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SUMMARY REVIEW OF ACTIVITIES AND ACCOMPLISHMENTS IN THE USE OF SOLAR ENERGY IN AFRICA

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SUMMARY REVIEW OF ACTIVITIES AND ACCOMPLISHMENTS IN THE USE OF SOLAR ENERGY IN AFRICA

1. Since early in the 1960s, 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 apparatus, such as water heaters, dryers, stills, cookers, refrigeration facilities and low-power solar engines for supplying water to grasslands and villages. Some of the techniques developed have already made it possible to start popularizing their use, and it is now possible to bring them to the semi-industrial or industrial stage.

ALGERIA

2. The National Board for Scientific Research has been carrying out research development activities on solar energy for several years, in collaboration with the French CNRS (Centre National de la Recherche Scientifique).

3. The universities of Constantine & Oran are engaged in research involving photoelectric conversion of solar radiation and thermo-mechanical conversion possibilities for irrigation and water pumping. Several models of SOFRETES type solar pumps have been ordered by the Algerian Government, with capacities from 1 to 5 kilowatts, mainly for use in large scale irrigation. Solar energy research and development programmes seem to have been worked out by universities and other institutions, such as the National Centre for Arid Zones in Beni-Abbes. Besides, the United Nations University is carrying out an integrated project on the use of solar, wind and biogas energies in Ouargla.

BURUNDI

4. No concrete work has been undertaken in the country as yet in the field of research and development of solar, wind and biogas energies. 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.

5. Recommendations include mainly:

- to set up pilot projects involving solar, wind and biogas energies, investigate operation and maintenance aspects and carry out an economic evaluation;
- to mobilize the people through demonstration programmes especially in schools;

- to establish, under favourable conditions, a national organization for tapping renewable energy sources;

- to co-operate with neighbouring countries or with other African countries which have some experience in the utilization of such energy sources;

- to improve solar and wind energy data gathering systems.

6. 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

7. 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.

8. There are, at this stage, national institutions which could undertake research and development activities. Beside the Ministry of Energy, there is a National Board for Scientific and Technical Research, under which 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 400wh/day.

9. 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) Assessment of needs:

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 stydy 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 constraints; to investigate construction of a biogas digestor;

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

10. 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.

11. Regarding existing operational devices, it should be noted that a SOFRETES type water-pump was planted at Makary in 1976. With a 70 sq.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

12. 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.

13. The Mindelo Shipyard manufactures Dampster type windmills and sells them. A 1.80 m. diameter unit costs about 700 US$.

14. About 60 windmills with diameters from 1.80 to 2.40 m have been installed by land-owners for irrigation purposes at Ribeira de Meirao and Vinha on Sao Vicente Island. These devices are working to satisfaction and are to be credited for horticultural development.

15. A SOFRETES water pump was also being assembled at Saint Domingos.

16. On Passaros Island, an Aerowatt 24 FP 7 type air-generator is being installed for the nautical marker-light. Similarly at Ponta Manyrade, an Aerowatt 300 FP 7 type air-generator is being installed for a light-house.

CHAD

17. 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 ought to 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.

18. Under the "CILSS" and "Sahel Alternative Energy" programmes, more installations ought to be commissioned before the end of 1978.

19. 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

20. 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.

21. 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.

22. 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.

23. 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).

24. More particularly, the study of the comportment of flat captors is undertaken simultaneously in Brazzaville, and in the kinetic and electro-chemical 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).

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

DJIBOUTI

26. 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.

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

EGYPT

28. A research programme was established in solar energy utilization in 1957, which includes fields of solar water heating, water distillation, solar energy concentration for power generations, solar cooling, cooking and recently thermo-electric generators and hydrogen production.

29. Different investigations were made regarding the performance and improvement of solar water heaters. It was dealt also with study and evaluation of selective coatings, dust precipitation effect, concave covers, optimization of flow rates and tilt angles. Finally, an economic investigation was made based on national needs for hot water, the available technology and prices.

30. Since 1957, the solar energy laboratory of the national research Centre at Dokki, Cairo has carried out a series of investigations and studies for utilizing the solar energy in different fields involving both engineering and economic evaluations. The ultimate aim of the programme is to find the suitable solar system which can cope with the existing energy sources as well as to save fossil fuel and minimize the effect of atmospheric pollution.

31. The programme was started with the thermal utilization of solar energy in different domains including solar water heating for domestic purposes, water desalination, refrigeration, cooking and power generation.

(i) Solar Water Heating Reliability and Economy

32. About 75 per cent of dwelling energy needs are for heating purposes, specially water heating. Thus investigating the possibility of solar water heating has taken the first priority in the research programme. Different investigations were made regarding the performance of solar water heaters of different designs.

33. Finally an economic investigation of solar water heating has been made involving the average actual consumption rates of an Egyptian family. According to Egyptian solar conditions, it was found that a solar heater of "2 m2" area is sufficient to provide a family of 5 persons with all their hot water needs (about 160 litres/day at an average temperature of 50 - 55°C).

34. The economic analysis was based on comparison of solar heating costs to that of three other methods. It was found that solar heating was the cheapest method between kerosene, butane gas and electrical water heating.

35. As for distillation, the programme included investigations of the performance and productivity of green house stills, as well as some improved designs for affecting both evaporation and condensation loops.

(ii) Solar Water Desalination

36. The laboratory began in this subject in 1958. More effort has been made in the research and development of this subject due to the fact that a large area of Egypt suffers from shortage of fresh water. The research started using a simple green house distiller. Developments to increase productivity occurred analysing the parameters affecting the coefficient of effectiveness. The distillation process is a complex one, it consists of an evaporation process and a condensation process. The two processes are improved simultaneously in the double chamber still. The process of evaporation is increased due to the increase in the amount of solar energy penetrating through the cover as the possibility of condensation on the cover is reduced. The process of condensation is improved due to the presence of fresh water in the condenser which acts as a vapour trap and by the effect of cooling caused by insulating the sun rays from reaching the condenser.

37. The process of evaporation could also be improved if the saline water temperature is increased. It is well known that the rate of evaporation is a function of water temperature. The improvement could be obtained if the surface of the evaporator were oriented to receive a greater amount of energy. To achieve this double exposure solar still was made and an increase of 8 per cent has been obtained.

38. Economic investigation of the green house type solar water distillation has been carried out. The total cost increases with the increase of the capacity of the still. However, the specific cost (cost per cubic meter) decreases with the increase of the capacity of the still, then increases suddenly and decreases again in a sawtooth manner. This is attributed to the addition of the operation cost.

39. In 1976 a programme of economic investigation and evaluation has been carried out on the above mentioned designs. Each still will have an area of 30 m2. The aim of our investigation is to find out the following:

- Simplicity in fabrication
- Possibility of using materials around the site of the still

- Cost of production
- Durability, maintenance, and repair, etc.
- Coefficient of effectiveness (CDE)
- The period needed for this programme (2-3 years)

(iii) Solar Refrigeration

40. An investigation was made for utilizing solar energy for cooling. Factors affecting the operation of an absorption refrigerator by solar energy were studied. A co-operative project with the Federal Republic of Germany is now being conducted on solar vegetable cold storage.

41. An absorption system of amonia water solution is a household refrigerator of 4 ft3 run by butane gas and is operated by solar energy. A solar energy heating loop is made to run the refrigerator by glycerine as the heat fluid carrier. Its boiling point at atmospheric pressure is 186°C while the working temperature of such a refrigerator is 120°C.

(iv) Power Generation

42. The programme of power generation started in 1963 with calorimetric investigations of a parabola-cylinder concentrator built of plane segment mirrors. It has been extended since 1975 through a grant of the NSF/USA for power generation using a thermodynamic cycle. Solar thermoelectrical generators and solar cells are under current investigations.

43. A model of a parabola-cylinder 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 focal energy distribution. It is found that it follows the same pattern as if it was made of one piece. The maximum temperature in the focus was about 400°C.

44. A joint project between the New Mexico State University and Egyptian Solar Energy Laboratory is to generate electricity through the Rankine cycle using 5 m2 collector for generating steam to operate a steam turbine. The concentrator is built on the same principle.

(v) Solar Cooking

45. An elliptical paraboloid solar cooker is constructed from aluminium strips. Its diameter is 1.5 m. The position of the focus must be in a horizontal plane to overcome the difficulty arising from handling the pot. The configuration of the present solar cooker has given us the previous advantage. The results of investigation showed that:

- two litres of water at 20°C need 20 minutes to boil
- cooking for 5 persons a meal consisting of vegetables, rice and kabab takes about 2 hours from 11 o'clock. 1/

1/ Mr. Ibrahim Ahmed Sakr, Head, Solar Energy Laboratory, National Research Centre, Dokki, Cairo.

46. At the present time, research and development in Egypt are oriented towards the industrialization of solar equipment as well as research activities. Some fundamental studies are undertaken on heat transfer, selective coating, dust precipitation and solar measurements.

47. The programme for the next coming year will be concentrated to a wider range of research and development activities as: water solar heating, water desalination, solar distillation, solar dryers, biogas, wind power for small scale electricity production and mechanical uses, solar cells, solar pumps (thermodynamics and photovoltaics), use of biomass by direct combustion, solar refrigeration, Actually some solar equipments are available in the market such as solar heaters, solar stills, solar dryers, small capacity wind power generators and the production of solar and wind pumps, solar cells, etc. is expected in the near future.

ETHIOPIA

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

(1) Direct use of Solar Energy

(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.

(2) Wind Energy

(a) For irrigation and water pumping;

(b) For mechanical drive;

(c) For flour mills and for application in other agricultural tasks.

(3) Biogas: Plants and Pyrolisis

(a) Supply of methane gas to rural areas for cooking, for lighting and for some mechanical tasks;

(b) Improvement of charcoal production efficiency through pyrolisis - to supply charcoal, alcohol fuels, charges;

(c) Improvement and development of appliances for using more efficiently above fuel products.

(iv) Wood

(a) Energy plantation - (fast growing tree species);

(b) Improved forest management techniques;

(c) Improved appliances for burning wood.

49. The use of microbiological conversion of plant materials to produce fuel presents too many constraints at this stage of the country's development, but Ethiopia would be interested in setting up two or three experimental plants within a period of five to ten years to explore the suitability of various local materials, to investigate the microbiology and physical chemistry of the fermentation systems, and to examine recovery operations and equipment in our context.

50. The development of small hydroelectric plants for electricity generation or, in particular cases, for mechanical drives.

51. Except for hydroelectric power and geothermal energy, Ethiopia does not yet have other proven sources of energy. Hence the development of the above-mentioned renewable energy sources can have revolutionary effects on its various development stages.

52. A limited programme of development has already started in Ethiopia in this area with the setting up of about 4 biogas experimental plants, the setting up of a number of windmills, and in the very near future the proposed acquisition of two solar pumping sets on aid basis. A very interesting solar cooker prototype was produced by an individual concerned.

53. In order to reduce further damage to the environment, to increase the productivity of the rural inhabitants and improve the quality of their life, to reduce dependence on foreign oil and lessen the drain on the foreign exchange earnings of the nation, it is necessary to look for alternative renewable energy sources at the economic and technical level of the country which can be developed with local materials and skills, and with the minimum financial strain on the nation.

54. Solar Energy, has been recognized - a priori - to partly satisfy the above requirements. 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.

55. 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

56. 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.

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

GAMBIA

58. No concrete activities have as yet been undertaken in the country in the field of research and development of solar energy. However the Gambian authorities would welcome the help of Sahelian countries which have gained experience in designing prototypes suited to the need of the country.

59. A first step would be to import solar water-heaters, solar dryers, distillers and windmills and to install them in an adequately equipped national workshop, which would be in charge of installation and maintenance. The second step would involve establishing a national applied research Centre that would tackle such burning issues as:

- water-pumping
- solar drying
- distillation
- refrigeration
- solar cooking, and
- air-conditioning.

60. Governmental authorities hope that some solar or wind water-pumping plants will be installed within the framework of the "Inter-State Rehabilitation Commission for drought-affected areas in the Sahel" (CILSS) and the "Sahel Alternative Energy" projects.

1/ Dr. Ing. Ghebru Woldeghiorghis, Executive Secretary, Electrical Engineer, Ethiopian National Energy Committee, (comments), in the Seminar on Solar Energy in Nairobi (Kenya), September 1978.

IVORY COAST

61. 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) The Boiké television complex

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) The National University of Abidjan

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 have 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 renewable energy sources, and to work out a practical development programme.

62. 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

63. At the moment, solar energy research and development in Kenya is uncoordinated and depends, to a large extent, on the interest of the individuals concerned. The only exceptions to this are the collaborative efforts on the solar oven (between the Government of the Federal Republic of Germany and Kenya), and solar water projects (between the French and Kenya Governments). The Kenya Government has, therefore, put forward proposals to a donor country for the establishment of the Centre for Energy Research and Development, to be located at the University of Nairobi. It is anticipated that negotiations for this Centre will commence towards the end of September, 1978. 1/

1/ Mr. S.J.N. Njoroge, Kenya Meteorological Department, Principal Meteorologist.

64. 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.

65. 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. Thermo-dynamic fluid is Freon.

66. 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.1/

67. In making an attempt to draw up a priority list of solar energy projects one is guided by the theme of Kenya's next Development Plan for the period 1979-83, which is: "Alleviation of poverty through the provision of basic needs." In energy terms, therefore, priority should be given to the provision of the needs of the population, particularly in the rural areas where 90 per cent of the Kenya population lives. In considering these needs, the following priority list is drawn:

(a) Cooking: Wood and charcoal are by far the most common cooking fuels in Kenya and yet the gazetted forested area in the country is only 3 per cent of the total land mass as compared to the global average of approximately 10 per cent. It is imperative, therefore, that supplementary fuels be found for use. Some examples of these are:

(i) Solar cookers for the more sunny and arid areas in Kenya;

(ii) Biogas units for the more agriculturally productive areas where animal and vegetable wastes are more abundant;

(iii) Solid Wastes such as coffee husks, sawdust, etc., which can be carbonised to produce briquettes;

(iv) Power Alcohol, which will be produced from sugar molasses at the proposed factory in Kisumu (and other future ones).

(b) Water Supply: Water is a basic and essential requirement for life. In recognition of this, the Kenya Government has made an undertaking to supply

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

clean piped water to every household in Kenya by the year 2000. The contributions which solar energy can make in this area are twofold:

(i) solar pumping of water

(ii) solar desalination of brakish water.

In addition, the potential of wind energy for water pumping should not be overlooked.

(c) Food Preservation: Kenya is an agricultural country which produces enough food for her population and for export. In order to enhance the quality of some of these agricultural products and preserve them over longer periods of time, it would be very useful if solar refrigerators were developed for use in the rural areas. Two examples of their use come to mind: First, use of solar refrigerators in butcheries in the rural areas, thereby preserving meat for more than the current two to three days. Secondly, a fishing community like the one which has been established through Government funds on the shores of Lake Turkana could be enabled to preserve and sell their fresh fish, rather than continue being forced by circumstances to dry their fish, thereby realising much less income than they would otherwise.

(d) Power (Electrical and/or Mechanical) for small scale industry in the rural areas, including the processing of agricultural products.

(e) Lighting of rural homes, which at the moment are lighted by kerosene lamps.

68. Presently in Kenya, for instance, a network of 25 stations with four measurement equipment for integrated radiation and 25 instruments for recording sunshine duration are operated. The efficiency of remote stations could be improved by installation of small electric power generators (solar cells). The usefulness of providing spectrally resolved radiation data has been considered but no continuous records of spectral distribution, especially for diffused light is envisaged, since no appropriate instrumentation is presently available.

69. Wind measurements in an extended scale and in correlation with radiation data should be included in view of optimizing operating conditions for windmills which are considred as playing an increasing role in energy supply for rural areas.

70. It should, however, be mentioned that a detailed study on the intensity of solar radiation and study on the distribution of possibilities and potential offered by photosynthesis have been prepared by the Department of Meteorology at the University of Nairobi in Kenya.

71. For a number of years a private entrepreneur has been manufacturing solar water heaters at Fort Ternan and has installed them in a number of private dwellings there. Unfortunately a shortage of finances, which is related to

the limited market and a failure to sensitize the population, has significantly restricted the scope of this undertaking. Two private firms are manufacturing solar water heaters in Nairobi. Apparently the "Tunnel Company" began its production since 1955 and the "Instrumentation Limited" since 1975-76, the latter under an Australian licence.

LESOTHO

72. 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.

73. 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).

74. Water pumping is commonly done with fan type wind-mills. Lack of wind is a problem during dry winter months. About hundred mills are now installed. A solar driven mechanism (Minto-Wheel, photovoltaic cells) would be valuable supplement.

75. Pumped water seldom needs treatment in Lesotho. Distillation of any water to H_2O 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.

76. 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.

77. 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".

78. 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.

79. Industrial water heating is presently of little importance. Preheaters may become viable for industrial processing.

80. Electricity for radio is of high priority. N.B.: Radios can not be run on candles or kerosine etc., they rely completely on electricity. Small wind generators and solar cells would do a good service to recharge accumulators on a small enterprise basis.

81. Missions and government offices communicate with radio. Battery charges are usgently required which need no maintenance at all.

82. Central power can be generated by Hydro-electric plants. Several sites are suitable, one is intended for construction. It should produce in excess of Lesotho's needs.

83. Power for workshops etc., is seldom required. Presently most workshops concentrate in the district centres where electricity is available.

84. Large cooling is seldom required. Small cooling is necessary in clinics, shops and hospitals for vaccine, dairy products etc., revival of the "fire-ice" or "Icy-ball" cooling could help a lot.

85. 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.

86. 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 all doors and windows are closed due to the cold.

87. Simple attached greenhouses for family quarters should be promoted with small capital assistance and a large educational programme. N.B.: A hospital report has listed respiratory problems as the most frequent, excluding tuberculosis. Part of this is common-cold, much is due to the smoke with which the people live throughout the winter, heating the houses with an open fire.

88. 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.

89. The Biomass potential is important:

- Solid waste is used mostly in rural areas (maize crops and stalkes for fire). A fair amount of energy could be derived from urban household waste (Maseru) presently unused.

- No tangible composing has been done so far (Privately a little and presently no biogas plant of any size is in operation. A sewage plant is in construction which will use the digestion method for slurry. A composting plant for solid waste together with the digested slurry which produce a highly valuable soil conditioner.

90. The traditional cowdungfire could be improved or eliminated with small digestives. Maintenance and finance are difficulties.

91. Aforestation should be intensified and secured with educational programmes. There is a certain possibility to grown algae in water ponds used for sewage stabilization. The raising of fish is being tried, in secondary sewage ponds. 1/

LIBYA

92. In the Libyan Jamahiriya, the first solar-energy based device was installed in the Sidi Rhouma area in May 1978. It is a water-pump for irrigation purposes.

93. 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.

94. 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.

MADAGASCAR

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

96. 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.

1/ Mr. W. Suremann, Ministry of Rural Development, Electrical Engineer, in "Solar Energy Seminar", Kenya, September 1978.

MALAWI

97. While Malawi has excellent hydro-energy potential, she has hardly any fossil fuel, no oil and other cheap energy sources like firewood are being fast depleted.

98. Following the global activities in solar energy research and in particular, the UNESCO International Congress on the theme "The Sun in the Service of Mankind", Paris, 1973, a fairly widespread discussion has emerged during the last year's Annual Meeting of the Association for the Advancement of Science of Malawi on the possibility of utilizing solar energy as an additional source of energy in view of its endless supply, non-polluting character and marginal need for distribution. Discussion centred around the technologies available elsewhere which can be adapted locally to suit local conditions and develop indigenous technology.

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

100. 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 photobatteries for educational needs and operating radio receivers.

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

(a) Measurement 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/

102. 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.

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

103. 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.

104. 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.

105. 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.

106. 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/

MALI 2/

107. The Mali National Solar Energy Laboratory in Bamako, established in 1964, is the main national institution involved in solar energy research. However, it took five years before a workshop was equiped with the necessary mechanical equipment and a few laboratory devices. In 1969, the date when effective work began, the staff consisted of the department head and one other employee. Now there are approximately 30 employees, all Malians, working in four sections. They include five senior research executives, one senior administrative executive, three technicians, foremen and so on.

108. Activities are concentrated mainly on the study of the means of using solar radiation without prior conversion. In this respect Mali can now be considered as having a certain degree of experience in the following five fields.

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

2/ Extracted from 'Development and use of solar energy in Mali' by Cheichnéi Traore, Ingénieur, Directeur du Laboratoire de l'Energie solaires.

(i) Water heating

109. Models of water heaters, well adapted to the national requirements and climatic conditions have been perfected.

(ii) Domestic water heating

110. After three years of research and experimentation a programme was undertaken to draw to the attention of the authorities and the general population our activities. This was achieved by opening our tests and measurements site to all interested and by demonstrating at exhibitions in Bamako and other places in Mali, working models which have been perfected.

111. Since 1972 funds have been obtained to manufacture almost 300 water heaters and more than 200 of these are already or will be installed either in hospitals, maternity wards, hotels private lodgings or administrative offices all over the country. Some of these water heaters were installed in homes of the members of the CMLM (Comité militaire de libération nationale) of the Government and other high rank officials with the aim to diminish the amount of electricity utilized by the Government itself. In this manner the recognition or agreement by the Government of the positive role which the use of solar energy is already playing in the social and economic development of our country is being sought. Among other users of water heating equipment are: maternity wards of Mopti and Sévaré (200 litres each), Markala (400 litres), and particularly Bamako where a 2,000 litre capacity heater is operating at Hospital "du Point G", and another at "Gabriel Touré", 2,000 litre capacity heaters are also installed at "Hamdall-Laye" maternity ward and at "l'Hôtel du Rail".

112. Although this aspect of the programme has been fairly successful it would have enjoyed greater success had it been supported by a publicity campaign. Such support is now possible as an industrial and commercial structure has been created which will collaborate with the Laboratory in commercializing water heaters and other solar equipment. This structure called "Fonds-Energie-Solaire" is now supplying local orders and export orders as well. Upper-Volta, for example, has ordered several dozen water heaters. It has also offered to build a distilling unit of brick to produce 500 litres of distilled water per day. Under these circumstances there is no doubt that Mali will soon stop importing electric water heaters and will stop or diminish the use of wood or charcoal to heat water in the future. This is its ultimate aim and seems to be understood by authorities.

(iii) Industrial heating

113. The study of water heating for industrial purposes as well as for other uses has not been limited to traditional methods of utilization. All sectors of the economy were examined for possible application. One example is the investigation of the posssible use of flat plate solar collectors for the preheating of fuel oil used in the furnace of SOCIMA (cement society) in Diamou. First results indicate a savings of nearly 60 million F.M./year on an investment redeemable between one and two years. This project is of great interest as it will be the first attempt to use solar energy industrially and one SOCIMA

considers a necessity. When initiated it will then be possible to think of systemizing the use of this heating process for other applications such as heating water to produce steam, for heating or drying needs, and where other fluids are heated.

(iv) Solar distillation and steam production

114. At the present time there is no commercial production of distilled water in Mali although there are many uses such as in the batteries of cars and pharmaceutical products as well as other sanitary commodities. Distillation can also be used to produce drinking water from polluted or blackish water but chemical treatment is also required before the water is potable.

115. Public services (State societies in particular) are eager to obtain distilled water. Since 1970 the Solar Energy Laboratory has been regularly supplying such important services as "Génie militaire" (Military Engineering), "Régie des chemins de fer" (Railway Administration), "Garage Administratif" and a great number of garage owners and private individuals.

116. The problem of scarcity of distilled water and its high price is expected to be overcome by the construction of a big distiller building (surface area 1,000 m) with a capacity of between 3,000 and 5,000 litres per day. This project has already been financed and its start is imminent. Construction of additional distiller buildings are included in the current five year plan. These will have a surface area of 200 to 300 m2 and will be located in five principal towns in the other regions of the country. In this manner the whole of Mali will have distilled water in sufficient quantity for a low price. Despite the low selling price it is expected construction costs will be recovered within one year.

117. One advantage of having distilled water available everywhere is in the distribution of medicinal products. Presently the "Pharmacies d'approvisionnement du Mali" of the Department of Drugs, located in Bamako, supplies the whole of Mali with medicines of all kinds. A high portion of these are solutions in glass containers susceptible to breakage during transit. If distilled water was readily available only the transport of the dry ingredients would be required. This would minimize transportation costs, shorten delivery time and prevent losses caused by glass breakage. Another advantage of readily available distilled water is that it can be used for drinking purposes. In regions such as Taoudenit (northern Mali) where water from wells is brackish this has considerable importance.

118. At the present time it is necessary to transport drinking water, at considerable cost, from far away. By producing distilled water on the spot, as the Solar Energy Laboratory can now do, there would be considerable benefit to the economy.

v) The distiller/water heater

119. A distiller/water heater has been developed which combines the processes of distillation and heating. The quantity of distilled water obtained in percentage of volume of water in the apparatus is 2 to 3 per cent and 5 to 6

per cent when water temperature in the tank is respectively 60 and 80°C. This equipment is available at a price hardly higher than that of the simple water heater and since distilled water is easily sold the initial investment is soon recovered and then the equipment becomes a source of income.

(vi) The cylindro-parabolic

120. Work has also been conducted on a cylinder-parabolic concentration type of captor, (length four meters, opening 1.5 metres). The quantity and physical characteristics of the steam produced is being determined for eventual application in distillation processes, motors, etc.

(vii) Solar drying

121. Extensive experience has been acquired drying food products such as meat, fish, mangoes, etc. Samples of these dried products have been kept for years with no noted alteration in their quality. This cannot be said of traditionally dried goods because they become infested with insects.

122. Solar drying has proven efficient allowing completely hygenic treatment and is economical with applications in the following Mali industries:

- SOCOMA (fruit canning plant), drying mangoes;
- Operation "Pêche" (the Fishing Board), drying fish,
- Sombepec and OMBEVI, Drying meat;
- The "Tannerie" (shoe factory", tanning hide;
- The "Briquetterie" (oven brick plant), manufacture of oven bricks.

123. The meeting with directors of these industries took place in 1970 to discuss the introduction of solar drying processes within their companies. For them the advantages of solar drying are numerous, in particular cheap conservation and increased production. An example is mangoes production. During the mangoes-season mangoes are picked everywhere and although some are sold locally and others exported, a great deal of waste occurs. After the mangoes-season SOCOMA finds it must cease operation because of lack of stock. This situation causes selling difficulties as consumers hesitate to buy a product which is available only during a certain time of the year. If however SOCOMA and other producers of mangoe products adopt the solar drying process the surplus of mangoes during the mangoes-season could be dried and sold all year round at a cheap price. This action would prevent waste, increase production, eliminate the necessity of importing other dried fruits at considerable cost and in general aid the economy of the country.

124. The use of solar drying would also increase the production of building bricks and thus decrease the necessity of using as much cement in construction. The drying of fish and meat when surpluses are available would prevent the loss of these foods. These considerations are of significant importance to the economic and social development of the country.

(viii) Solar cookers

125. Although technically practical, the use of solar cookers has encountered psychological problems. Their use upsets the habits of the population and therefore careful preparation and the education of the people is necessary before the device is introduced. This introduction must not be hurried to avoid the possibility of the people rejecting the principle of the solar cooker.

126. The method of introduction has already been decided. Through government subsidy, the equipment will be offered free in rural areas in exchange for assistance in such activities as planting and caring for trees. In this way the introduction to the solar cooker will contribute in several ways to the economic development of the country. Its use will diminish the dependence on conventional fuel sources and consequently reduce atmospheric pollution and also it could be a determinant factor in the success of the reforestation project.

(ix) Solar pumps

127. Interest in solar pumps began in 1969 but in February 1975 only before the first installation was made. A one kw thermodynamic cycle pump made by SOFRETES (France) was installed at Diofla, 175 kms from Bamako, where a water supply is available. The pump draws water from a well for a dispensary, a maternity ward, a secondary school, several water fountains and ponds for cattle. The sun collectors are used as a roof for the dispensary.

128. There are plans to install a similar pump at the Rural Polytechnical School in Katibougou, 50 kms from Bamako. It will provide water for the school and for the irrigation of a field where practical agricultural activities are conducted.

129. The Ministry of Interior has also commissioned the Solar Energy Laboratory to study the material requirements for pumps at a large number of wells. This includes pumps for wells in the Sahel region of the country which was affected by the recent drought. Finances have already been arranged for two pumps to be installed at Dyli and Kerbane in the department of Nara. One of these pumps may be of the photoelectric type.

130. Also in the coming months work will start on the first integrated project involving solar energy. The participants are the Departments of Tourism, hydraulics and agriculture, as well as the Solar Energy Laboratory. A thermodynamic solar electric power station of 50 kw capacity will provide electric power for the following:

- pumps to draw water from a river for irrigation of 100 ha of land;
- pumps to provide drinking water from a well for the population of Diré and Tourist Centre;
- all electrical installation in the Tourist Centre (lights, refrigeration, air-conditioning).

The sun collectors will be used as a rooftop for a Tourist Village. In preparation for this project, two engineers from the Solar Energy Laboratory have taken a course in France on thermo-dynamic cycle pumps.

131. While practical activities proceed research is being conducted to improve techniques and attain other goals. In particular the following is being investigated:

- the improvement of the efficiency of the collectors;
- heating and drying for industry;
- water distillation on a large scale;
- improving dimensions, efficiency and transportability of the solar cookers;
- sun air conditioning;
- production of electricity (photocells);
- production of steam for use in motors.

132. The infrastructure required to satisfactorily carry out the various programmes outlined is considerable. In addition to the staff already described, three buildings contain offices, laboratories, workshops and store-rooms. Future expansion includes the construction of a new laboratory, a new solar plant and a 100 m2 masonry distiller. They will be built on two large open lots donated by the government. New laboratory equipment for the solar plant costing more than 60 000 000 FM will soon be installed to complement recent acquired supplementary material worth 30 million FM. A library of general scientific and specialized literature contains more than 800 volumes.

133. To continue these activities financial means must be reasonably constant. The Government, in order to show its interest in the development of solar energy in Mali, has agreed to create a commercial and industrial structure for production and selling solar energy devices. This structure will be named Fond's Energie Solaire. Part of the profits, if not all, will permit certain self financing of the different programmes of the laboratory.

134. In Mali the idea of using solar energy is just beginning to be accepted and it is becoming urgent to give priority to schemes to exploit solar energy. This is a readily available resource and with its great potential it will be the answer to the future energy needs of the country even though hydroelectric potential exists. Other sources of more conventional energy however are limited.

135. Since sunshine is Africa's greatest wealth it will provide the continent with an independent energy source. This independence however must not become technologically dependent upon outside development. Research must be undertaken in Africa and technological advances adapted to each country's needs. Struggle for this independence is more than an option. It is a question of ethics. For the time being it is also and above all a question of simple survival.

MAURITANIA

136. A thermodynamic cycle flat collector solar pump has been planted at Chinguetti, for water-supply to 2,000 dwellers. Its duty is 8 to 10 m3/hr, its consumption 1 kw, against a 20 m head (40 m according to other sources). It was commissioned in 1973, and was expected to operate during 5 to 6 hrs/day. The collectors are integrated in a solar plant rooftop.

137. Its working principle is the same as for the pump planted in Senegal. Basic maintenance is trivial: over a one-year period, it included the supply of two bottles of butane-gas, replacement of stuffing-boxes and one driving belt. Unfortunately, due to scarce water at that depth and on the pump location, actual operating time is at present 0.5 to 1 hr/day, or 4 to 5 m3 water/day.

138. A windmill for water pumping had been installed at Chinguetti before the present solar pump, but results were below expectations because of sand and inadequate maintenance.

139. Future activities in Mauritania in the field of solar energy applications include:

(i) Commissioning two pumps similar to the one already installed at Chinguetti, but with simpler and cheaper installation requirements. They ought to have a duty of 6 m3/hr against a head of 50 m. They should supply about 50 m3/day with an operating time of 8 hrs/day.

Proposals have been made for a solar pump with a similar working principle, that would supply 35 m3 water per day to communities of 3,000, including 80 consumers, 4 public fountains and 3 km of plastic pipe-work, with a 30 m3 water tower, against a head of 20 to 24 m. The most powerful type of pump working on this principle is 50 kw. One 5 kw photocell pump is being installed at Garak for irrigation purposes.

(ii) Two windmills are also scheduled for installation. They shall be 7 m in diameter, fitted on a 15 m high pole, and shall each work a sunk electric pump against a head of 45 m. Air-generators operate with wind speeds ranging from 4 to 7 m/sec. Above a given wind speed, the propeller locks so as to avoid breaking stress. The propeller is equipped with sealed bearings and is protected from sandstorms by neoprene. On the coastal areas of Mauritania frequent wind with a rough 7 m/sec. speed is observed, and seems favourable to windmill use.

(iii) As an example the Ministry of Planning and Industrial Development underlined that the main issue in Mauritania is water, particularly in the wake of the dramatic drought that was rampant over the past few years. As far as water supply is concerned, priorities are:

- Coastal villages which are at present supplied by tankers; then
- Inland villages with shallow wells; lastly
- Other villages in the hinterland.

Sea-water desalination would provide water-supply to coastal villages which are inhabited part of the year only. Conventional desalination plants would be uneconomic in small dwellings, and water supply through solar distillers ought to be investigated.

(iv) The Ministry of Rural Development emphasizes the importance of underground water pumping for irrigation and livestock water supply. The majority of the population lives on cattle-breeding. This Ministry has defined two highly urgent problems:

- cold storage rooms are necessary for the preservation of market garden produce, the production of which has been boosted to a surplus level, following the drought period. This produce may be jeopardized for lack of preservation equipment;
- A hundred or so pumps reaching 6 to 20 m in depth would be necessary for the rural areas, in the southern part of the country. The Ministry would welcome suggestions to that effect based on solar energy, as well as experts in the field.

140. There is at present no governmental organization concentrating on the various applications of solar energy in Mauritania. The various ministries concerned by the various aspects of its utilization are: the Ministry of Planning, the Ministry of Rural Development and Planning and the Ministry of Development particularly the hydraulics and power department.

141. The Mauritanian Government's policy in the field of solar energy application has not been laid out in an official document as yet. A national pilot-project could be worked cut on the basis of priorities defined by the national development plan. The following priorities have already been short-listed:

(a) sea-water desalination, fish-drying and cold storage rooms;

(b) water-heaters;

(c) water-pumping for irrigation;

(d) rural electrical power supply.

At a second stage, the Governemtn is planning to define one pilot-project in every selected field of application, in order to carry out experiments and evaluate results. A wider-scope implementation project could be set up at a third stage in the light of experimental data. At every stage the Government intends to emphasize personnel-training geared to solar technology basic learning and local maintenance.

MAURITIUS

142. In 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 1,700 kWh/m2, and secondly implementation of a programme based on alternative source of energy will lead to a significant reduction on dependence of imported fuel.

143. The economy of Mauritius is primarily based on sugar cane cultivation. Despite all the draw backs associated with mone crop economy, the main compensating feature is that no imported fuel is used, as bagasse derived from sugar production is the only source of energy in reducing its dependence on imported fuel to about 50 per cent for its total energy consumption.

144. Any excess electricity generated by the sugar factories during the milling season is fed to the national electric grid; it represents five to ten per cent of the total plant capacity of a Central Electricity Board.

145. Against the background of a raising population and new industries being set up making demands for more power, what are the options available for reducing this dependence on outside fuel oil. They fall under two headings: 1/

(a) Adopt alternative source of energy, wherever feasible.

(b) Maximise the generation of power.

MOROCCO

146. 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, biogas digestors, wind power generation, wind water pumping, solar water pumping and wind energy utilization for mechanical purposes.

NIGER

A. The Solar Energy Board (ONERSOL) activities

147. Tests in the field of solar energy utilization for water heating and cooking have been undertaken in Niger ever since the nineteen-sixties, and the interest aroused by the implementation of these pioneering projects has encouraged the Niger Government to establish a Solar Energy Board (Bill of Establishment dated May 5, 1965, voted May 15, 1965).

148. The Niger Solar Energy Board 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.

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

1/ Mr. S.C. How Pak Hing, Lecturer in Mechanical Engineering, University of Mauritius (in comments at the Seminar on Solar Energy), Nairobi, Kenya, 1978.

- on the one hand, to carry out research and development towards designing, testing and perfecting prototypes of installations or devices operated on solar energy,

- on the other hand, to popularize such installation or devices, manufacture them industrially and trade them, in the country as well as abroad.

150. 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.

151. During the 1966-1975 period, 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 have been designed, experimented and perfected.

152. Since 1971, about thirty water heaters have been installed in private dwellings as well as in schools or public health buildings, about ten solar distillers have also been installed. This has been so popular that mass-prduction of these devices is planned for widespread use.

153. 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, a mass-production capacity plant was built (from September, 1975 to July 1976) and has just started production in Niamey industrial area.

154. This plant was designed to be the manufacturing and trading department of solar energy devices designed by ONERSOL Research Department, and will allow more effective distribution of tasks in two distinct, although complementary, fields of activity. As it were, towards the end of 1974, dealing concurrently with research and sales in a Centre meagerly staffed with four physical scientists, one engineer, two technicians and a score of workers has become increasingly burdensome.

155. The Research Department is now in a position to bend all its energies to 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 elicited conclusive data on the thermal efficiency on the plant, so that actual construction of a first prototype is being considered, this motor ought to have a 1 kw capacity with a 24 m2 collector surface area. ONERSOL is at present engaged in negociations with a foreign company towards a draft cooperation agreement to bring this prototype into operation. Other interesting applications could be derived from the success of this project: regrigeration based on a compression system, power generation with alternators.

(b) Solar-energy flat collectors and water heating: Prior to marketing solar water heaters, numerous tests had been carried out on various selective coatings covering the flat collector hot plate. Investigations are pursued aiming at improving these solar furnaces energy output, whose standards are already up to anything produced elsewhere in the world.

(c) Solar oven for cooking pottery items: A research programme on collection with solar-ray focusing has been undertaken at ONERSOL; this programme aims at equipping the country with a solar oven with a 40 to 50 kw capacity, an operating temperature of 1,500°C, for building material processing (burnt bricks, lime, cement). A furnace temperature of 1,500°C will make it a very versatile oven, for example it could be converted for tests in the field of ore-processing. The installation includes:

- one parabolic mirror which was entirely designed at ONERSOL - Data were subsequently forwarded to CNRS (Odeillo, France) for testing and further information;
- two 8 m x 15 m heliostats to follow the sun;
- the oven 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 Castres, France) in April, 1975 and have arrived in Niamey.

(d) Solar air-conditioning

(e) Thermo-electric and photovoltaic: These two fields of activity are still future perspectives, although they are very short-term plans, since basic material has been ordered and even installed at ONERSOL. About solar air-conditioning, there are plans to experiment brine-based refrigeration systems (lithium bromide) in the Sahel climatic conditions, within the framework of the laboratory-complex scheduled for installation as part of the solar oven project implementation.

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

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

(f) Water pumping for irrigation: In a joint venture with the relevant department of the Ministry of Rural Development, ONERSOL has just obtained EDF (the European Development Fund) support to finance water pumping plants for irrigation purposes. Thus over the next three years, two SOFRETES type solar pumps with 5 kw capacity each shall be experimented in the Niger river valley, and one 2 kw capacity pump up country. Solar pumping equipment currently traded by SOFRETES costs 40 million CFA francs FAS in Rouen for 5 kw; adding shipping and civil engineering costs, the installed kw would cost 12 million CFA francs in Niger, assuming the best. International credit organizations have already shrunk from incurring such an investment, which would cater for four hectares of rice field only, against 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 collectors locally. ONERSOL thus expects to save at least 2 million CFA francs per installed kw.

B. Staff enrolment and training

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

157. From 1969, a Niger high-level physicist specialized in solar energy was enrolled; tests were consequently resumed and manufacturing standards were improved. Basic material selected for metal devices is aluminium, the insulator being fibre-grass. Their cost is higher of course, but their energy output is higher and their wear should be 10 years minimum.

158. From 1967 to 1973 the strength did not change much (one expatriate scientist, one expatriate engineer and one expatriate overseer, two technicians for recording instrument maintenance, seven workers). After 1973 three physicists with 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 Niger technicians and sixteen workers: six are assigned to the Research Department, ten to the Manufacturing Department. Staff increase is scheduled for the next three years; however there are intangible factors in this respect, such as present staff educational achivements.... Up to now, senior staff came from the Ministry of Education (on a 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.

C. Research issues and financing

159. ONERSOL initially received foreign financial support (ACF, UNDP, Libyan Aid, UNESCO) which provided for the construction and equipment of the Research Department offices and workshop, as well as the purchase from abroad of the necessary sunshine and temperature measuring instruments. From 1966 to 1973 the grant from the National budget was increased from three to ten million CFA francs, and reached 22 million in 1976.

160. The newly-built factory, which was entirely government-financed, cost 75 million CFA francs for the premises. The machinery, which was mostly imported from France or Germany and financed in part by UNESCO (Saudi Arabian Fund for the Sahel Countries) to the extent of 10,500,000 CFA francs, cost 27,250,000 CFA francs; thirteen million were spent on the factory raw material supply (aluminium sheets, tubes, extruded sections, fibre-glass, mirrors, etc.).

161. These figures show the Government's growing commitment to encourage solar energy research and popularize applications. Nevertheless research often slackens out of financial shortage as well as for lack of senior staff. Management and administration tasks, trips and various advances towards financial support often bring research work to a standstill.

162. Besides, given the sophisticated standards of some current or forthcoming projects, ONERSOL will have to approach foreign countries. European countries in particular for assistance in carrying out some of these projects. This is already happening for the solar motor since there is thermal motor manufacturing plant in Africa.

163. ONERSOL is also dependent on foreign supplies in measuring instruments or raw material (semi-finished projects). However the initial raw material is extracted from mines in the country, and only lack of organization and exchanges between African countries compells ONERSOL to deal with third parties. There is neither aluminium industry (particularly extruded sections) nor glass in Africa, hence the necessity to import tons of glass from Europe, a good deal of which is wasted through breakage - or fibre-glass, the best thermal insulator at the moment.

164. As regards inter-African scientific co-operation, exchanges are negligible, and opportunities for African scientists to meet generally occur within the framework of international conferences and seminars outside Africa.

165. However, regarding solar energy research specifically, there have been more than one attempt at co-ordinating activities between existing centres, with emphasis, at least for scientists, on data exchange or in-service courses for staff from laboratory to laboratory. This year for instance, ONERSOL has accommodated a scientist from Mali for a two week course, who is engaged in the same type of research on thermo-electric and photovoltaic conversion. However, since he left, the co-operation process has been discontinued for luck of legal provisions to facilitate such contacts which, it goes without saying, would be most beneficial to both countries. ONERSOL has just received a Chad trainee and Senegal has requested it to cater for two trainees. 1/

166. Following the UNESCO general conference (Nairobi, 1976), ONERSOL was requested to set up specialized post-graduate courses in heliotechnics for African research workers. These courses were started in Niamey on April 3 to 24, and on July 1 to August 31, 1977, for 22 trainees from 9 African countries (Senegal, Mali, Upper-Volta, Ivory Coast, Togo, Nigeria, Sierra Leone, Algeria and Niger). Subsequent programmes are under consideration and Niger is anxious to put a stronger emphasis on African research worker and qualified staff training in the field of solar energy.

D. Solar energy utilization in telecommunications in Niger

167. Up to 1973 all postal and telecommunications installations were run on conventional energy sources: electric power from the interconnected network in cities, posts and telecommunications generating sets and batteries in villages.

168. In 1974 OPTN, (Niger Post and Telecommunications Administration) for the first time, equipped a radio relay station with turbo-generators. Performances are satisfactory but the cost is high. Therefore OPTN turned to solar energy, and requested information from some manufacturers.

1/ Mr. Wright Albert, Research scientist with ONERSOL (Bamako Symposium on Solar Energy and Development).

169. Meanwhile the Malagasy Postal Administration had approached OPTN for information on solar energy utilization in the Niger telecommunication network. Prior to answering this request OPTN forwarded it to ONERSOL, who supplied data concerning telecommunication (capacities from 1 w to 1 kw), on July 18, 1975. Since then OPTN has studied this question at length.

170. In October 1975, the first photocell-based self-contained power pack was ordered for the Boukanda radio-relay station, 60 km North of Niamey.

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

171. The power equipment is composed of a solar collector, an electronic current limiter and a battery. When sunshine fails the collector stops supplying energy and the battery takes over.

172. The Boukanda relay station has a 35 watt average consumption and a 40 watt peak consumption. This type of power supply has a 10 year average wear. The project cost 5,385,266 CFA francs, or 538,526.6 CFA francs average maintenance cost per year.

173. Prior to the commissioning of the solar collector the Boukanda relay station was run on AD 608 type large capacity power batteries. In 1975, 160 batteries of this type were used in this station. The batteries average cost C.I.F. in Niamey being 20,000 CFA francs, the relay station maintenance expenditure amounted to 3,200,000 CFA francs.

174. The collector is made of 33 modules with a 8.1 watt nominal capacity, with a total supply of 267 watts. The size of each module is 1 m x 0.15 m, so that the collector surface area is about 5 m2, the modules are counted on aluminium extruded sections set on a metallic frame with a tilt angle in accordance with the latitude of the location (14°N). In the day time the collector supplies power to the radio relay system and to a battery made of 17 lead cells with a 250 A.h. capacity.

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

176. Transmitting: Ouallam-Banibangou Link, Maradi-Dakoro Link, Zinder-Tanout Link. The latter two are currently operated with decametric-wave radio transmitters with an average 30 minutes period of duty.

177. Switching: 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 running on 6 V. supply instead of 48 V. for the obsolete equipment. Besides the new exchanges will serve from 20 to 200 subscribers for a 12 to 120 watt power-consumption.

178. School-television: 22 classes are run on 10 watt average capacity photo-cells. This was achieved in a joint project with ONERSOL.

179. Generally speaking solar energy was introduced as a consequence of the conversion, or replacement, of obsolete or ill-suited equipment in the context of the telecommunication network modernization for meeting the requirements of the social and economic development of the country. 1/

NIGERIA

180. 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 edevices.

181. 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. 9280271 - Domestic Electrolux Absorption Refrigeration Unit". Thermal energy from the sun then replaces the kerosene burning process in such systems. Aqua-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.

182. The conventional Aqua-ammonia system is therefore not the best suitable for solar refrigeration except perhaps for the intermittent cooling of drinking water on hot days. Lithium-Bromide/Water systems and other that abound in Solar Energy literature may well be attractive propositions; yet a "Solar Powered" cooling system that relies on non auxilliary power source and yet produces large enough refrigerating effect (even for domestic use) is still a challenge.

183. 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 600 type using solar cells.

RWANDA

184. Solar energy research is carried out under the Energy Research and Application Centre in Rwanda (CEAER), which was established in 1974, within the National University in Butaré, under the Ministry of Natural Resources, Mines and quarries.

1/ Mr. Ibrahim Idrissa, Head, Transmission Division, OPTN, Niamey, Republic of Niger.

185. This national centre has three basic objectives:

- to experiment and construct simple devices running on local energy sources and suited to needs and specific conditions of the country;
- to encourage popularization of these devices and small-scale manufacture from reliable prototypes which could be advantageous to the population;
- to contribute to research and managerial staff training.

186. Against this background, five main lines of research have been short-listed as priorities:

- solar energy,
- low capacity turbines,
- peat,
- lake Kivu methane gas, and
- geothermal energy.

187. As regards solar energy, several investigations and developments have been completed since the onset of CEAER, in the following fields:

(a) Solar water heating: Solar water heaters have been studied. 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 (temperature 40 to 60°C). Prototypes with various capacities have been designed and tested in the aim of popularizing solar water heating, with several purposes:

- to reduce firewood consumption, thus alleviating deforestation effects;
- to improve the rural population's standards of living by facilitating better prophylaxis; rural out-patient departments and maternity clinics could be equipped with solar water heaters;
- to use hot water as an energy source for running solar pumps in order to improve rural water supply.

(b) Flat collector performance data improvement: Several tests have been performed. Flat collector construction has been improved so that now perfected collector prototypes are quite competitive vis-à-vis foreign made collectors. The Butare Centre is installing 50 m2 flat collectors.

(c) Solar distillation: One solar distiller supplies the Butaré National University chemistry laboratories with distilled water. Distilled-water supply to garages for battery charging is under investigation.

(d) Solar refrigeration: A large capacity absorption solar refrigerator prototype (4 to 6 m3 for the cold storage room) is being constructed. Some technical snags, particularly the 18 m2 parabolic cylinder shaped collector unsatisfactory efficiency, are delaying the perfecting of this device.

In the same line of thinking, farmers are being approached concerning the usefulness of 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 recording stations for about ten years. Statistical data processing is being carried out with one computer.

188. Rwanda has achieved small scale experiments on biogas conversion. CEAER has boosted research in this area. Larger capacity units are being installed at the moment and consumption evaluation regarding various applications (cooking, lighting, etc....) is being investigated. One gas producing prototype based on cowdung fermentation is being tested in an agricultural college of the country with a sizeable cattle-herd.

189. Concerning low water fall harnessing, Rwanda, being a mountainous country, is undertaking an overall review of electric or mechanical power generation. Low capacity turbine integration in Rwanda has been investigated since 1975. One 20 HP rustic turbine is planned for installation on a low water fall in the vicinity of the University, with the help of a party of civil engineering students. This turbine could run a sorghum mill and act as a prototype for future plants.

SENEGAL

190. Senegal started actual research on solar energy in 1960 under the Meteorological Physics Institute (IPM) which is incorporated to the Dakar University Science Faculty. Several falt collector solar pump prototypes have been investigated and experimented. It should be stressed that the first solar pump operational prototype was achieved in Senegal.

191. The same institution has carried out experiments in the field of solar cooking. Of late, research and experiments have been carried out towards designing and constructing collectors in their various features, particularly their shape and basic materials.

A. Present activities and programming perspectives

192. In Senegal, present and anticipated solar energy activities are situated in the following areas:

Water-pumping

(a) The first water-pumping method is based on standard electric pumps running on solar energy conversion into power, either through photocells or through a thermodynamic cycle. The Dakar University Science Faculty (Semi-conductor and Solar Energy Laboratory) is planning to perfect photocell-power supply to 1 kw electric pumps. One prototype has been in operation since 1976.

(b) One flat collector solar pump with 1 kw capacity has been operated at the Meteorological Physics Institute (IPM) of Dakar University since 1968. This pump is based on the following principle: solar energy heats water in the flat collectors to a temperature of about 70°C. These calories are then transferred to a fluid (butane) in a heat exchanger. At this temperature butane vaporizes and drives the motor piston which in turn runs the pump located at the bottom of a well through a hydraulic drive. This system thus includes a hot-water cycle (flat collector and heat exchanger), a butane cycle (with motor, condensor and reinjection pump) and a pump-hydraulic drive cycle (with hydraulic press). Another pump of this type was installed with the agency of UNIDO in 1975. Similar pumps are operated in 4 villages, at the rate of one pump per village; in addition they have a refrigeration action through a compressor coupled to the motor and by expanding part of the low pressure fluid. These villages are: Medina Dakar , Niachène, Toki and Bahak. Three more solar pumps were being installed, in particular at Dakar University technology Institute (IUT) and at Diaglé. One SOFRETES MS-5 type was being assembled for Bambey as well as one 10 kw capacity pump for Dahra. Orders have been placed for several plants scheduled for 1978:

- for the town of Bakel, one TS-60 pump for water-pumping. This pump ought to supply 4,000 m3 water/day and produce cooling (25,000 negative kilocalories/day);
- for the village of Bagador-Doune, one TS-10 pump for pastoral hydraulics;
- for the village of Meouane, one SOFRETES MS-7 type (improved) pump, for village hydraulics.

IPM is planning to investigate a 50 kw pump of a similar principle. Large-scale use of pumps of this type is anticipated, with some parts being manufactured locally, under the National Research and Industrial Promotion Comapny (SONEPI). Mass production would thus reduce costs. Lastly, IPM is perfecting two prototypes of diaphragm motors.

(c) Water may also be pumped through wind-pumps. Thiès Polytechnics Institute (IPT) is installing 7 wind pumps for experimentation of their operating performances under local conditions. ITU in Dakar is perfecting a "bush wind-pump" using a local material. When this wind-pump is installed in a rural area, then a training course shall be set-up teaching on the spot manufacture. One Savonius wind-pump has been perfected and installed at IUT in Dakar. Four wind-pumps of the same type are scheduled for installation in 1978 for village hydraulics at Tiep, Sao, M'Baye M'Baye, Peul and Diaglé.

Water processing

(a) Distillers: One solar distiller supplying 10 l/day is being tested at IPM. It is of the "evaporation" type: salt water evaporates under the effect of solar heat; steam condenses on tilted glass panes; it is then drained to a tank. Another type of distiller, called the "membrane" type, is being tested at IUT.

Various types of research are planned in the field of water desalination by the Science Faculty (FS) and IUT, and IPM is planning to test 10 prototypes on location in actual operation.

The Head of Rural Development Water Resources has emphasized the importance of the desalination problem in Senegal, not only because of the extent of coast, but also for the tapping of underground salt water. There is 3,000 billion m3 phreatic water at a depth of 520 m; it is of the semi-Artesian type and surges up 7 m deep at places; its salinity rate is 5 mg/litre. This considerable resource is not yet tapped, but it would certainly be useful to investigate the part solar technology could play in the desalination process.

(b) Water heaters: Two types of water heaters are being tested at IPM. One with a heat-exchanger, the other without. In the first type, the water for use is independent from the solar collector hot water cycle, it is heated by calory-exchange in the tank. In the second type, the hot water circulating in the solar flat collectors by convection is used directly from the tank. About ten water heater prototypes of five different types are scheduled for testing at IPM; one of the problems under investigation is scaling.

The Ministry of Industrial Development is planning mass production, of water heaters, particularly to equip low-cost dwellings; a 10,000 dwellings/year programme has been set up. As far as water heaters are concerned, the problem is therefore twofold: to finalize selection of one model, and to mass produce it. One of the initial prototypes was commissioned at the Prime Minister's residence in 1976.

Heating and air-conditioning

(a) Dryers: One model of solar dryer is being experimented at IPM. It is intended for foodstuff preservation and particularly for fish-drying. It is of the hot air type, the air, heated by the flat collector, flows through the dryer chamber by convection; the foodstuff is kept there on trays. One 1,000 litre dryer which can dry 250 kg fresh fish has been constructed with a 8m2 flat collector. After experimentation one operational prototype shall be installed in a fishing co-operative store. IUT, in a joint project with the Food Technology Institute (ITA), has perfected a fish-drying plant for use in rural areas.

The Ministry of Industrial Development is planning mass production of fish-dryers, which rank as priorities in the economic development of the country.

(b) Refrigeration: IPM is planning to experiment refrigerators running on thermal solar energy. Besides, IPM is planning to build an air-conditioned experimental building with a cold-storage room in order to investigate absorption and compression refrigeration system.

(c) Building-design: IUT is carrying out research on building materials from the criterion of suitability to the insolation conditions of the country, either concrete or vegetable fiber. The School of Architecture and town-planning is looking into optimal architectural designs with respect to insolation data.

(d) Solar energy conversion: The National Livestock Laboratory is investigating biogas production from manure, and is planning to set up an applied research programme in this area.

Power generation

The semi-conductor and solar energy laboratory of the Science Faculty is investigating (i) photocell construction (basic research); (ii) photocell utilization to run small power generation plants, solar receivers (radio, television and tape recorders), 1 kw water pumps, environmental data recording stations and pilot-control mechanisms. Three small power plants running on photocells are scheduled for installation. One school television prototype running on photocells is being experimented. The Senegalese television network, which ought to cover three-quarters of the country, might use this power-supply system as soon as it is perfected.

The Laboratory has established that conventional electrical power cost prices in Senegal are cheaper than photocell-generated power for a 260 kw capacity. On the other hand, for low capacities of 2 kw or 10 kw, photocell supply is already cheaper than Diesel-engine generated power.

The Senegalese Electrical Power Authority (SENELEC) has placed an order for one TS 17 type motor for power generation for the village of Diakhao. Other such experiments are being planned. One 4100 FP-7 type electrowatt air-generator for power supply to M'Boro and village hydraulics is also scheduled for installation in 1978.

The Scientific Technical Research Department is planning an applied research involving several pilot controlled power generation project plants using photocells, in various areas of application. The Ministry of Industrial Development is planning a mass production programme when prototypes are developed.

Insolation recording

The Senegalese meteorological organization in Cape Verde has been recording meteorological data for 20 years; data are forwarded to the WMO Centre in Leningrad; it included insolation data. It would be appropriate to extend data-recording to the whole of the country, particularly inland.

Prototype tests and grade control

IPM and IUT are carrying out prototype tests, grade controls and performance evaluation. IPT is planning to establish a General Experimentation and Testing Centre in which systematic tests could be carried out.

Economic evaluation and market research

The Ministry of Industrial Development and SONEPI are planning to undertake economic evaluation of solar devices and market research.

Manufacture and local industry promotion

Senegal is planning to set up a mass production programme, starting with water heaters, dryers, wind-pumps, and some solar thermodynamic pump components. With this in view the Senegalese Government has just set up the Solar Energy Application Industrial Company (SIAES) whose main emphasis shall be mass-production of solar and wind energy based devices (water heaters, solar and wind pumps, solar dryers, rural power supply). In addition to the Senegalese State, this company is amalgamated under MENGIN Company in Dakar, and Senegalese industrialists and businessmen.

In order to contribute to the selection of solar devices to be manufactured, Senegal wishes a seminar on solar energy applications to be held in Dakar, where, the various applications already in operation in the world could be presented to the scientific, technological, industrial and educational communities as well as to the decision-making bodies.

Education and training

Various courses on solar energy are offered by the Science Faculty (semi-conductor and Solar Energy Laboratory) whose purpose is to train highly qualified lecturers/research workers. "State" as well as "3rd Cycle" doctorate theses are outstanding on various aspects of photocell construction and utilization. The "Diploma of Advanced Studies" (1st year PHD) on Solar Energy and hydraulics is offered by the Hydraulics and thermodynamics Department of the Science Faculty, which is planning a research project on water heaters, refrigerators, air-conditioners and thermodynamic solar pumps. IUT trains graduate engineers in technology and higher technicians particularly in electronics, electro-mechanics, mechanical engineering, food technology and meteorological technology. Activities related to solar energy include solar drying, habitat, hot air motors, wind pumps and photocells in collaboration with the Science Faculty. IPT trains graduate engineers, and partly deals with wind-pumps.

Popularization

The popularization office in the Ministry of Rural Development has undertaken an awareness and education project for rural population in the field of cookers, wind-pumps, dryers and distillers. IPT has a similar project for wind-pumps.

193. The relevant organizations in Senegal concerning activities related to solar energy and applications are the following:

(a) at ministerial level: Delegation général à la recherche scientifique et technique (DGRST) (Scientific and Technical Research Department); Ministry of Industrial Development (MDI); Ministry of Rural Development (MDR); Population Awareness Department;

(b) scientific, technical and educational institutions: the Physical Meteorology Institute (IPM); the Science Faculty (Physics Department - Semi-Conductor and Solar Energy Laboratory - Hydraulics and Thermodynamics); the

University Technology Institute (IUT); the Thies Polytechnics Institute (IPT); the National Livestock Laboratory (LNEL); the School of Architecture and Town-Planning (EAU); the Food-Technology Institute (ITA);

(c) In the industrial field: the National Industrial Research and Development Company (SONEPI), at the instance of the Ministry of Industrial Development (MDI), and the Solar Energy Application Industrial Company (SIAES).

194. The first body of institutions has a hand in working out solar application projects at ministerial level. The second body carries out scientific and technical research, prototype development, and education and training.

195. It seems that IPM is the focal point of Research and Development (R & D): it initiated solar activities in Senegal and could act as a co-ordinating body under the Scientific and Technical Research Department (DGRST). Priority is given to applied research and, whenever possible, to use of results already obtained in other countries, in order to reach the industrial stage.

196. The third body of institutions is involved in the industrial part. The Government, which views this aspect as essential, is planning to strengthen the existing set-up in order to reach the manufacturing stage. Some productions could be subcontracted by existing Senegalese firms; others could be tackled by co-operative workshops.

197. Manufacturing models shall be derived either from local research data or from prototypes already adopted abroad, or from prototypes that might be perfected by the Regional Centre that the UN is planning to establish.

198. At the device operation stage, rural communities are expected to play an important part. Thus solar pumps purchased by the State shall be remitted to rural communities which shall assume responsibility and maintain them on their local budgets. An intervention fund will allow rural power-supply with the rural communities' contribution.

199. The Senegalese Government has short-listed the following priorities:

(i) Water-pumping for village and pastoral hydraulics;

(ii) Solar dryers for foodstuff preservation, fish in particular;

(iii) Water-heaters for rural communities and institutions.

Second priorities concern the following applications:

(iv) Solar distillers, water desalination;

(v) Photocells to generate power for water pumping and power supply to rural communities on the one hand, to telecommunications and school television on the other hand.

200. Senegal has a sizeable academic set up which can carry out applied research and device perfecting in the field of solar energy. However, more effective co-operation between academic institutions on the one hand, research centres such as IPM on the other hand, is advisable in order to improve co-ordination and bringing into line of activities.

201. IPM must have adequate scientific and technical staff with a view, not only to pursuing present activities, but also to carrying out systematic performance evaluation as well as check up and maintenance of prototypes under experimentation. A sizeable additional batch of equipment is required in the small IPM workshop: machines-tools and welding sets (argon-arc-welding).

202. Besides above-quoted research institutions and related organizations, ventures take place here and there. For example the National Vocational Education Centre has experimented a calabash-type solar cooker at Fissel Langomak and a biogas-digestor pilot project has been carried out at N'Dioukh Fissel, Thiadiaye district, in 1978, within the framework of a hydro-agricultural complex covering all aspects of a rural area development. The latter project, carried out by "Caritas-Senegal", is a simple and effective alternative to firewood consumption. Another project, sponsored by UNEP, tries to associate solar, wind and biomass energies.

203. A leading project seems to have been worked out in view of the forthcoming regionalization of research in Senegal. To that effect the Scientific and Technical Research Department is planning, or so it seems, to approach the various regions in order to 'list development agencies' requirements; then according to such requirements, set up projects that shall have to be related to development projects. The final objective is the drafting of Research guidelines covering the next six years". A feasibility study on research regionalization is to be undertaken shortly in connection with the setting-up of CERER (Alternative Energy Research Centre).

SIERRA LEONE

204. 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.

205. One locally manufactured solar water heater 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

206. The Somali Government is planning to construct one large solar distiller with 2,000 m2 surface area at Khuda, in view of supplying a fishing community with drinking water. The project is 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.

SUDAN

207. The Institute of Solar Energy and Related Environmental Research (ISERER) at the University of Khartoum has conducted significant work and experiments on solar distillation, water heating and solar drying. A number of 6-20 square-metre solar stills have been in operation in the country for several years. The drying of vegetables, especially onions, is performed in a food processing laboratory.

208. Two SOFRETES MS-7 solar pumps have been installed in the Gezireh Valley, one at Soba and the other at Armad; and a number of other units have been ordered. A recent agreement with the Centre National de la Recherche Scientifique (CNRS) in France provides for the installation of solar kiln for baking bricks.

SWAZILAND

209. 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.

210. Other experiments are to be undertaken in view of extending the use of solar water heaters to the whole country.

TUNISIA

211. Tunisia has started the marketing of some solar water heater models and is carrying out research and development activities in:

- small-scale solar power generation: projects are being implemented;
- water-pumping with low capacity wind-pumps: prototypes are being tested and economic evaluation is being undertaken;
- solar water-pumping: several prototypes are being experimented and economic evaluation is being planned.

TANZANIA

212. 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.

213. 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.

214. 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.

215. 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.

216. Tanzania made a formal request for a Seminar and Workshop on solar energy, in April 1975 with the following terms of reference:

(i) To survey and review the latest state of knowledge of both the technical and economic aspects of the utilization of solar energy for space cooling and heating, for boiling water for human dwellings, especially institutions, and for the generation of electricity;

(ii) To select the technologies for solar energy utilization which would be most appropriate for Tanzanian economic ans social conditions; and

(iii) To design one or more pilot projects in this general area and to recommend on how the pilot project or projects should be implemented.

217. However, it was not until early 1977 that funds to support BOSTID's participation became available. The Workshop followed publication of a recent BOSTID's study "Energy for Rural Development: Renewable Resources of Alternative Technologies for Developing Countries" and used the section of that report dealing with solar energy as the main background document.

218. The Assistant Commissioner for Ujamaa and Co-operative Development in the Prime Minister's Office, summed up the points that his Government views as vital to the success of the discussions on solar energy applications in Tanzania:

(i) Energy questions are central to the attempt to improve the quality of people's life anywhere in the world;

(ii) Conventional fossil fuel resources are rapidly being exhausted and are not easily replaceable;

(iii) Tanzania does not have sufficient financial and manpower resources to harness the limited conventional fossil fuel sources they have;

(iv) There is an abundant supply of solar energy which, through sophisticated research, could be tapped for human use.

(v) Nations such as Tanzania, which are limited in financial and manpower resources to undertake sophisticated research on solar energy, could use the research findings from more technically advanced nations with modifications to meet local requirements.

219. The following recommendations were made by the workshop participants:

(i) A Solar Energy for Villages Pilot Project (SEVIPP) should be established as soon as possible under the Tanzania National Scientific Research Council;

(ii) Attention should be focussed on those technologies having the greatest potential in terms of cost-effectiveness, availability of resources, and long-range power requirements as follows:

- photovoltaic electricity generation;
- biogas generation;
- small-scale hydroelectricity generation;
- solar drying and cooling for food and crop preservation; and
- solar stills for water purification.

(iii) The Tanzania Research Council should work in consultation with other specific organizations in Tanzania;

(iv) A Solar Energy Promotion Committee should be established under the Tanzania National Scientific Research Council;

(v) Demonstration solar energy projects in three villages in each agro-economic zone of Tanzania should be initiated;

(vi) Criteria for the selection of villages for the demonstration projects should include:

- the village's energy/power needs;
- availability of renewable energy resources (e.g., water, wind and sun);
- human skills;
- the economic viability of the project;
- village enthusiasm and interest in participating; and
- social utility of the project.

(vii) The demonstration projects should make use of existing research data in local organizations before initiating long-term research;

(viii) A limited programme for training village technicians should be created;

(ix) Reforestation programmes should be implemented at the village level;

(x) The feasibility of collecting and storing rainwater from roofs should be assessed before funds are expended on solar pumping of potable water;

(xi) The establishment of Dodoma as the new capital of Tanzania should be seen as a unique opportunity to utilize renewable energy in Tanzania.

220. 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.

UPPER VOLTA

221. Although there is to date no co-ordinating body in the country in charge of solar energy research and development, Upper Volta has already undertaken several research and development projects with special emphasis on solar water pumping and refrigeration.

Water pumping

(i) Thermodynamic solar pumps

222. Only thermodynamic cycle water pumps using flat collectors and low temperature have been experimented to date. One of these has been in operation at the Inter-State Rural Development Engineering School (EIER) since 1971. Its operating features are as follows: "OUAGA" type solar pump; flat collector surface area: 30 m2; one-cylinder motor; heat carrying fluid: initially methyl chloride; now butane. The expected capacity was 2 m3/hr from a 6 to 8 m head. EIER obtained flows of 1.5 m3/hr. The pump is planted on a reservoir without renewable subterranean water supply. In order to keep water in the reservoir, it is necessary to transfer the pumped water back to the reservoir. The latter also acts as a cold source for the condensor; the water heated in the condensor also flows back to the reservoir, thus raising the temperature. This is instrumental in altering the efficiency of the system.

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

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

(b) one to supply water to Djubo village;

(c) one for agricultural hydraulics. This pump ought to equip a well drilled in Markoye and shall supply water for cattle and irrigation;

(d) one pump that was installed at EIER in 1975 has a collector surface area of 75 m2 and a capacity of 3 to 5 m3/hr with a 45 m head, and an operating time of 5 to 6 hrs a day.

224. These four stations will, among other things, make it possible to study operating conditions and evaluate costs. The first two projects are financed by "Catholic Life"; the third by DGRCST (France) and SOFRETES Company. The pumps shall have a capacity of about 1 kw; drillings shall be 18 to 25 m. deep. Water shall be stored in earth banks covered with a plastic sheet. According to available information these pumps have already been installed. More stations are scheduled for installation within the "Sahel Alternative Energies" project. In 1976 about ten SOFRETES MS-5 type pumps were installed in the following places: Kembara, Djibasso, Kassoum, thiou, Gorom-Gorom, Ouahobe, Banga, Tapaiko, Darka and Zinibeogo for village hydraulics and pastoral hydraulics. These stations have a capacity of about 15 m3/day. Financial support came from French bilateral aid. Under the same project two SOFRETES MS-7 type pumps were installed at Kongoussi and Barsalogho. While they are destined to village water supply, these two pumps can supply 250 litres of hot water a day each and produce refrigeration (they are equipped with a 150 litre-refrigerator at 3°C). Besides, EIER is planning to supply water to hospitals, stock-breeding centres in communities and rural villages.

225. EIER is engaged in an applied research programme aiming at improving the solar thermodynamic pump components and reduce cost. In order to reduce flat collector costs, it is investigating concrete flat collectors and streaming systems, with a view to have them built locally at 90 per cent. A high efficiency diaphragm-motor has been designed in the school and a patent has been taken out. Research is also carried out to improve the condensor and suit it to local low-hydrometry climatic conditions. Evaporation type condensors would elicit lower temperature in the cold source and reduce its water consumption.

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

(ii) Windmills

227. The Industrial Development Department plans to manufacture locally operational windmills suited to local conditions. EIER has built and installed a windmill at the school for testing. Another model is being tested on a rural location. These devices are meant to pump water from 5 m deep wells. They are made of local material (bamboo and canvas) so that they are easily manufactured by local craftsmen. Extension to refrigeration and power generation is planned. Available results point to maintenance difficulties, particularly as regards the crank-connecting rod system. They are dependable only insofar as maintenance is available. EIER plans to replace this mechanical drive by a hydraulic pump with hydraulic power transmitter down to the immersed pump. Automatic regulation and feathering of the windmill in case of overstrain are also under study.

228. Following the prototype perfecting stage, EIER plans local manufacture of windmills, on a semi-industrial scale. EIER has offered to dispatch kits that could be assembled by local craftsmen after simple training. A locally-produced plastic version is also under study.

229. Some years ago, the World Meteorological Organization (WMO) had worked out a project involving eight windmills for water-pumping. Unfortunately the first windmill had failed expectations and the project was dropped.

Water-heaters and cookers

230. Manufacturing solar water heaters and cookers locally would go a long way towards saving firewood. Water heater prototypes built in Niamey fulfilled expectations and could be manufactured locally. Solar cookers would solve the crucial issue of wood supply and would be instrumental in checking the deforestation process which is assuming alarming proportion. At present, the firewood used in Ouagadougou comes from 50 to 60 km away. In 5 to 10 years time, this distance will be such that supply will be out of question.

Dryers

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

Cooling

232. EIER has undertaken research in the field of refrigeration with solar pumps and windmills with a view to adjoining compressors.

Solar household equipment

233. The Volta Valley Authority is planning to flood some onchocerciasis affected areas (the desease eliciting blindness). Dwellers will be relocated in new villages to be built. The head of Town-planning and Architecture has suggested that these houses be equipped with solar collectors integrated into their architecture for water heating, power generation or water pumping.

Power generation

234. At present nothing is being done in Upper Volta regarding solar power generation. Designs of low-capacity power generating devices would be welcome (1kw) to run well-pumps (3 to 6 m3/hr. from 5 to 25 m head), to secure lighting of part of a dispensary, or medicine-preservation, etc....

235. The Inter-State Rural Development Engineering School (EIER) plans to generate power from thermodynamic solar pumps, with capacities ranging from 2 to 5 kw. This would secure power to small rural communities. EIER puts great emphasis on reliability, since maintenance and spare-part supply is a headache in such countries.

Solar radiation and wind measurement

236. Since 1962 solar radiation measurement has been made by the Meteorological Services through 13 stations equipped with heliographs. Daily sunshine duration is recorded. It is found that annual sunshine duration ranges from 2,800 hrs to 3,200 hrs. These figures match with those in the South of France.

237. 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.

Education and training

238. The Inter-State Rural Development Engineering School (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.

239. There is no constituted authority in charge of solar energy in Upper Volta. This partly explains the lack of solar application programme within the National Development Plan. Institutions involved in solar applications are the following:

(a) at ministerial level: the Planning Commission, the Ministry of Rural Development and Water Resources and Land-Use Planning (ER-MAER); the Industrial Development Department (DDI);

(b) Technical and educational institutions: the Nations Electrical Power Authority (VOLTELEC); the Inter-State Rural Development Engineering School (EIER); the Volta Valley Authority (AAV); Ouagadougou Technical School.

In order to include solar activities in the next national development plan, an organization supervising all solar energy applications in Upper Volta should be established.

240. Among regional organizations that are or could be involved in solar energy, there are:

- the Inter-State Rural Development Engineering School (EIER) in Ouagadougou, a pool of 13 States, 8 of which of the Sahel;
- the Inter-State Hydraulic Study Centre (CIEH) in Ouagadougou;
- the Inter-State Rehabilitation Commission for drought-affected areas in the Sahel (CILSS) in Ouagadougou;
- the West African Economic Community (CEAO);
- the Liptako-Gourma Authority.

It should be noted that CILSS has included a solar energy project in the Compendium of projects approved by the Sahel member States (no. 801).

ZAIRE

241. The present world oil crisis is no doubt a serious hindrance for some non-oil producing developing countries. Zaire, which is an oil producer, is nonetheless affected, given its area and its population. Thus, the addition of solar energy to the development programmes of African countries could go a long way towards alleviating the lack of electric power in rural areas and saving oil energy.

242. 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.

243. As it stands, within the telecommunication network development project, Zaire has acquired several items of equipment such as two wireless beam arteries with a total length of 2,800 km (300 km + 2,500 km). These two transmission paths are made of more than 50 relay stations running on fuel by solar energy would be beneficial to Zaire in this specific area.1/

244. Ten television sets run by photocells are already in operation in Zaire and a telecivision 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.

245. As to power supply to rural areas, it could benefit mainly to public institutions such as schools, dispensaries, hospitals, etc.

246. Lastly, rural development could be extended by solar energy through water pumping for communities.

ZAMBIA

247. 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.

248. Harnessing the vast potential of solar radiation present certain difficulties mainly due to its intermittent nature and great meteorological effects. Many applications require consideration of alternative sources of energy and using energy storage systems.

249. Certain research and development work is being carried out on the utilization of solar energy for such processes 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.

1/ Mr. Mulamba Kapajika, Engineer Head, PTT (Posts and Telecommunications).

250. 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.

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251. 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;

- 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.

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

ANNEX I: INTEREST SHOWN BY AFRICAN STATES

1. African countries have been interested in promoting the utilization of solar energy since 1964 as shown by requests submitted to various United Nations bodies and by the seminars which have been organized at various levels. Some examples of the interest shown are listed below:

(i) In 1965, at the request of the Government of the Niger, ECA and the United Nations Office of Technical Assistance organized a mission to the Sahelian-type countries under the leadership of Professor Trombe;

(ii) At its sixth session held in Cotonou from 21 to 24 April 1971, the River Niger Commission strongly supported a request submitted to UNDP by Chad, Mali, the Niger and the United Republic of Cameroon aimed at promoting the practical use of solar schemes in the Sahelian area of the River Niger basin for purposes of economic and social development. The objective of this project was to create, with UNDP assistance and on the basis of existing structures and resources, a Sahelian solar energy centre and a regional network of centres for developing and testing schemes for the practical use of solar energy and to establish these schemes locally and to ensure that they spread and that the public was made aware of them;

(iii) The rejection of this request by UNDP prompted the Seminar on the Applications of Solar Energy in the Developing Countries, organized jointly by UNESCO and the Government of the Niger and held at Niamey from 25 to 31 October 1972, to recommend the creation of a multinational centre for research and development on the use of solar energy (Resolution No. 1);

(iv) Meeting in Dakar in January 1974, CASTAFRICA considered that the problem of solar energy should be given priority and adopted two important recommendations on it (Nos. 21 and 25). On 30 and 31 May 1974 the second consultative meeting of CASTAFRICA, between ECA, UNESCO and OAU, a decision was taken to keep the use of solar energy in its programme of priorities;

(v) In 1974 the Government of Senegal submitted a request to UNIDO through UNDP concerning the creation in Dakar of a centre for the development and manufacture of facilities using solar energy. This request was formulated pursuant to the official visit made by Mr. Kurt Waldheim, the Secretary-General of the United Nations, to Senegal in February 1974, during which the problem of the use of solar energy was discussed between him and President Senghor. Following the visit correspondence was exchanged between the two and also between the President and his Prime Minister and Mr. Rudolph Peterson, the Administrator of UNDP;

(vi) In support of the Senegalese request, the States members of the Inter-State Committee on Drought Control in the Sahel asked UNDP to

send an inter-agency mission composed of officers, experts and consultants of UNESCO, UNDP, ECA, UNIDO and the Office of Technical Co-operation to the countries in the Sudano-Sahelian area to perform the following functions:

- Visit institutions in Mali, Senegal, Mauritania, the Niger, Chad and the Upper Volta which conduct research into the use of solar energy or are already working on the production of equipment using solar energy with a view to assessing their present activities and examining their plans to continue or expand those activities, with special reference to the financing envisaged for them;

- Determine the usefulness of initiating the experimental production of prototypes of equipment using solar energy, such as solar pumps, desalination equipment, water heaters and refrigerators, which are specially adapted for operation in the conditions of the Sahel region;

- Examine other existing technical possibilities: such as the use of systems for the production of wind power, and the economic justification and the probable costs and benefits of those possibilities;

- Define, as a preliminary exercise, the scope of the research and production activities to be included in a regional programme on the use of solar energy and consider the best way of deriving most benefit, within the framework of this overall programme, from the facilities and activities of institutions existing in the Sahel, taking account of prevailing conditions in this area;

- Recommend the best way of strengthening technical and financial co-operation among the countries concerned with a view to avoiding any dispersion of efforts, overlapping of activities and waste of credits;

- Formulate recommendations concerning the most appropriate location for the establishment of the regional Centre responsible for co-ordinating the activities of the national centre doing applied research in this field;

- Recommend measures to promote concerted action among all organizations and countries undertaking advanced research in this field so as to ensure a direct link between UNDP assistance to the Sahel and the efforts made at the world level, thereby ensuring the maximum effectiveness.

The mission visited Senegal, Mauritania, the Gambia, Mali, the Upper Volta and the Niger from 16 April to 3 May 1975 and submitted a detailed report.

(vii) Since at its meeting in Ouagadougou on 18 November 1974 to consider problems of co-operation in transport and communications, the Committee of Experts of the States members of the West African Economic Community (CEAO) expressed a keen interest in the continuation of the experiments being carried out in certain countries in connexion with solar energy, the Council of Ministers and the Heads of State decided to hold a symposium on the use of solar energy for the economic and social development of the subregion;

(viii) In pursuance of this directive a symposium on the topic "Solar energy and development" organized jointly by CEAO and CILSS was held in Bamako, Mali, from 28 September to 2 October 1976 to consider the following items:

- A rapid analysis of the data on the potential energy resources of the subregion;
- The present uses of energy and the sectoral needs of the member countries;
- The value to the subregion of using solar energy as part of a global approach to the energy problems as they relate to the objectives of integrated development and the economics of energy;
- The present situation with regard to research in solar energy and its applications in the countries of the Community and in the subregion as a whole, etc.

(ix) An increasing number of requests are being received at ECA for the assistance of the Commission's Regional Adviser in Solar Energy to promote the use of solar energy in the member States, including Ethiopia, Rwanda, the Sudan, Liberia, Sierra Leone and the United Republic of Cameroon, etc.

2. All this confirms the strong interest in solar energy which has been aroused in African countries in recent years. The steady rise in the price of petroleum is of course not unrelated to this display of interest, especially since it has now been shown that the traditional sources of energy are not inexhaustible, except for hydraulic power, and that there is still a long way to go before the many pollution problems posed by their exploitation can be solved.

ANNEX II: INTEREST SHOWN BY THE UNITED NATIONS

1. The United Nations Economic and Social Council began to concern itself with new sources of energy in 1956. In its resolution 598 (XXI), it requested the Secretary-General to submit a report to it on the Proposals for the utilization of new sources of energy, such as solar energy, wind energy and geothermic energy. The Secretary-General of the United Nations accordingly assigned five experts to draft a report entitled "New sources of energy and economic development". In its resolution 653 (XXIV) of 26 July 1957, the Council requested the Secretary-General to prepare a progress report on development, together with appropriate recommendations regarding the convening of an international conference on new sources of energy other than the atom and their applications. After considering this interim report, the Council adopted resolution 710 (XXVII) of 17 April 1959, in which it requested the Secretary-General to take appropriate measures for the holding of a conference in 1961 on Solar energy, wind power and geothermic energy considered particularly from the point of view of their application in the least developed countries.

2. In preparation for this conference, three meetings of experts on solar energy, wind power and geothermal energy, were held in 1960, the first in Madrid (23 to 28 May), the second in Grenoble (14 to 17 June) and the third in Rome (27 June to 2 July), during which proposals were made concerning the final agenda of the Conference and an outline of the documents to be submitted to it. In its resolution 779 (XXX) of 3 August 1960, the Economic and Social Council adopted those recommendations, decided to hold the Conference from 21 to 31 August 1961 and accepted the offers of the Italian Government to host it.

3. Pursuant to all these resolutions and recommendations, the International Conference on New Sources of Energy was held at the headquarters of FAO in Rome from 21 to 31 August 1961. A large part of the work of this Conference was devoted to the various applications of solar energy, especially in the least developed among the developing countries.

4. The first African Electric Power Meeting organized by ECA in co-operation with EEC in 1963 requested that the ECA secretariat examine with the competent United Nations bodies the possibility of undertaking systematic surveys of solar radiation and wind conditions in the various member countries to serve as a basis for future studies on the extent to which the use of these two new sources of energy would be economic, these records and studies being entrusted, possibly, to future subregional institutions.

5. In its resolution 113 (VI) of 2 March 1964, ECA recommended the setting up in conjunction with the West African subregional Office of the Commission at Niamey, of a solar energy experimental centre. This centre was to be responsible for perfecting the various prototypes of solar apparatus and for

disseminating the results and experiences. This proposal was taken up and adopted by the United Nations Economic and Social Council in its resolution 1033 (XXXVII) of 14 August 1964.

6. In pursuance of this resolution, ECA sent two missions to Niamey, one in August 1964 and the other in January 1965, within the framework of Israeli bilateral assistance. In the course of the second mission, two solar collectors were installed at the meteorological station at the Niamey airport to measure the amount of solar energy they were likely to use.

7. In response to a request by the Government of the Republic of the Niger, the United Nations Office of Technical Co-operation requested Mr. Felix Trombe, Director of Research at the Centre national de la recherche scientifique (CNRS) in France and of the Solar Laboratory at Mont Louis, to assist in leading a United Nations mission on solar energy in the Sahelian-type countries from 22 February to 12 March 1965. The purpose of that mission was to advise on the orientation of the work to be carried out by the proposed Centre with reference to the services it could render to all the African countries in the Sahelian zone with comparable insolation conditions.

8. In the course of their visits to Niamey, Tahoua, Agadez and Zinder (Niger); Bamako (Mali); Nouakchott (Mauritania); Dakar (Senegal) and Ouagadougou (Upper Volta) the members of the mission met with the competent authorities of the various countries concerned and talked with them concerning those applications of solar energy most likely to satisfy the needs of their population, the steps already taken in that connexion and the possibility of their co-operating in the work of the experimental centre at Niamey.

9. In following up the report of that mission, the United Nations Natural Resources and Transport Division approached a number of solar institutions and laboratories with a view to enlisting their support in the implementation of the mission's recommendations. In that connexion, contact was made with 17 recognized authorities in various parts of the world (Asia, America, Europe and Australia).

10. The initiative where the Niamey experimental centre was concerned passed out of the hands of ECA and into to those of the Economic and Social Council. At the same time the United Nations Technical Assistance Office took steps to recruit an expert in solar energy and to study the market with a view to acquiring equipment for the base station at Niamey, a list of equipment having been provided by Professor Trombe in advance.

11. An Australian expert in radiation and solar energy measurement visited Niamey from 13 December 1966 to 29 May 1967. He was replaced by another expert in solar energy measurement, who stayed in Niamey from 1 July to 30 September 1967. This French expert was scheduled to carry out another mission there from 1 April to 30 June 1968.

12. A regional seminar on solar energy and its applications in Africa organized jointly by UNESCO and the Government of the Niger was held at Niamey from 25 to 31 October 1972.

13. UNESCO sponsored an international conference on the topic "The sun at the service of manking", which was held in Paris from 2 to 6 July 1973. Following this important world conference, this United Nations specialized agency concerned itself greatly with the problem of Research and Development in the field of solar energy, especially in the developing countries.

14. The foregoing led to the joint organization of a seminar on solar energy by UNESCO and the World Meteorological Organization (WMO) in August and September 1976. Representatives of the countries members of the Inter-State Committee on Drought Control in the Sahel (CLISS) took part in this seminar with UNDP financing.

15. Prior to the seminar, the United Nations Development Programme had, at the request of the countries members of CILSS, organized an inter-agency mission composed of representatives of UNESCO, UNIDO, ECA, the United Nations Office of Technical Co-operation and UNDP, to study the conditions relating to the use of solar energy in the Sudano-Sahelian countries.

16. At the Second African Meeting on Energy organized by ECA in Accra from 8 to 19 November 1976, the view was expressed that "measurement data on solar radiation were inadequate and should be supplemented by improving existing stations, since such data were valuable for development of remote rural areas where energy supply was difficult and extremely expensive and where solar energy could help to satisfy energy needs". It was also felt that "the best way to obtain such information was through an expanded network giving standardized information on solar radiation". Stress was also laid on "the need to manufacture solar energy equipment using materials available on African markets, instead of importing, it at high cost" and to co-operate to that end without neglecting "the problem of training in that field".

79. Consequently the meeting made the following recommendations with regard to non-conventional energy sources and new energies:

- "The inclusion by African Governments in their development plans, with priority status, of projects for the development and utilization of new energies in general and of solar and wind energy in particular, such projects benefiting from a special domestic financing efforts, and active and sustained participation by those Governments in the promotion of scientific and technical research on new energies;
- The introduction of studies of new energy utilization in school and university curricula and the strengthening of existing national institutions for solar energy research, experimentation and applications in Africa;
- The establishment, with assistance from WMO, of a network of observation and measurement centres to supplement the existing meteorological

network, with a view to obtaining data as full as possible on meteorology, solar radiation and wind speeds, as well as the organization of visits by WMO experts to countries on request, so as to assist in identifying the specific problems of each country and proposing appropriate solutions;

- The encouragement of the establishment of new national centres everywhere where that may be necessary and useful, as well as the establishment of a regional centre for liaison and co-ordination in the field of research and development on solar energy utilization with assistance from ECA, WMO, UNESCO, UNDP and United Nations Headquarters;

- Encouragement of the popularization and local manufacture of machines using solar energy and the promotion of local industries in all fields of construction, metallurgy, glass-making, mechanical and electrical engineering so as to reduce the cost of machines made in Africa;

- Improvement of the standards of living of researchers and the granting to them of positions of status which will motivate them to devote themselves to research on a permanent basis as well as the establishment of a system of bonuses and prizes to further encourage research activities".

17. In consideration of these recommendations, ECA included a number of activities related to solar energy in its current programme of work and agreed, inter alia, to:

- Furnish, on request, consultancy services in respect of the expansion of existing solar energy centres, the creation of new research and experimentation centres and the setting up of a multinational solar energy centre to service the Sudano-Sahelian area;

- Encourage the popularization and the local manufacture of equipment using solar energy;

- Ensure that courses on new sources of energy, including solar and wind energy, were included in school and university curricula;

- Give encouragement and assistance to the establishment of observation and measurement centres to supplement the existing meteorological network and obtain additional data on solar radiation in the various economic subregions of the continent;

- Encourage and promote multinational co-operation with regard to the practical use of solar energy.

18. The Commission is pursuing its activities in this respect, and an expert in solar energy whose services were made available by the French Government within the framework of its bilateral assistance to ECA, has already carried out a number of missions mounted to follow up on the requests submitted by several African countries in respect of the practical use of solar energy.