local resources, demand and its likely growth	-Elaboration of national energy integration of solar energy within national energy programmes; initiation of co-operation with world wide specialized institutions for an eventual international assistance.

V. SUGGESTIONS FOR A PROGRAMME OF ACTION POLICIES AND PRIORITIES FOR DEVELOPMENT AND UTILIZATION OF SOLAR ENERGY IN AFRICA

273. Effective and rational exploitation of solar energy by African countries necessarily presupposes the following action:

- The formulation and implementation of a concerted global energy policy in its various aspects at the national, subregional and regional levels, with attention being paid to the specific conditions in the individual countries;
- The rational organization and the conducting of Research and Development through programmes in which account is taken of national priorities based on findings pertaining to the sectoral contribution of solar energy to the solution of problems relating to energy in particular and to economic development in general;
- The establishment of agencies or institutions at the national, subregional and regional levels for the purpose of designing, carrying out and monitoring the execution of Research and Development programmes in the field of solar energy (Regional Subregional and National Energy Centres);
- The establishment of a network of solar radiation observatories and measuring stations adapted to the demands of the new techniques for exploiting solar energy, including the centralization of findings and the formulation of complete measuring programme, with account being taken of the possibilities of using existing meteorological stations for the collection of data on the radiation regime of inclined surfaces, the measurement of direct and diffuse radiation and the carrying out of spectral analyses, the measuring of albedo and the like with appropriate apparatus;
- The promotion of local industries in the building, metal-working, glass-making, mechanical and electrical engineering and other sectors, with the aim of putting into practice and vulgarizing the results obtained by such industries all along with the development of solar devices which might be produced industrially.
- The promotion of co-operation on as broad a base as possible with foreign agencies and institutions concerned with Research and Development in the field of solar energy and in the mass production of solar apparatus and facilities;
- The training of the necessary research workers and technical personnel, possibly including advanced training or retraining courses;

-Making government authorities and people aware of the enormous possibilities of solar energy potential and the value of practical applications already available through a large-scale campaign to demonstrate and popularize prototypes already produced in Africa and other parts of the world, by promoting their use and mass industrial production in situ with a view to increasing their economic viability and improving their performance; etc. (Demonstration Centres, Seminars, Conferences).

274. Solar energy offers new possibilities which merit the making of substantial efforts aimed at generalizing the use of its various application. Programmes covering all aspects of their rapid promotion should be initiated right away at the national, subregional and regional levels with the help of ECA, UNESCO, UNEP, and other United Nations bodies.

275. The order of priorities for basic action as recommended by previous ECA meetings is as follows:

(i) Increased knowledge of solar potential through improved and more extensive measurement and monitoring (inventory).

(ii) Problems related to water

(a) Pumping
(b) Distillation
(c) Irrigation

(iii) Solar heating

(a) Heating of air and water
(b) Solar cookers
(c) Solar kilns
(d) Green houses

(iv) Preservation of products

(a) Drying
(b) Refrigeration

(v) Production of electricity

(a) Rural electrification
(b) Telecommunications
(c) Air-conditioning

(vi) Integrated use of solar, wind and biomethane energy for rural areas.

276. The basic action outlined above should be strengthened by parallel action in the following order of priority:

(i) Training of research workers, engineers, technicians and support staff

(ii) Information

(a) Creation of structures for the promotion of co-operation among research workers and countries

(b) Measures to make government authorities and the general public aware of advances in the field of solar energy and related energies

(c) Exchange of ideas and expertise

(iii) Industrialization and extension

(a) Use of local materials

(b) Transfer of technology

(c) Regional co-operation in the establishment of indigenous industry and in the standardisation of equipment

(iv) Integration of research-development in industrial and social matters.

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