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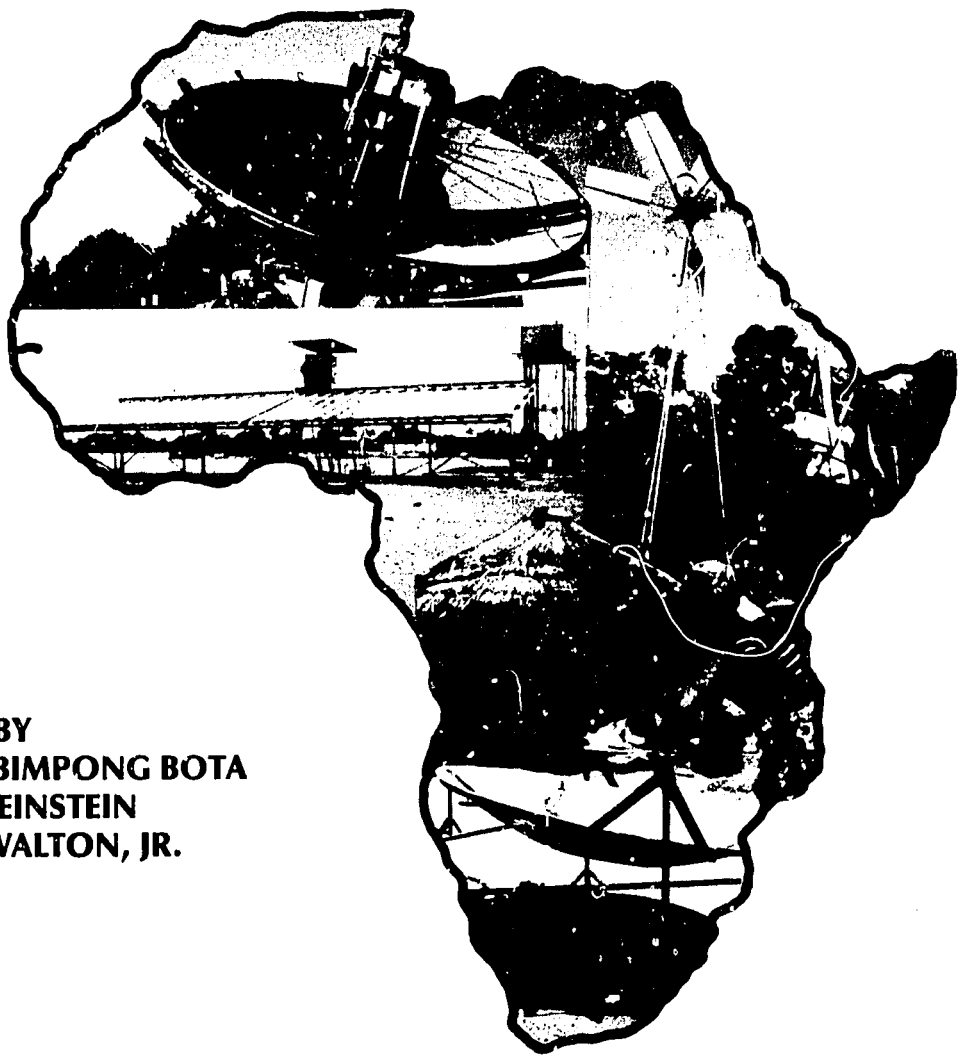
African Solar Energy Workshop

May 21-26, 1979, Atlanta, Georgia U.S.A.

VOLUME I SUMMARY REPORT



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OCTOBER 1979

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PROCEEDINGS OF THE AFRICAN SOLAR ENERGY WORKSHOP

May 21 - 26, 1979, ATLANTA, GEORGIA, U.S.A.

VOLUME I: SUMMARY REPORT

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OCTOBER 1979

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FOREWORD

Since time immemorial, mankind has exhibited an inordinate fascination with the sun and its influence as the center of our solar system. More recently, attention has been focused on its energy capabilities for regulating life, chemical and physical change and the yielding of its secrets to the inhabitants of the earth. The enormous changes in the world economy precipitated by political, economic, cultural and social dynamics impacting on the production, distribution, conservation and utilization of fossil fuels necessitate the search for energy alternatives for the remainder of the twentieth century and beyond.

The Atlanta University in cooperation with the Georgia Institute of Technology welcomed the opportunity to co-host the African Solar Energy Workshop. The timing and substance, related to defining, assessing and sharing scientific and technological understandings about solar and other alternative energy technologies between American and other developed world scientists, technologists and policy-makers on one hand, and their African counterparts on the other hand, hold great promise for development.

Support from the United States government, the United Nations system, the al Dir'iyyah Foundation and the academic community has made this initial conference possible. We look forward to effectuating major ties between African and American scientists and technologists through our respective universities in unlocking secrets of the universe that might provide energy alternatives for us all, but especially for Third World countries whose economics are engaged in accelerated levels of modernization.

Cleveland L. Dennard
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October 1979

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the United States Agency for International Development, USAID
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the Solar Energy Research Institute, SERI
the United Nations Development Program, UNDP
the United Nations Environment Program, UNEP
the al Dir'iyyah Institute of Geneva, Switzerland

A project of this magnitude would not have been possible without the sustained help of many individuals, who gave generously of their professional and personal time and effort; to them we express our heartfelt appreciation. Among these were Mr. John Blumgart of the Africa Bureau, USAID; Mr. Murrey Goldberg and Dr. Charles Berberich of the Division of International Programs, USDOE-SERI; Ms. Odile Sorgho of the Africa Bureau, UNDP; Dr. Essam El-Hinnawi of UNEP and Dr. Lawrence Ervin of the al Dir'iyyah Institute. Our very special thanks go to Dr. David French of the Africa Bureau, USAID and Mr. Tilahun Wubneh of the Office for Projects Execution, UNDP, for working with us on an almost daily basis throughout the planning phase of the Workshop. We also thank Mr. Jim Bever of the Institute for Energy Research, State University of New York at Stonybrook for serving as a consulting editor for the preparation of the proceedings.

Special thanks are expressed to the Mayor of Atlanta, the Honorable Maynard H. Jackson for taking time from his busy schedule to be the keynote speaker at the opening session of the Workshop. His inspiring address set the tone for the deliberations which took place on the subsequent days of the Workshop.

We cannot fail to mention the untiring efforts of many individuals to make the two week stay of the African participants in Atlanta memorable and most enjoyable. Among these individuals were Mr. Robert Thompson of the United States Department of Housing and Urban Development, Atlanta, Georgia and Ms. Carol Hinton of the Council for International Visitors, Atlanta, Georgia.

We are indebted to the staff of the Workshop secretariat for the very fine job they did to provide smooth coordination of all the arrangements: to Ms. Ingeborg Wichmann of Washington, D. C., for putting together the brilliant team of bilingual (French-English) interpreters and to Mr. Sailor Harlow and his colleague from the Danish Interpretation Systems, Inc., for the excellent technical support they provided to the interpreters. Last, but not least, great tribute must be paid to, and very special thanks go to, Mrs. Marian Bota, Ms. Te Burt, Ms. Claudia Huff, and Ms. Geoffrey Baker Roberts for working so hard and selflessly to see this project completed, through the publication of the first volume and the much more comprehensive Volume II of the proceedings.

Kofi B. Bota
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J. D. Walton, Jr.

Atlanta, Georgia
October, 1979

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I. INTRODUCTION

The global impact of diminishing fossil fuel resources and rapidly rising oil prices have focused attention on the serious energy problems facing the less developed countries (LDCs) of the world. With a small technological base and low levels of socio-economic development, LDCs depend heavily upon human and animal power for mechanical energy, and upon fuel wood for thermal energy. Since wood is the primary source of thermal energy in the LDCs, development leads to a vicious cycle of over-population and over-consumption of available firewood, deforestation, siltation, flooding, and reduced productivity. Nowhere is this combined energy, environmental, and social problem more serious than in sub-Saharan Africa. The environmental problems associated with normally small amounts of precipitation in the sub-Sahara have become even more serious during this decade because of below-normal rainfall. The combined tasks of reducing the requirement for firewood and at the same time providing the water needed to reverse the process of deforestation have been considered by some to be the most profound ecological challenge of the late 20th century.

Since the mid 1950s, there has been growing interest in the development of renewable energy resources. One of the most popular and perhaps the most promising among these is solar energy. During this period, a number of concerned organizations and individuals began to consider the growing energy problems of the third world and began to experiment with the use of solar energy as a means of satisfying energy needs. In general, these efforts have not been successful on a significant scale, for technical, economic, social, or political reasons. They have, however, served to identify and establish priorities among the most serious energy problems facing the LDCs and to bring these problems to the attention of the rapidly growing solar community.

In recognition of the state of solar energy technology in the third world as well as the potential of solar energy for helping to solve the energy problems of Africa, the African Solar Energy Workshop was conceived. The objectives of this workshop were (1) to bring together a cross section of African energy experts and social scientists to share their experiences, ideas and plans for applying solar technology to the needs of their countries, and (2) to bring energy technologists, social scientists, and policy experts from the United States and other developed countries together with the Africans so that they might have a deeper and more personal understanding -- and an appreciation for the needs, problems, and resources -- of the African community. The time and place for the Workshop were selected to coincide with the 25th anniversary Congress of the International Solar Energy Society so that the African participants might have the opportunity to see the current state of solar energy research, development, and application throughout the world.

Through the activities of the Workshop, the publication and distribution of the proceedings, and the establishment of lines of communication among African countries and between these countries and developed countries, it is hoped that a significant contribution will have been made in helping to solve the energy problems of the people of Africa and, ultimately, to contribute to the development of solar energy technology to help meet the energy needs of all of the less developed countries of the world. The proceedings are being published in two volumes. Volume I includes the summaries of the topical Workshop discussions, the recommendations made at the plenary session and the abstracts of the country presentations made by the African participants. The full details of the Workshop discussions and the deliberations of the plenary session will be published in Volume II, which will also include the papers submitted to the Workshop.

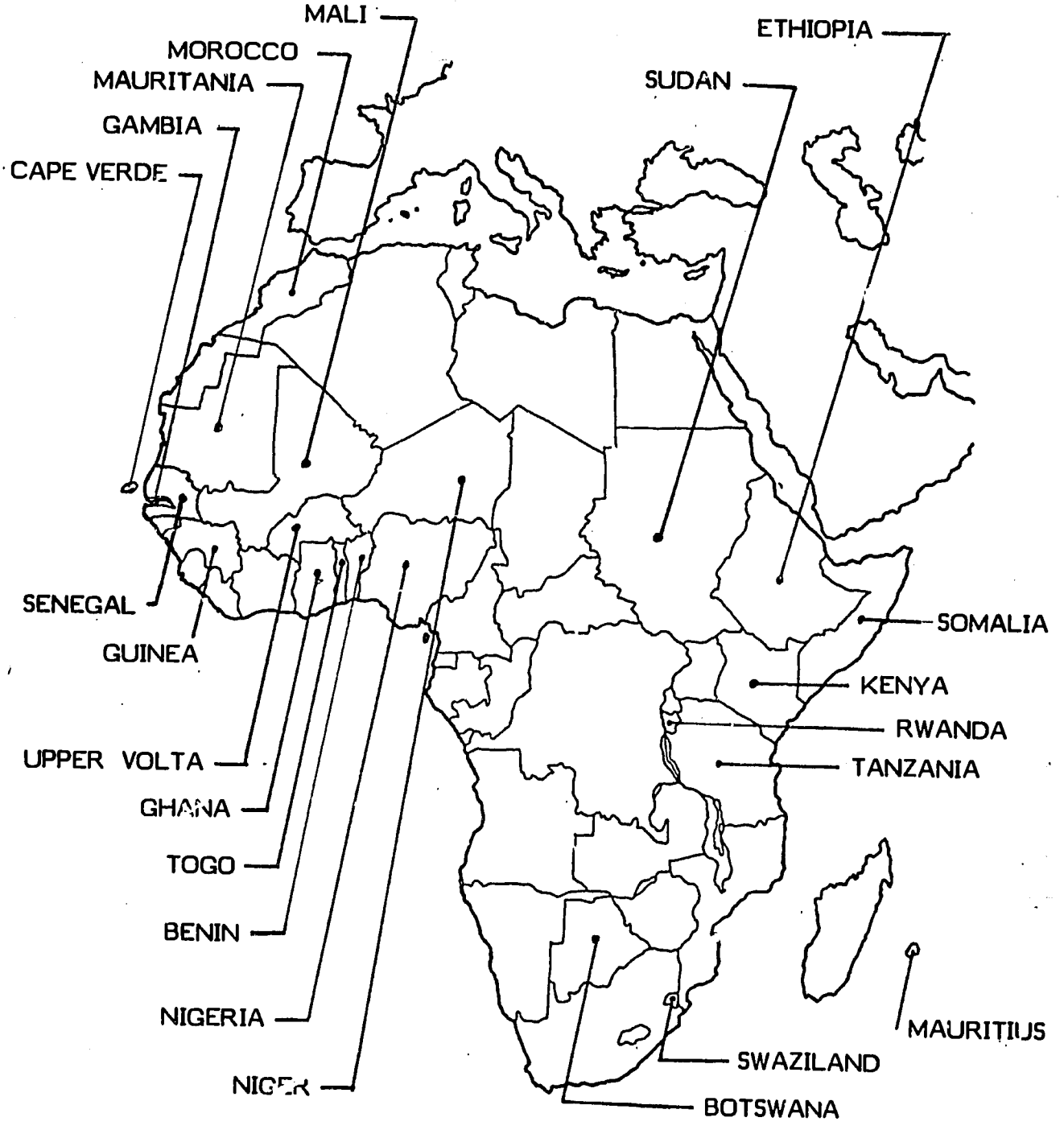

Figure 1: Map of Africa showing countries represented at the Workshop.

II. BACKGROUND

During 1977, Georgia Institute of Technology conducted a state-of-the-art survey of solar powered irrigation pumps, solar cookers, and wood burning stoves in sub-Saharan Africa for the al Dir'iyyah Institute. Sixteen countries in the region were identified as those most affected by the problems of deforestation caused by the extensive cutting of firewood and the devastating effects of inadequate water for agriculture and the support of life. Although the problems are essentially common among these African countries (and it is, thus, possible that common solutions may be found), the approaches and ability to realize solutions to these problems are as diverse as the countries themselves. Also, it was found that a serious need existed to improve communications among these countries and between them and the developed countries which have access to the technology and resources necessary to help solve their energy and ecological problems.

Concurrent with the conduct of this survey, Georgia Tech was also in the process of organizing the 1979 International Congress of the International Solar Energy Society (ISES) which was to be held in Atlanta, Georgia during May 28-June 1. The 25th anniversary of ISES was expected to bring together the largest delegation of international solar energy experts ever assembled. Thus, the idea was conceived for holding a sub-Saharan African Solar Energy Workshop in Atlanta, Georgia the week prior to the ISES Congress. By conducting the Workshop at this time, it became possible for the participants to attend the solar energy Congress to obtain the latest information on solar energy activities and developments throughout the world, and to visit displays and exhibits of the latest hardware and other practical, operating solar energy devices. Also, by presenting the results of the Workshop to the ISES Congress, a large portion of the solar community would then be brought up to date on the status of energy activities in sub-Saharan Africa and be made aware of the energy problems and needs of this important segment of the third world.

Because of Georgia Tech's long and close association with Atlanta University in areas of research and education, and because of Atlanta University's many contributions to the black heritage, demonstrated achievement in science, technology, and the humanities and its deep concern for the disadvantaged of the world, it was natural that the Solar Energy Workshop should be developed jointly by Georgia Tech and Atlanta University.

Responding to proposals for assistance in conducting the Workshop, offers of financial support were received from the United States Agency for International Development, the United Nations Development Programme, the United Nations Environment Programme, the Solar Energy Research Institute, the United States Department of Energy, and the al Dir'iyyah Institute of Geneva, Switzerland. With these offers came suggestions to include African countries other than the sub-Saharan group earlier identified. The addition of these countries made the Workshop much more continental in scope; thus, the name "African Solar Energy Workshop" was adopted. Unfortunately, as the program was expanded to include additional countries, financial assistance was not increased, so that is was possible to support the attendance of delegates from a total of only 24 African countries. Although the 24 countries selected included all geographic regions of Africa, many other countries with significant solar energy experience, expertise, and major national solar energy programs could not be invited because of the limited funds. Included among those who could not be extended an invitation were Algeria, Libya, and Egypt; it therefore

appeared to some that the workshop intentionally excluded northern Africa and that the designation of the Solar Energy Workshop as African was not appropriate. For this reason, we wish to stress that, in considering future meetings or other activities which might result from this Workshop, and in establishing lines of communication between African countries, all African countries should be included. Certainly the experience and information available from the developing national solar energy programs and on-going solar energy activities in Libya and Egypt and the long history of solar energy research, development, and demonstration in Algeria make these countries essential participants in future meetings or workshops involving African countries.

III. PURPOSE AND SCOPE OF THE WORKSHOP

This Workshop brought together selected representatives from those African countries which are most affected by critical energy problems resulting from increasing energy costs, population growth, and deforestation. Participants considered the role that solar energy may play in alleviating these problems. The Workshop concentrated on the status of on-going solar and other alternative energy activities in each African country represented, with particular attention given to (1) documenting efforts to introduce solar energy technology into the village or rural situation and (2) the identification of social, cultural or ecological conditions which may have contributed to the success or failure of such efforts.

Forty-four (44) participants from twenty-four (24) countries in Africa were invited. In the case of those countries from which two were invited, one was to be a person actively involved in applying alternative energy technologies to his country's energy needs and the other a person familiar with village life and culture as they are affected by present energy, environmental, or economic problems and by the introduction of solar and other alternative energy technologies. Other energy technologists and social scientists from North America, Europe, and international agencies were invited to participate and share experiences concerning existing, mature alternative energy technologies which could be readily and economically adapted to the needs of African and other third world countries. Following the Workshop, many of the African delegates attended the ISES Congress, at which the results and recommendations of the Workshop were presented.

Each participant from Africa was asked to prepare a three-to-four thousand word paper (with photographs, charts, tables and bibliographics appended). These papers will be published in the second volume of the proceedings. Participants had the opportunity to discuss these papers in a variety of forums during the five-day workshop: as part of one of twenty-four (24) specific country reports, in group discussions with fellow technologists or social scientists, and in a regional format with both technologists and social scientists whose countries have similar climates, topographies, and resource endowments.

All of the participants from Africa were asked to address five key issues related to solar technology innovation in their countries: (1) needs assessment, (2) resource assessment, (3) technology design and implementation, (4) field test and evaluation procedures, and (5) diffusion and accomodation of new technologies. The solar energy technologists reviewed the current status of energy use in their countries and reported on field experiences with solar technologies, especially in relation to the different types of energy needs prevalent in Africa today. The social scientists focused on social, cultural, and economic characteristics of their countries (and the principal regions of their countries) which are most likely to interact in significant ways with solar technology innovation. Special attention was paid to techniques for conducting research before innovation and during the diffusion process, and for evaluating the social impact of solar and other energy technologies.

The purpose of these presentations was to stimulate an exchange of views among specialists representing a wide range of national and disciplinary orientations. A principal objective of the Workshop was to recommend areas for future solar energy activities and to encourage research collaboration on a regional and a continental level. To these ends, the participants were asked to address problems such as: variations in local resource endowments which affect appropriate production and use of alternative energy technologies in general and solar technologies in particular; local norms, institutions, family and kinship organization, ethnic values, and related factors which are likely to be impacted by solar innovation; and the need for village-level participation -- through education and community organizations -- in the engineering, implementation, and utilization of solar and new alternative energy technologies.

Figure 2: The Honorable Maynard H. Jackson, Mayor of Atlanta, delivering the keynote address at the opening session.

Figure 3 Shown from left to right at the opening session are: Dr. Essam El-Hinnawi of UNEP; Mr. John Blumgart of USAID; and Mr. To Van Tong of UNDP.

Figure 4: Dr. Checkne Traore of Mali registering for the Workshop.

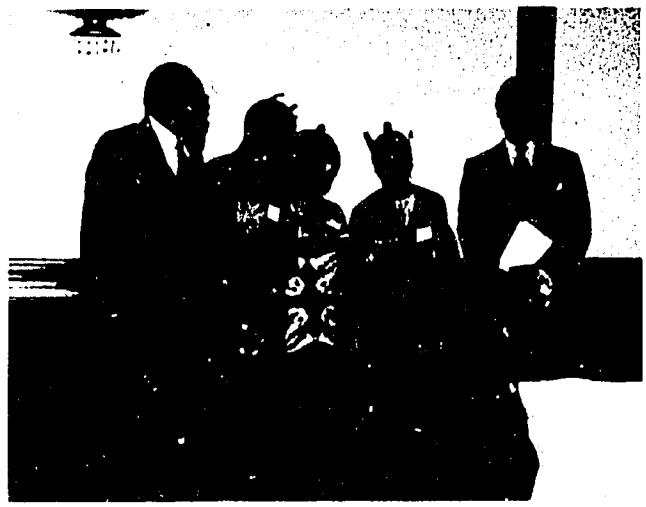

Figure 5: Mayor Maynard H. Jackson and Dr. Cleveland L. Dennard, President of Atlanta University with the Swaziland delegates. From left to right: Dr. Cleveland L. Dennard, Harry Dlamini, Linda Vilakati, Abraham Tsabedze and Mayor Maynard Jackson.

Figure 6: Christian Okolo of Atlanta University, Charles Ntakirutinka of Rwanda, S. Wane of Senegal and I. Cisse of Senegal talking with the Mayor of Atlanta.

Figure 7: Dr. Ghebru Wolderghiorghis of Ethiopia chatting with guests at the opening session.

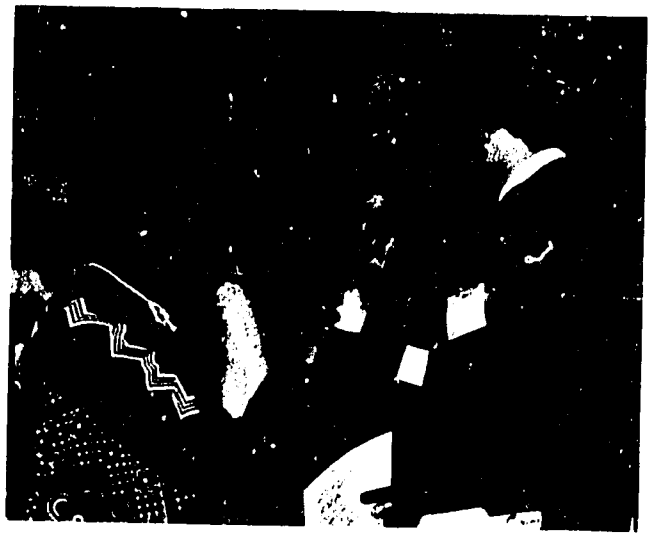

Figure 8: Dr. Jay Weinstein and his spouse chatting with Abraham Tsabedze of Swaziland.

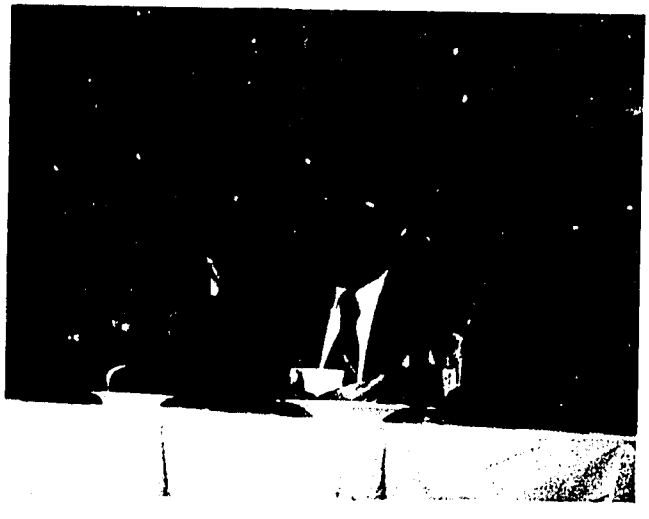

Figure 9: Kofi B. Bota, Workshop Director and J. D. Walton, Workshop Organizer.

IV. SUMMARIES OF THE PROCEEDINGS OF THE WORKSHOP SESSIONS

In the following pages, the major issues and themes discussed at the various workshop sessions are reported. This material is the result of the distillation and editing of many hours of conversation and debate that extended over five long days. Numerous subtleties, details, and qualifications will, therefore, be evident only upon examination of the full transcript, which will appear in Volume II of the proceedings. Nevertheless, certain points were made so clearly and insistently (and, often, by several different individuals and groups) that they can serve to indicate the general course of the Workshop.

Four general subject areas appeared to dominate the discussions at most or all of the sessions, and might be highlighted here. These are (1) the urgency of immediate energy needs, particularly but not exclusively in the rural areas, in the face of resource depletion, environmental change, and general poverty and lack of education among energy users; (2) the complex interpenetration of technical, economic, social, and cultural aspects of alternative energy development, implementation and, diffusion; (3) the need to explore diverse traditional and new energy systems rather than to search for a single technology which can respond to the great variety of needs and conditions which characterize contemporary Africa; and (4) the very early stage at which most alternative energy research and development now exists and the consequent pressing need for resources to support future work in these areas.

In specific instances during the topical workshops, discussions of technical and social aspects, regional discussions, and the plenary session, these issues were raised, debated, and their relationship to one another examined. From this interchange it becomes increasingly apparent that the effective development of Africa's energy resources and technologies is a multi-faceted, multi-disciplinary problem whose solution will require a, perhaps unprecedentedly, high degree of cooperation, communication, and material support. Current energy use patterns, sources, and applications in Africa are the result of a complex combination of traditional practices, environmental factors, and political relations. The alteration of these patterns through alternative energy innovation or better management of present systems must be based not only on the best equipment and technical know-how available, but it must also proceed with due sensitivity to traditional, environmental, and political realities. Thus, the challenge for the future is enormous. At the same time, as is amply documented in the proceedings which follow, the general recognition of the gravity of the present situation and the common desire to meet the challenge on the part of those involved suggest that this challenge can and will be met.

TOPICAL WORKSHOPS A. DISCUSSION OF ENERGY PROBLEMS, USES, NEEDS, AND RESOURCE ASSESSMENTS.

Chairpersons:

A. Diallo, Guinea; W. Ghebru, Ethiopia; S. Wane, Senegal; A. Dondo, Kenya

The patterns of energy use in contemporary Africa vary in detail from country to country and between regions within each country. These variations are related to several factors, including climate, geography, type of social and economic system, and general level of development. One of the most significant differences in energy use patterns (as with most other aspects of energy in Africa) is that which exists between more and less urbanized areas. In and near the major cities, both domestic and public uses are characterized by large scale centralization, and in some cases, formal delivery and maintenance systems (e.g., hydro-electric power grids, centralized residential heating, and public utilities). In the countryside, villages, and smaller towns, where 80 percent of Africa's population continues to live, energy use is shaped by the small scale, decentralization, and informal nature of both residential and non-residential activities.

In the rural areas of Africa, three general sets of activities dominate energy use: domestic, agricultural, and small scale (or cottage) industry. It should be noted that it is frequently the case that all three activities take place at one site, i.e., at the family farm on which handicraft or another type of small-scale industry is located. This often means that the same sources and general use patterns (though not necessarily the same quantities of energy consumed) do now and might in the future serve all three needs simultaneously. In the city, on the other hand, home and economic activity are generally separated, and vast discrepancies can -- and do -- exist between the types, quality, and quantity of energy available for different purposes. Furthermore, urban energy use patterns are not (directly) affected by demands from agriculture; thus, an entire range of uses (including crop-drying and fertilizer production) are, at present, specifically rural. Instead of agriculture, formal large-scale <u>industrial</u> activity contributes (to varying degrees between African cities) to the shaping of energy use patterns in ways which do not (directly) affect energy use in the countryside.

Among all of these activities, urban and rural, first priority must be given to domestic uses: cooking, lighting, heating, grain-grinding, waste management, and delivery of potable water. Once these basic necessities are addressed, energy must be directed toward those activities which bring improvements in living standards: agriculture, cottage industries, transportation and, in the cities, larger-scale industry. In general, energy use in the rural areas of Africa, at their present state of development, provides the bare minimum for survival. Thus, very little energy actually remains for the improvement of quality of life or productivity.

Very few people in either the urban or rural areas of Africa can afford to consume commercial sources of energy. Non-commercial sources, which lack formal delivery and maintenance systems, continue to dominate use patterns in the countryside and, to a large extent, even in the larger cities.

As a source unto itself and as it is associated with the use of other types of energy, human and animal muscle power continue to play a major role. This, often-cited, labor-extensivity in the home, in agriculture, and in industry has a bearing on several aspects of energy use in Africa. Perhaps most significant is the fact that any alteration in source or consumption patterns is bound either to displace workers or to alter the character of the labor market (formal and informal) in other ways. The social and economic costs and benefits of such alterations, especially in highly rural areas in Africa, where alternative employment is scarce, are manifold, complex, and -- in most instances -- largely unknown.

Beyond human and animal labor, most of the energy used in rural areas comes from renewable sources. Yet, energy use patterns are generally wasteful: only a small proportion of usable energy in raw materials is consumed, and resource management is not practiced on an adequate scale. One result of this is widespread environmental degradation, especially deforestation in many countries. In various regions, especially in the Sahel but elsewhere as well, the lack of vegetation has combined with other environmental changes to bring about widespread desertification. As the percentage of non-productive land increases, the very renewability of the "renewables" is in doubt.

Domestic uses, especially in rural areas, are served by renewable sources such as wood, charcoal, dung, vegetable oils, and agricultural residues. Various applications of wind and solar energy have existed, some of them for centuries, for drying, cooling and heating, and -- in agriculture -- for crop preparation. In addition to these sources, some use is made of kerosene, methane gas, diesel (e.g., for generators), petroleum gas, butane and, from various sources, electricity. Some use is also made of biogas and biomass conversion, as well as chemical fertilizers, but, in general, firewood and charcoal predominate (and thus continue to strain forest resources).

Economic activity in the rural areas, agricultural and cottage-industrial, consumes energy from most of these same sources. Here, however, production processes -- rather than heating, lighting, etc. -- predominate. This allows for greater utilization of passive solar and wind energies and of most of the small amounts of electricity and petrochemical sources which are available.

In the urban areas, greater (but still relatively little) use is made of electricity -- hydro- and coal-powered -- and imported oil. While domestic uses do consume some of this energy, a large portion goes to formal sector industrial, commercial, and administrative purposes, and to serve urban transportation and communication systems. In most homes, even in the larger cities, and, to some extent in the smaller-scale (informal sector) urban industries, charcoal, wax, kerosene, and other traditional fuels continue to be used.

It is abundantly clear that reliable information about actual energy uses, energy needs, and the effects of alternative energy sources in Africa is scarce. Much work needs to be undertaken to assess energy resources and prospects. Available and reliable sources of information apply almost exclusively to the commercial, largely urban, sectors. Yet the majority of the energy users in Africa depend upon non-commercial rural, and non-formal sources. Electricity boards and commissions charged with management of particular sources of energy can provide only a partial picture of actual and future needs.

In some ways, villages and urban dwellers are aware of the nature of the resources which are employed in their homes and economic activity. Their participation in needs assessments and evaluation of current resources is necessary and can be effective. But a well-organized effort is still required in which government agencies, scientists, technologists, and social scientists participate along with local farmers' organizations and urban dwellers' associations, in developing an accurate and reliable body of knowledge about energy use patterns and prospects.

The dwindling and uncertain supply of energy in rural areas is among the most urgent problems in Africa today. The highest priority should therefore be given to the endowment of local and governmental organizations with the necessary personnel, financial resources, and equipment to undertake rational energy assessment in the rural areas. Such assessments would provide a good basis for the formulation of effective development policies.

Since energy use affects and is affected by a variety of social and cultural factors, e.g., family life, political and ethnic relations, sex roles, and the use of leisure time, it is essential that research on energy use deal not only with technical and economic factors but with these sociological parameters as well. Knowing how, when, and why energy is used and understanding the values and practices associated with energy use is as important as knowing the types and quantities of energy consumed. Similarly, when future needs and possible alternative energy resources are considered, it is necessary to anticipate and account for the types of social and cultural changes likely to occur under various conditions, and for the effects of different technologies, as well as economic cost/benefit and technical factors.

Solar and other renewable energy forms can restore the energy balance in rural households, farms, and small scale industries (as well as in much of the urban sector). But, regardless of the specific innovations and developments undertaken, such projects must be adapted to actual use patterns, the types and quantities of local resources available, and the lifeways of the energy consumers. They must be supportive of general developmental goals, and perhaps most importantly, they must be based on an adequate store of knowledge about actual use patterns -- formal and informal; household, agricultural, and industrial; urban and rural.

TOPICAL WORKSHOPS B. DISCUSSION OF ALTERNATIVE ENERGY TECHNOLOGIES, PROBLEMS OF DEVELOPMENT, INTRODUCTION, FIELD TESTING AND ACCEPTABILITY

Chairpersons:

J. Lamadieu, Upper Volta; L. Vilakati, Swaziland; S. Hurry, Mauritius; A. Tsabedze, Swaziland

Various types of solar and other alternative energy technologies have been tested and, to an extent, diffused in several African countries. These technologies are at different stages of development, ranging from highly experimental to fully tested and implemented, but most are quite new and require further study.

Biogas and biomass systems are among the non-solar sources most frequently cited as having promise for such uses as drying, distilling, heating, and cooking. The achievements of India, China, and on a smaller scale, some of the African countries in converting vegetable, animal, and even human wastes are noteworthy, not only because of the technical advantages of such systems, but also by virtue of their demonstrated effectiveness (as in China) when combined with a well-functioning extension network.

Other non-solar, alternative energy sources which have been tested and/or planned for the rural areas, especially, are wind power, pyrolitic conversion which produces charcoal, gas, and oil from rice husks, sawdust, and other agricultural waste products, alcohol production from, e.g., molasses, and hydroelectric and geothermal power. Small-scale windmill production (for water pumping and electricity generation) is one example of a technology which appears to hold promise for certain regions, but which requires further work in order to simplify design and to make greater use of locally available material.

Several different solar energy systems have been tested in household, agricultural, and industrial applications. Flat plate collectors have seen limited use for heating and distilling, and a variety of solar dryers for preparing cereals, fish, and meat have been developed. Solar water heaters are now in production in at least one or two countries and solar cook stoves have been tried -- and a few adapted -- throughout the continent, as is the case with other alternative energy technologies. However, the wholesale replacement of traditional energy sources and technologies remains in the distant future, if indeed wholesale replacement of traditional sources is desirable. Several complex problems -- not, by any means, all of them technical -- remain to be solved before solar, biogas, wind, or other alternative technologies become widely diffused and accepted.

One such problem centers on the need to assure that, once solar and other alternative energy systems are in place in the village or urban center, they are durable, reliable, and continue to work as they were intended. The solution to this problem lies in a two-fold effort to (1) simplify design or, perhaps more accurately, assure that the design of these systems is based upon principles with which producers and consumers (where these are different parties) are familiar and (2) train potential users how to operate, maintain, service, and -- eventually -- manufacture such systems. This approach requires, in turn, cooperative and well-supported research on

appropriate energy technology involving specialists from different countries, from government, the universities, and representing various scientific, social scientific, and technical fields. At the same time, it is necessary to assess the likely economic, social, and cultural impacts associated with each specific technology (as its effects are experienced in different countries and in different geographic, economic, and cultural regions within countries). Eventually, attention must be directed toward the development of national, regional, and local extension networks to prepare potential users for the introduction and successful utilization of alternative energy technologies. In this instance, the experiences of agricultural extension workers in Africa and industrial extension services in Africa, China, and elsewhere may be most valuable.

A related problem which requires attention before widespread use is made of new energy sources is the frequent lack of acceptance of these innovations for psychological, social, or cultural reasons apart from the lack of operative know-how per se. Limited instances exist in which villagers have been consulted on questions of design or implementation; but, in general, alternative energy systems and devices are ordinarily designed without due account of the traditional (widely varying from region to region, tribe to tribe, and ethnic group to ethnic group) technological and aesthetic principles to which potential users are accustomed. Furthermore, insufficient attention has been paid to the disruptive effects which new technologies are likely to have on the local division of labor and the distribution of time between work and leisure. As a result, it is frequently too costly -- in non-tangible, but nevertheless essential, ways -- for householders, farmers, or craftsmen to employ these innovations, despite the fact that an arguable economic advantage would be gained through acceptance. In Africa, as elsewhere in the third world, "purely" economic or technical aspects of energy use are combined with familial, ethnic, political, and ideological aspects in actual day-to-day household and commercial activities. The successful design and implementation of alternative energy technologies cannot assume these factors away in the attempt to develop ideal prototypes.

The design of new energy systems must incorporate labor intensivity, local resources, and ease of operation; and these systems must, in form and function, include a base in (rather than ignore or, worse, insult) local wisdom and values. To achieve this degree of appropriateness, and to insure that these systems are not overspecified before they reach the user, that they do not offend certain segments of the community, and that they do not create or exacerbate unfair political advantages or economic competition, substantial resources are required for research and development. This situation poses a challenge to African scientists and technologists, national and local governments, and donor nations and international organizations to provide substantial material and administrative support for alternative energy innovation. A high degree of organization and a sound knowledge base -- both of which are demanding of time, money, and labor -- are required in order to achieve the energy balance in rural Africa (and in the cities) which solar and other alternative energy sources can bring. Above all, however, the immediate problems of deforestation, desertification, and the management of existing resources continue to demand the attention of African energy specialists and citizens.

DISCUSSIONS OF TECHNICAL AND SOCIAL ASPECTS OF ENERGY APPLICATIONS

Chairpersons:

E. Paraiso, Benin; F. Taylor, Botswana; K. B. Dickson, Ghana; L. O. Jobe, Gambia.

Recent research in Africa, elsewhere in the third world, and in the industrialized countries has revealed a wide variety of applications for solar and other alternative energy sources. While several possible classification schemes exist for distinguishing between these various applications, one appears to be especially applicable to the problems of energy use and needs in contemporary Africa. This perspective begins with a distinction, stressed in Topical Workshops A and B, between (i) the technical and economic efficiency of a particular energy technology and (ii) the broad and complex range of social, cultural, and environmental impacts which the technology might induce when it is actually produced on a large scale, diffused to users, and utilized on a day-to-day basis.

While it is clear that these two sets of factors ultimately affect one another, it has occurred in test after test and throughout the continent that the solution of the technical problems associated with any application of solar, etc., energy systems -- as difficult as these may be -- far outrun the solution of the socio-cultural problems associated with the actual social implementation of these applications. The result is that new technologies which appear to be developed to a stage sufficient for trial use cannot or will not be tried effectively (or are rejected in the long run) because users are not prepared -- or may even be unwilling -- to make the new system a regular part of their lives.

This lack of fit between technical and social aspects of current alternative energy applications in Africa is apparent over the broad range of specific technologies which exist or have been proposed. It is, therefore, essential that research on the application of solar and other alternative energy sources include extensive and intensive examination of social, cultural, and ecological factors associated with these alternatives. Clearly, certain general second -- and higher -- order impacts of a particular technology can be anticipated whenever they occur; others, however, are demonstrably specific and relate to local, cultural, environmental, or economic conditions. This means that socio-technical research on alternative energy systems requires an effective balance between cooperative, international, and interdisciplinary approaches and intensive country-and regionally-focused case studies. While some preliminary work has been done (in Africa and South Asia) on these types of projects or on their integration in actual appropriate technology design, the gap between technical and economic feasibility versus societal acceptability of solar and other appropriate energy innovations remains wide.

Based on this general distinction between technical and social aspects of alternative energy technologies, three broad types of applications can be identified: (1) solar-thermal and other alternative thermal technologies; (2) mechanical and electrical technologies; and (3) fertilizer and soil preservation methods. Several different systems have been developed (or are at earlier stages of development) for each of these applications, although it would be difficult to determine, at this time, which one or ones appear(s) to have the greatest promise. In general, significant

amounts of technical and especially, social research remain to be done. The solution to many of the current problems will depend upon how researchers, the government, and potential users manage to adapt new energy technologies to daily needs and habits, which are currently being served by human and animal power and other traditional methods.

Alternative thermal systems have potential domestic, industrial, and agricultural applications in activities such as cooking, drying, heating and distillation of water, heating and cooling of buildings, and refrigeration. With the exception of a few experiments with photovoltaic and photosynthetic heating, most of the work has been done with systems which absorb solar energy and convert it directly into heat. In these cases, the use of wood and charcoal currently dominates, and these energy sources are (for better or worse) integrated with current customs, habits, and economic realities. Thus, the several experiments with solar cookers which have been carried out in western, central, and eastern Africa have not been successful, costs were found to be high, energy was not available when needed (e.g., for the evening meal), or potential users were reluctant to treat the cooker as a serious alternative to traditional methods.

Trials with solar water-heaters have been found to be relatively successful in hospitals and other public buildings, but far less is known about their prospects for residential and rural use. Drying of crops, etc., an ancient passive solar technology, is essential for storage and conservation of scarce resources. But this practice could (like solar cooking) be much improved through the use of flat-plate collectors or, at least, shelters so that the solar resource may itself be stored and conserved.

It is likely that the solution of energy problems related to thermal applications, and to the other applications as well, lies in the development of several different solar and non-solar sources. Biomass and biogas, solar and other forms of electricity, coal, and natural gas technologies -- not to mention forest resource management--have all been shown effective but also to require further improvement. The application of solar and other alternative energy sources for cooking, heating, and drying is still on a small scale. With well-supported research, a high degree of international cooperation, and the extensive participation of potential users, it is likely that useful, inexpensive, simple, and reliable systems will be developed.

Other than some of the work going on in Niger and neighboring parts of Francophone Africa, little if any fundamental research on alternative mechanical and electrical technologies has been carried out. At this early stage, it is clear that each country and region has distinctive needs and conditions which will affect the success of new technologies. Problems of design, maintenance, and siting of solar, wind, or biomass powered mechanical and electrical systems have, for example, been shown to vary between Francophone countries.

Several priorities for future research and development have been identified in recent work on mechanical and electrical applications. These include (1) more efficient and cheaper storage and concentration of solar energy; (2) direct conversion of solar to mechanical energy; (3) greater use of local materials and know-how in design and maintenance; and (4) more efficient storage and conversion of electricity for domestic use, operation of pumps, and other uses.

As in the case of thermal applications, the solution to problems related to mechanical and electrical applications must be multi-faceted. Development of hand-and-foot-operated pumps, small hydroelectric units, biogas power, and, again, more effective use of wood and coal, should all be pursued in conjunction with solar R and D.

The majority of work on the application of alternative energy technologies to fertilizer production and soil preservation methods has focused on improved forest management, irrigation, and, of major interest, biogas. The application of solar energy per se in these areas has barely been explored.

Both China and India have produced biogas systems which have promise in Africa, especially the less-expensive Chinese system. Tanzania has already produced a similar design which employs local materials. At the same time, the more efficient use of wood resources remains a central issue. In Senegal, a 30 percent improvement in the efficiency of charcoal (with creosote as a by-product) has been achieved. This type of work, as well as further study of forest conservation methods and the development of irrigation and pumping technologies, needs to be encouraged and continued. Agricultural wastes, animal wastes, and fast-reproducing organisms such as algae are all known to be potential sources of abundant energy for fertilization and the generation of power. The realization of this potential still remains in the future, however.

As this needed research proceeds -- in relation to each application -- attention must be paid to several issues which have been raised by anthropologists, sociologists, and other social scientists. It is evident, for example, that the degree to which a particular application will create friction will vary from place to place. Ideally, in order to be maximally acceptable, a new system must have a minimal degree of outside intervention; instead, a relationship of accomodation and reciprocity between donor and donee should prevail. In addition, the system must be as compatible as possible with on-going ways of life, be easily substitutable with minimal change required, and have the highest possible degree of control by the community. On the other hand, the probability of social resistance increases as an energy innovation requires participation in formal economic and political systems. These latter might be referred to as elite technologies, for their innovation requires significant participation of specialists and influentials and must be conducted with the greatest care in order to minimize friction.

Within this broad range, several specific criteria for the acceptance of a new technology have been identified. These include: (1) the extent to which the innovation can be institutionalized by users; (2) the degree to which local users contribute their own resources and contribute to design and design modifications, construction, installation, and management; and (3) the likelihood that a large proportion of potential users (rather than a select segment of the population) can actually utilize the system.

The widespread diffusion of an alternate energy system in the rural areas of Africa is likely to be a slow process, in part because social and political acceptance must be gained among diverse groups and individuals. Successful diffusion will also depend upon the extent to which costs can be kept low and financing and other economic aspects of the innovation can be adapted to local ownership and inheritance systems. African social life involves a complex mixture of familial, kinship, lineage,

ethnic, and tribal relations. All of these represent distinct patterns of rights and obligations which affect diffusion. Finally, the successful diffusion of alternative energy technologies requires capable local organizations for the generation of capital and for the performance of managerial functions.

Several other social and cultural factors which relate to the application of solar and other alternative energy systems have bearing in Africa. The planning of on-site demonstrations and the organization of credit require attention to the roles of local and outside entrepreneurs, the need for education and extension work, and the effects of sex roles on the management of leisure time. In addition, innovation must be undertaken with due sensitivity to the aesthetic values of potential users as well as an awareness of the possibility of over acceptance, or "runaway adoption", of a technology which has immediate popular appeal but which is not developed adequately for widespread distribution. Above all, perhaps, it is necessary to have a responsive administrative system, since the introduction of any reasonable scale of a new energy technology will require complementary adjustments in the activities of several groups and organizations. Rural communities are not necessarily static; they themselves undergo changes from within. Nevertheless, we must avoid the type of new application which functions improperly or has other negative effects which are so serious that the continued acceptance of any technological innovation is endangered.

The introduction of time-and-labor saving energy systems into rural Africa will have numerous possible consequences for social and economic relations in the village and community. If effectively introduced, diffused, and managed, they can broaden the range of rural economic activity and contribute significantly to rural development.

REGIONAL DISCUSSIONS.

Chairpersons:

I. Cisse, Senegal; C. Traore, Mali; W. Ghebru, Ethiopia; S. Nkonoki, Tanzania.

Inter- and intra-regional research and development related to alternative energy technologies are plagued by communication problems of various types. It is essential, especially at this early stage in the development of solar and other energy systems, that borders be open to the exchange of ideas and that regular links be maintained between universities and research centers throughout the continent. Yet, several obstacles stand in the way of achieving this necessary level of communication.

One element is the inability and/or reluctance on the part of the researcher himself to report his work and results to colleagues in neighboring countries. Often, too, political contradictions at the governmental level have affected good relations among research centers. The lack of coordination between various branches and agencies of government, and the consequent failure of most countries and regions to centralize information and resources, further exacerbate these problems. The variety of national and regional languages spoken in Africa and the fact that most of the few occasions on which African researchers from different countries do meet are held outside of Africa also contribute to the sense of alienation felt by those involved in alternative energy R and D. Finally, it seems clear that an inordinately large share of scarce resources earmarked for research on solar and wind energy, biomass, etc., actually goes for administration and management and very little for the promotion of inter- and intra-regional linkages.

Another set of issues which affect research within and between African countries are those concerning priorities for the timing and material support for the development of alternative energy technologies. As noted in the other sessions, no one type of system, whether it be solar, biomass, or forestry management, is likely to be the solution to present and future energy problems in Africa. Instead, all promising systems deserve serious consideration. At the same time, pressing present crises of deforestation, desertification, and environmental degradation require immediate solution. Thus, as urgent as the development of alternative sources may be, it is perhaps more important that conservation and more efficient use of present resources be encouraged.

For these and related reasons, more effective national and regional energy R and D requires the establishment of a framework (or set of frameworks) for communication across national borders, between private and academic research centers, and among technologists, planners, social scientists, and potential users. Specific elements of such a framework include: the creation of an African association such as that attempted by Niger in 1972; the promotion of technological centers such as those in Dakar, Bamako, and Ibadan; regular publication of a journal and/or scientific bulletin which reports on research throughout Africa; centralization of research findings and the investigation of ways to share national resources; the establishment of educational and extension services through which energy technologists, social scientists, and poten-

tial users in the villages and towns can exchange their views and experiences; the strenghtening of existing vocational centers and the establishment of new ones for the training of technologists who can produce and manage effective alternative energy systems; and the encouragement of exchanges, funded by international agencies, between energy researchers in different African countries. All of this, it is evident, requires considerable time, effort, and material resources from African governments and, especially, international development agencies and donor countries such as the United States.

New technologies must be simple, inexpensive, and adapted to local, social, cultural, and environmental conditions. Their development must be directed, first, toward day-to-day survival needs and, second, toward the improvement of productivity and quality of life. The present state of communication between researchers in different countries, regions, and sectors must be improved in order for these complex challenges to be met. For, despite the great variety of energy sources and applications, social and cultural systems, resource endowments, and physical environments which have been discussed in all of the sessions, at root, Africa's people have similar problems, confront similar circumstances, and have similar needs. Consequently, the solution of these problems and the satisfaction of these needs require the participation of all of Africa.

V. RECOMMENDATIONS AND FOLLOW-UP ACTIVITIES

During the course of the working and plenary sessions, several proposals for future projects and activities involving the participants were discussed. Consensus emerged from this discussion on two types of recommendations. The first type includes projects and activities to which the participants agreed in principle but which will require further detailed planning as well as material support from the Workshop sponsors or other funding agencies. The second type includes those plans on which the Workshop participants intend to act immediately, in part so that the first set of recommendations may be implemented effectively.

RECOMMENDATIONS

Workshop participants agreed, in principle, that:

1. A journal of energy options for Africa be initiated and published on a regular basis (e.g., quarterly). This publication would focus on technical, policy, social, and economic aspects of alternative energy options. In addition, an annual or biennial review of energy-related research should be published as a special issue of the journal.

2. Regularly scheduled workshops be held in Africa for African social scientists and technical specialists to share their experiences in research and development, field-testing, and other aspects of energy innovation.

3. Information exchange networks be established and made available to all African experts. These exchanges should concern both technological developments and successful methods of technology transfer and exchange.

4. Agencies and donors who support energy-related research and development should focus on the strengthening of institutions in Africa which currently are involved in energy work (e.g., research centers, universities, planning agencies).

5. Donors should support intra-African and African-third world collaboration in all energy projects. For example project travel funds should not only be provided for travel between the United States and Africa, but should help Africans visit other third world countries; funds for technical consultants should be provided to pay for African and other third world experts to work on projects.

6. Donors and African specialists should expedite energy needs and resource assessments, as well as field-testing of socially or technically promising innovations.

IMMEDIATE FOLLOW-UP ACTIVITIES

Workshop participants agreed to pursue immediately:

1. To cooperate with existing UNECA and OAU efforts to establish an Energy (solar and other alternative) Society for Africa.

2. To hold a workshop in Africa in late 1980 or early 1981 as preparatory to the 1981 U. N. Conference on Renewable Energy Technologies.

3. To form a working committee (of Workshop participants) to consider these and other future activities. Such a committee was in fact elected, and has the following composition:

   Y. Hamid, Sudan; Chairman
   S. Hurry, Mauritius; Secretary
   M. Kaba, Guinea
   S. Nkonoki, Tanzania
   C. Traore, Mali
   K. Bota, Atlanta University (ex officio)

Figure 10: Checkne Traore of Mali delivering report on solar energy programs in Mali. Seated to the right is Kofi B. Bota, Workshop Director.

Figure 11: B. McNelis, Suresh Hurry of Mauritius and Andrew J. Sofranko in conversation during a session.

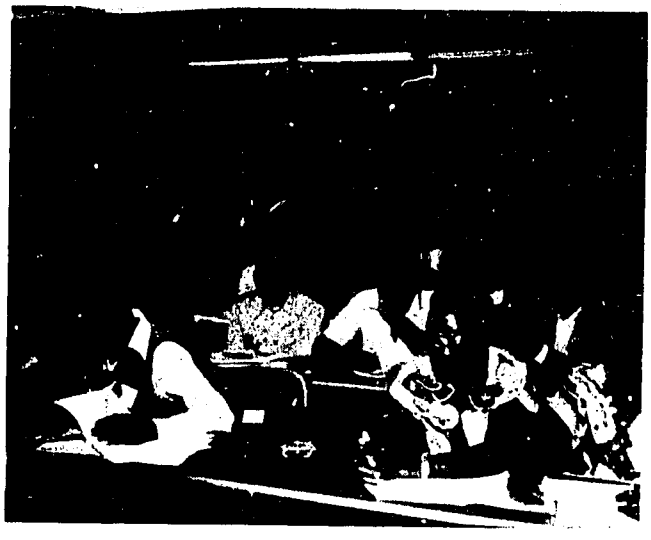

Figure 12: Delegates listening attentively during a session.

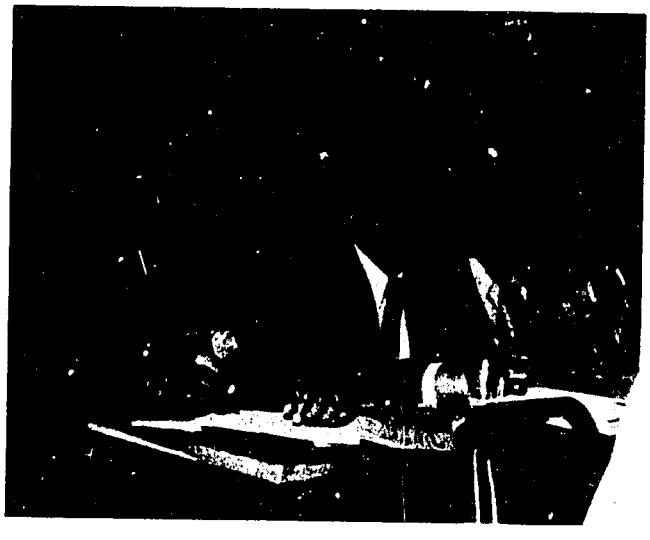

Figure 13: From left to right, Emile Paraiso of Benin, To Van Tong of UNDP, Miguel Dacraca of UNDP and Margot Aronson of Peace Corps during a Workshop session.

Figure 14: Linda Vilakati of Swaziland and Everly Driscoll of USICA in discussion during a Workshop session.

Figure 15: Jim Bever in conversation with Aleke Dondo of Kenya.

Figure 16: Shown from left to right: K. O. Kessey of Ghana, Clark Spooner of USAID (Abidjan) and Ms. Fran Gulick of OECD (Paris) at a Workshop session. In the background is Jacques Lamadieu of EIER, Upper Volta.

Figure 17: Shown from left to right are: David French, J. D. Walton and Murrey Goldberg at a Workshop session.

Figure 18: A visit by some of the African participants to a solar energy project site at the Ralph Bunche School in Atlanta.

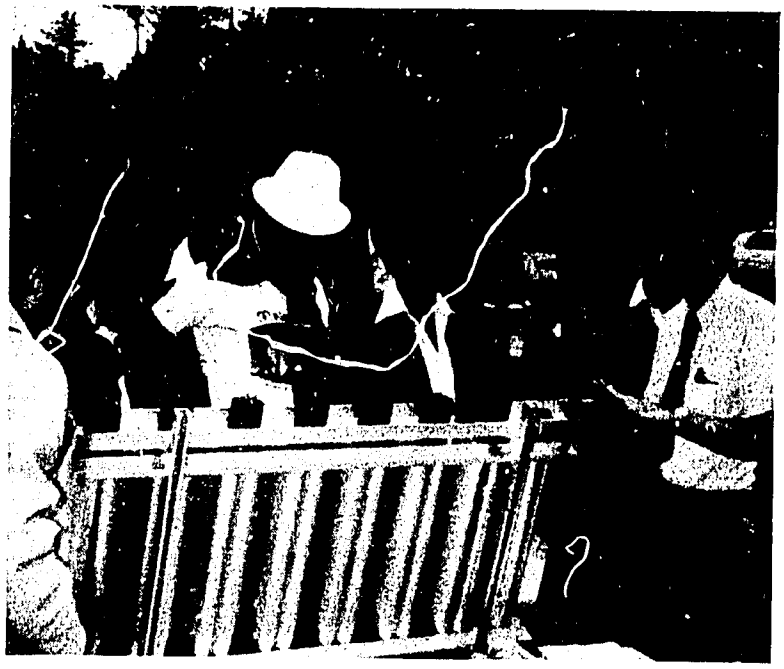

Figure 19: Dr. James Craig of Georgia Tech describing a solar collector model at the Ralph Bunche School.

VI. SUMMARIES OF SOLAR ENERGY PROGRAMS

A. WEST COASTAL AND SAHELIAN STATES

BENIN

Presentation made by Emile Paraiso

Benin has a population of 3.2 million people and a land mass of 43,000 square miles. Its physiography varies from sandbars and lagoons on the coast to low-lying plains and plateaus to the north. Climatically, the coastal belt falls into the anomalous zone that extends west across Togo to eastern Ghana. Most of the region has a savannah climate, but north of the Atakora Range, rainfall diminishes sharply and becomes highly variable in the vicinity of the Niger River. The country is relatively poor, with most of its foreign exchange earnings obtained from few agricultural exports, mainly oil palm and cotton. While there has been a recent discovery of offshore oil deposits, Benin currently imports all of its oil, part of which is used for a thermal plant of 40 MW capacity. Part of the country's electrical needs is also met by importation of hydroelectric power from Ghana. The population is predominantly rural and depends almost entirely on firewood, charcoal and coconut oil to meet its lighting and cooking needs. Current annual estimates of firewood consumption is between nine and ten million cubic meters.

There is indirect use of solar energy involved in drying of agricultural products, and in the central and northern sahelian region, the solar radiation regime may be sufficient to make direct use of solar energy possible. Two Pompes Guinards photovoltaic pumps were installed in 1978, one of which is operating very well with outputs of about 30 cubic meters per day. We have also tested 20 windmills along the coastal areas for about three years. However, the operation of these windmills has been unsatisfactory (with frequent piston breakdowns), so that they may have to be redesigned to suit local conditions.

We recognize that the country is faced with serious problems in the energy sector, both qualitatively and quantitatively, and efforts will have to be made to develop new sources of energy. A program of experimentation with new forms of energy, especially solar, is included in our second development plan, scheduled to start in 1981.

CAPE VERDE

Presentation made by Horacio Soares

Cape Verde is a small country of 300,000 people which became independent only in 1975. As in all African countries, the present energy situation is very critical because of the important role of energy availability in development programs. Electricity production, transportation, and water pumping depend on the importation of fossil fuels and this has created a host of problems for us, not only because of high prices but also because of the relative isolation of the country.

For the rural sector, which is about 80 percent of the population, the primary use of energy is for basic necessities such as cooking, drying of agricultural products, irrigation, and provision of adequate fresh water; the last two being the most crucial. Efforts are being made by the government to improve the social and economic life of the people, and an assessment of the utilization of alternative energy sources has been made, specifically focused on the contribution of solar, wind and biogas. Little firewood is now available for use by the rural people because of the massive deforestation which occurred during the colonial days. Solar and wind energy could be used for heating, cooking, water pumping, drying of agricultural products and fish and sea desalination.

With the help of friendly countries and international agencies such as the United States Agency for International Development, we are now developing a center whose first task will be to conduct a comprehensive survey of the potential of each alternative energy system before developmental work is begun. At the moment we are testing a small wind-powered water-pumping unit. Biogas is also one of the possibilities being explored.

Two small biogas units are now under construction on the main island. We also intend to investigate the utilization of ocean thermal energy conversion but foreign aid or external financing may be needed for this.

GAMBIA

Presentation made by L. O. Jobe

The Gambia is continental Africa's smallest independent state with a population of 500,000 and a land mass of 4300 square miles (11,000 square kilometers) making the density of population the fourth highest in Africa. The country has no fossil fuel deposits, and all oil and gas are imported. Most of the commercial energy is utilized in the urban areas for the production of electricity and the operation of vehicles and machinery. Present installed electrical power generation capacity is 12.6 megawatts.

The Gambia is part of the Sahel with over seventy percent of the population living in the rural areas. A recent survey conducted by the Department of Land Resources Development established that annual wood consumption per capita by the urban, rural and national population is 1.44 cubic meters, 1.33 cubic meters and 1.36 cubic meters, respectively. This extensive reliance on wood, coupled with the recent drought and increasing population, has caused some concern nationally, so that a reforestation program was initiated in the Banjul Declaration of 1977. However, present estimates indicate that by the year 2000 the demand for wood cannot be met even by replanting so that a search for alternative sources of energy must be initiated.

In the Gambia, solar energy utilization has hardly been studied. However, some measurements pertinent to the solar energy potential have been carried out by the Department of Hydro-Meteorological Services. The country experiences over 3000 hours of sunshine per year, mostly via direct radiation, except in August when the radiation flux is less than 400 Langleys per day. A significant use is already made of solar energy in the production and processing of agricultural products. For example, over 130,000 metric tons of groundnuts and over 70,000 tons of cereal, mainly millets,

sorghum, and rice are dried yearly by stacking or spreading them in the sun before thrashing; and up to 20,000 tons of marine products caught locally, of which 50 percent is exported, are usually sun-dried. Plans for economic and social development call for increased output of smoked or dried fish. Given the fact that tons of groundnuts turn moldy each year, solar assisted crop drying techniques could be useful in this regard.

We can, therefore, identify three major areas in which solar energy development could prove to be of great benefit to the country:

1. As a solution to the environmental and ecological problems of deforestation.

2. As an operable alternative in the face of rising energy needs, especially of the rural population, and population growth.

3. As a middle level technology providing jobs and income.

Solar energy systems could be utilized in various forms:

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

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

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

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

GHANA

Presentation made by K. O. Kessey and Kwamina B. Dickson

Ghana's energy requirements are currently being met mostly from conventional sources, such as imported oil and hydroelectricity, and unconventional sources, like wood. These energy sources almost exclusively serve the industrial and urban needs of the country. The imported oil is used primarily in the transportation sector and to a limited extent in electrical power production by small diesel generators. Commercial and urban residential energy is supplied mainly from the Akosombo hydroelectric power project, which will have an ultimate generating capacity of 883 MW. Based on projected economic growth, it is predicted that Ghana's electrical energy demands will outstrip the capacity of the Akosombo dam by the turn of the century. Hence, efforts are underway to identify new water power resources. An atomic energy commission has also been set up to facilitate development and training for nuclear power generation, if the country decides to use that option.

Wood is the main source of energy in the rural areas for domestic purposes such as cooking, smoking of meat and fish, heating and drying, while charcoal is used in the urban centers and large towns because of its light weight and ease of transport. Direct sunshine is also utilized for all kinds of drying processes, especially for agricultural products, meat and fish.

A solar energy committee was recently set up under the aegis of the Council for Scientific and Industrial Research (CSIR), to coordinate direct solar applications. A few modern solar devices, such as solar heaters and dryers are now in varied stages of R and D at the universities and research centers.

It is evident that Ghana is far from self-reliant in her energy requirements. Indeed, there is a need for diversification of available resources, especially in the rural areas. To date, conventional energy sources have played a notable role in the developmental effort. However, in our view, the continued over-reliance on imported oil and hydro-power sources is short-sighted. The unconventional and renewable sources could be given greater attention even if only for the sake of improving cottage technology in drying and water heating. Solar refrigeration, water pumping and irrigation, by way of solar-powered thermal and photovoltaic systems, could assist on-going efforts to make clean water available and to improve agricultural productivity, especially in the northern and upper regions.

It is also important to appraise the local, cultural and social conditions, as well as the economic and technical parameters, prior to the development and introduction of new energy technologies. We believe in a concept of development which avoids simplistic definitions of growth in terms of GNP. We would like to think of development in terms of reduction of general poverty both in towns and villages. The tragedy is that all too often, important projects are imposed on rural people with dire consequences because of lack of consideration of the "extra-technical" factors. It is true that, at present, the purchase of charcoal and firewood has become a considerable item in household budgets in some of the rural areas, especially in the central region of Ghana where the population density sometimes exceeds 150 to 200 persons per square kilometer. Nevertheless, for the successful dissemination of new energy technologies, the socio-cultural sensitivities of the rural people must be respected and factored in at the outset.

GUINEA

Presentation made by Mohammed Lamine Kaba

Guinea is a country of just four and a half million people with a land mass of about 95,000 square miles. The physiography varies greatly from the swampy, hot and humid, low-elevation coastal plains to the sudden highland mass of the Futa Jallon. Though the country is not quite in the Sahelian zone, we have experienced some drought in the northern part of the country. All the major rivers of West Africa (the Niger, the Senegal and the Gambia) have their source in Guinea and this, in combination with the broken terrain and heavy rainfall in the south, has given the country a significant hydroelectric potential. We intend to develop this potential only in the context of regional development; thus, the Konkoure Dam project, for example, is tied with the construction of an aluminum factory -- Guinea is richly endowed with

minerals, possessing, for example, about thirty percent of the world's known deposits of bauxite.

With the exception of the power-stations in Grandes-Chutes, Manea, Kinkon and Sabola, which serve approximately ten cities and towns, the majority of the country's electric generating plants are fueled by oil imports, the expenditures for which have become a drain on the country's foreign exchange reserves. However, most of the population live in the rural areas and depend on wood and charcoal for cooking and on vegetable oils (palm-oil and carite oil), and kerosene for lighting. This dependence on wood is causing deforestation in many parts of the country especially in the north and northwestern areas.

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

MALI

Presentation made by Checkne Traore

For the developing countries which do not produce oil or natural gas, energy availability has become a critical problem, especially when the countries are as isolated as Mali. Our expenditures for oil went from 8 million dollars in 1974 to nearly 30 million dollars in 1977, a flow of foreign currency representing about 30 percent of the total expenditures on imports. While we expect that the construction of dams such as the 140 MW Manantali Dam will provide some relief, hydroelectric power alone cannot be expected to solve all the energy problems of the entire country -- which has a land mass of 1.2 million square kilometers and a population of 6 million people spread throughout the country. Ten diesel plants with an installed capacity of 37 MW currently supply the electric needs of the cities, not including many industries which have autonomous power plants. It is in the rural areas that we face the greatest challenge to serve the energy needs of the people who at the moment rely entirely on wood and charcoal. Even though exact figures are lacking, estimates made by the Forestry Department show a doubling of wood consumption in the two-year period from 1973 to 1975.

We believe that solar energy applications could provide a significant solution to at least part of the energy problems of Mali, located as it is in the Sahelian belt and endowed with abundant sunshine throughout the year. As many as forty solar pumps

were set up over the decade before independence, though few of these are still in use. We have also been testing many solar devices since 1969. These include water heaters dryers, cookers, and distillers. The water heaters are now commercialized, with more than one hundred in operation in cities, rural areas, hotels and clinics. We should point out that many problems have been encountered with respect to the introduction of these devices, some of which are lack of materials, and manufacturing capability, and resistance due to local customs and mores.

From 1975 to 1978, five solar pumps were installed in Mali with the assistance of the Laboratoire d'Energie Solaire, which also followed up on their performance. The first solar thermodynamic pump of 1KW capacity, manufactured by SOFRETES, was installed in 1975 in the Djiola Hospital and the second, in 1977, on the grounds of the Polytechnic School of Mali. Three photovoltaic pumps of the Pompes Guinards type with ranges from 900 peak-watt to 1.2 peak-kilowatt were set up in 1977 and 1978. Two other photovoltaic pumps manufactured by a French company have just arrived in Bamako and will be set up in the Niara section. Other types will soon be set up in different parts of Mali. There are also plans to set up a solar-thermal power plant, manufactured by SOFRETES, in June 1979, with a 60 peak-kilowatt capacity. Most of the power from this system will be mechanical and would be used to pump water from the Niger River for the irrigation of 100 hectares of land, at a production rate of 800 cubic meters per day. The rest of the power will be electric and will operate pumps for wells to provide drinking water at a rate of 600 cubic meters per day for a village of 12,000 inhabitants, and will meet the domestic needs of lighting, cooling and refrigeration for a tourist camp with about twenty rooms. This will be the largest installation set up by SOFRETES and the first of its type in Africa -- and perhaps even in the world. A 10 KW solar electric generator for a hospital at San will also be the first on such a scale in the world.

Up until now, the distribution of solar materials in Mali has been the responsibility of our laboratory, which has minimum equipment. Financing has now become readily available to cover construction of new buildings; this will enable us to start industrial manufacture of solar devices. We are now in a position to build water heaters and thermodynamic pumps, and to provide the support services needed for their operation. In five years, we should be able to produce a range of other devices.

We have more than one-hundred water heaters being tested in the field throughout the country, even though problems such as the availability of galvanized sheet metal continue to plague their efficient operation. Solar distillers, cookers and dryers have been successfully tested in our laboratories, but we recognize that greater efforts will have to be made to make them widespread. The selected groups which have used the solar pumps are satisfied with the results though, reportedly, the photovoltaic pumps have fewer problems than the thermodynamic units. We will soon host part of a project, called "The Use of Solar Pumps of Low Power for Irrigation", which will be carried out in four countries, each one representing a well defined geographic zone. This project will involve carrying out thermodynamic tests for concentrating pumps and for photovoltaic pumps. The technical and socio-economic information obtained will be distributed to all of the developing countries.

After a long phase during which material needs did not allow us to progress as desired, the solar energy laboratory has just received financing from the United States Agency for International Development, which will help us to intensify and diversify our research and application activities. Research and Development in the first phase will

be over a period of two years and will concern the study, manufacture, and test of a series of solar processes. The second phase features evaluation of rural needs and energy resources through preliminary studies in the field, including evaluation of economic resources, customs, and preferences of the local population. The third phase features field test of the technologies, including technical training. In the fourth phase, an evaluation of the whole project will be undertaken and a policy decision about mass production will be made and submitted to our government and the sponsoring agencies.

MAURITANIA

Presentation made by Moulaye Abdellah and Mustapha Kane

Mauritania is a country of scanty vegetation and barren surfaces bordered on the west by the Atlantic Ocean and to the north and east by the Sahara. Though rich in minerals, no oil deposits are known to exist. The difficult physical conditions and the vastness of the country make it impossible to develop centralized power systems. Hence, the government has taken a great interest in alternative energy systems and is encouraging the technical personnel in the country to learn from the experiences of other countries.

The lack of economic development of the rural sector, which represents 85 percent of the population, and the ecological imbalance due to the geographical position of the country are causing migration to the urban centers. Solar energy development and application, we believe, would make life more bearable for the rural people though we would like to move rather cautiously in introducing new technologies so as to minimize the social costs. The greatest needs which solar energy technologies could help satisfy involve provision of adequate fresh water, water heating, sanitary facilities and the efficient drying of agricultural products.

A one-kilowatt solar pump, a Rankine thermodynamic system with a capacity of 50 cubic meters per day, has been installed at Chinguetti with a second bore-hole system to be installed at Butileme, which will produce 400 cubic meters per day. A 12 KW pump, financed by a grant of $500,000 from the European Development Fund, has also been installed to provide irrigation for a rice field of 22 hectares, located along the Senegal River. This pump will have a capacity of 200 cubic meters per day. We have also installed a one peak-kilowatt photovoltaic-powered pump with a capacity of 25-30 cubic meters per day. Three stations are now performing an evaluation of wind-energy potential in the southern part of the country. An aerogenerator has also been set up in the national park, with a rated power of 1 kilowatt. Finally, we are studying solar stills which would help to solve the water supply problem of the rural population living on the sea coast. This project is financed by the United Nations Development Programme with feasibility studies done by Tom Lawand of the Brace Research Institute of McGill University, Canada.

Mauritania is considering the creation of a solar research institute to train personnel, test equipment, monitor the performance of field test units, investigate the use of local materials in the development of prototypes and conduct studies on the impact of new technologies. Confronted as we are with serious problems of economic development and desertification, we know we have to do all we can to promote energy research in our country. We call upon the developed world to help us in this effort.

NIGERIA

Presentation made by S. O. Adenubi

Nigeria is a country of great diversity, geographically, politically and culturally, with an equally varied potential in her energy resource base. It is not only the eighth largest oil exporter in the world, but also has abundant coal reserves and hydropower sources. This fact may have accounted for the little interest which had been shown until recently in renewable energy sources such as solar.

Recently, however, there has been increasing interest in the potential contribution of renewable energy systems and a federal agency, the National Science and Technology Development Agency (NSTDA), has been created with a responsibility to fund and initiate research and development of alternative energy technologies including solar. R and D in solar energy applications are being undertaken in a number of institutions including the Universities of Ahmadu Bello, Lagos, Ile-Ife, Ibadan and the College of Technology in Ilorin. Some of the aspects of solar energy applications under study are solar water-heating and cooking, water distillation, drying, air-conditioning, and radiation data collection. Few installations of solar water-heaters have been made at some schools and hospitals and there is also an installation of a solar-cell pump in Kano which is located in the semi-arid belt of Northern Nigeria.

With problems of maldistribution of energy resources and great distances between cities, towns and villages, it is our opinion that there is a great potential for utilization of solar energy devices, especially the photovoltaic systems, in the rural areas where programs of electrification were recently launched.

SENEGAL

Presentation made by Ibrahima Cisse

The energy crisis has underlined the heavy dependence of Senegal on oil, which has so far become an essential element for the development of the country. Senegal's installed electric power is about 134 MW from all secondary diesel stations. These networks cover only a small portion of the nation, mainly the most urbanized and industrialized. Electrical energy production is based on petroleum products which are imported at a heavy financial and foreign exchange cost. The increase in the price of petroleum products has curtailed a massive rural electrification scheme. This has led the Senegalese authorities to explore and encourage innovations in solar irrigation and other solar uses for the rural environment. The majority of the rural population is very dispersed in traditional village communities of a few hundred people. Thus a decentralized energy program such as that provided by solar could offer real benefits to the rural population. It would permit the use of small production and independent units for cooking, lighting, water heating, and pumping, educational television, and radio communications in the rural areas. We believe that the solar cooker, for example, may prove to be very important some day in reducing the consumption of firewood, even though, at the moment, it has encountered some resistance because the women are used to traditional ways of cooking and find it difficult to accept a system which cannot operate beyond sunshine hours.

The Institute de Meteorologique et Physique is the coordinator of research on solar energy. Other research centers are charged with the responsibility for different aspects of solar energy research and development. The Ecole Nationale Superieure, a technological university specializing in training of technical staff for Senegalese industry, is studying photovoltaic energy conversion, solar refrigeration, aerogeneration, and solar conversion, through thermodynamic cycles, to mechanical power. The Semi-Conductor Laboratory at the University of Dakar works on photovoltaic conversion of solar energy, trains specialists in this area as well as teachers, and conducts research on the fabrication of silicone cells. The Office of Intermediate Teaching, under the Secretary of State for Human Resources, is conducting tests on many solar energy devices -- cookers, stills, dryers and windpumps --in a village called Fassel. We also have an industrial company, called SENELEC, a parastatal agency involving the French company, SOFRETES, which deals with the fabrication and marketing of all kinds of solar materials. The extension work and diffusion of solar devices in the rural environment is the responsibility of the National Secretariat for Scientific Research, which funds and promotes scientific and technical research. In 1975, this agency provided funds for the installation of four one peak-kilowatt SOFRETES thermodynamic pumps in newly created villages. The Senegalese government has decided to support the installation of solar pumps in areas where water is difficult to obtain. One of these is a thermal system, with peak power capacity of 30 kilowatts and a production rate of 7000 cubic meters per day, which will be used to irrigate a field of 130 hectares. The total cost is $[illegible],400,000 to be provided by the government of France and the United States Agency for International Development. A 10 KW pump, which will provide 200 cubic meters of water per day for village and cattle use, is operated by SENELEC, under the aegis of CNIS, the National Economic Society, and SOFRETES. The financing for this is provided by the World Bank and the Economic Cooperation Fund. Another $1.7 million project, conducted by CNIS and SOFRETES, is a solar electric power generating plant for the village of Jaha. This plant, which will have an installed capacity of 25 KW, will be comprised of a thermal electric conversion system and a storage system, and will be connected to the existing electrical network.

In the next Five Year Plan, $30 million has been requested in order to expand these projects, on a case-by-case basis, to replace inefficient, small diesel-powered plants. The plan is to introduce solar pumps, for village water supply and irrigation, which are powerful enough to pump at a depth of sixty meters. All of these projects favor the development of industrial fabrication capability in Senegal, which in the future may lead Senegal towards greater autonomy from the point of view of energy and rural development. External financing is needed to promote the rapid diffusion of these and other technologies that have already been developed, to mass produce the solar equipment which would help reduce the unit costs, and to conduct training for the technical staff which is indispensable for the maintenance of the equipment. Aside from technical and economic problems, there are cultural and social problems that will have to be taken into account at the policy level. In our view, research and development, and introduction and dissemination of these new energy technologies, must be conducted by multi-disciplinary teams including economists and sociologists as well as scientists and technologists.

TOGO

Presentation made by Gnininvi Messan

Togo is a nation of over two million people, with a land mass which extends 30 to 100 miles east to west and about 350 miles north to south. The climatic characteristics range from humid-tropical at the coast to Sahelian in the north. The current commercial energy situation leaves Togo completely dependent on imports: seventy-five percent of the annual electrical consumption supplied from the Akosombo hydroelectric power project in Ghana and twenty-five percent from thermal plants fueled by oil imports. The annual consumption of all petroleum products is about 160,000 tons, representing approximately 7 percent of total expenditures on imports.

People in the rural areas, who constitute about seventy-five to eighty percent of the population, enjoy almost no benefits from the commercial energy expenditures of the country, for wood and charcoal are the main sources of energy in these areas. No reliable estimates have as yet been made about actual energy consumption from biomass sources, but a serious deforestation problem already exists and, given the fact that, on one hand, the ecological balance of the region is rather precarious and, on the other hand, that the energy needs of the rural people far exceed current consumption, the situation poses a formidable challenge to both the government and all concerned individuals and institutions.

Concerning the natural energy resource base, no oil deposits are known to exist; exploitation of the hydropower potential of the Mono basin is only at the planning stage, and no plans exist as yet to exploit the tidal waves of approximately one meter along a 50 kilometer coastline. No systematic measurements of wind speeds, which seem frequently to go above two meters per second, have been made and there are no plans to exploit this resource.

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

The general comments on problems of diffusion and acceptance of new technologies which have been made at this meeting apply to Togo as well, but we would like to call for increased cooperation on technical exchanges on alternative energy technologies with our neighboring countries.

UPPER VOLTA

Presentation made by Jacques Lamadieu

Upper Volta is a country of six and a half million people, with a land mass of 106,000 square miles (275,000 square kilometers). Most of the country lies in the Savannah-Sudan belt, and though it receives more and dependable rain than the rest of the Sahelian states, much of the land has a thin top-soil and hence is infertile. The

country is, therefore, going through great economic and ecological difficulties, which have been worsened by mounting expenditures for oil, mostly used to generate electrical energy. With the large part of the population being rural, almost 95% of the estimated total energy consumed comes from wood, the high demand for which is causing an even greater ecological imbalance because of deforestation. Wood is becoming rare in the Sahelian countries, and it is common to see wood being transported in donkey carts for more than sixty kilometers to the cities. A recent study in Ouagadougou estimated the annual consumption of wood to be nearly six-tenths of a metric ton per person. Solution to the energy problems will necessarily have to be long-term; but, in the short term, the country has launched a campaign for wood conservation and has set up a research program for developing alternative energy resources.

The Interstate School for Rural Engineers (EIER) has been conducting research on solar energy since 1971. Our first research work was done on a solar-thermal pump of the SOFRETES type. Then a solar water-heater was developed, several units of which have been set up and are working well. We have developed a solar cooker with a flat-plate collector and a solar dryer for nuts, made of concrete collectors. Commercially, compared to an electric heater rated at 1500 watts operating six hours per day, we can amortize our solar water-heater competitively over ten years. At the moment we are testing two photovoltaic solar pumps, one manufactured by Briau and the other of the Pompes Guinards type. A team of researchers at the Institute of Physical Science and Mathematics of the University of Ouagadougou have been collecting climatological and solar radiation data and have also been working on four principal items: drying of agricultural products, solar cookers, production of hot water and steam for industrial uses, and solar air-conditioning and refrigeration. Over one-hundred cookers are being tested under a United Nations Development Programme project. A solar photovoltaic system, which is used for water pumping and milling of grain, has been installed in Tonga, a small village to the east of Ouagadougou. This project is funded by the United States Agency for International Development and the Lewis Research Center of the United States National Aeronautics and Space Administration. A photovoltaic telecommunication system is also being tested in a branch Post Office in a city located about 140 kilometers to the west of Ouagadougou. This system is operating well and could be used to replace ordinary batteries. A team of researchers from the Polytechnic School of the University of Ouagadougou, the Agricultural Services and the Inter-African Committee for Hydraulic Studies, have been working over the past several years to develop a system for the anaerobic fermentation of agricultural residues.

A Division of New Energy within the Ministry of Higher Education and Scientific Research has been set up to coordinate all the research on energy in Upper Volta. We believe the creation of a research center will help to accelerate research and manufacture of solar water-heaters, cookers, and dryers. We conclude by calling for increased regional cooperation among neighboring countries to standardize policy and avoid duplication of efforts. We believe that the enormous solar energy resources which we have should be used as best as possible to develop our technological, commercial and scientific infrastructure. We must not simply become markets for foreign solar equipment.

Figure 20: Solar - Cell Pump at San, Mali.

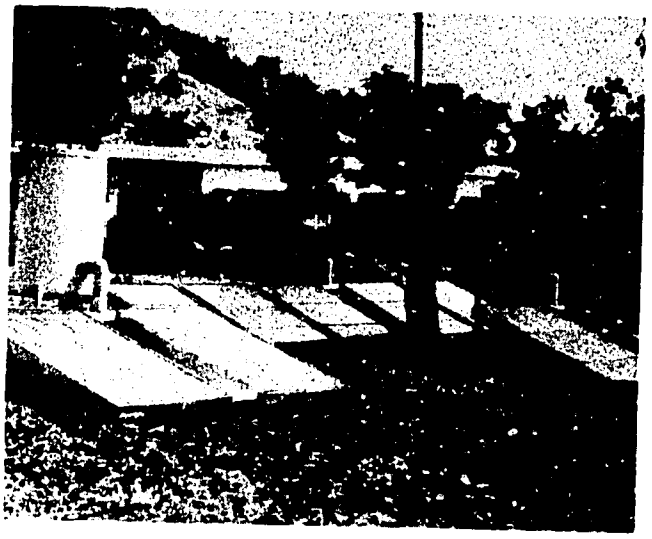

Figure 21: Solar Hot Water Heater and Dryer at the Laboratoire d'Energie Solaire, Bamako, Mali.

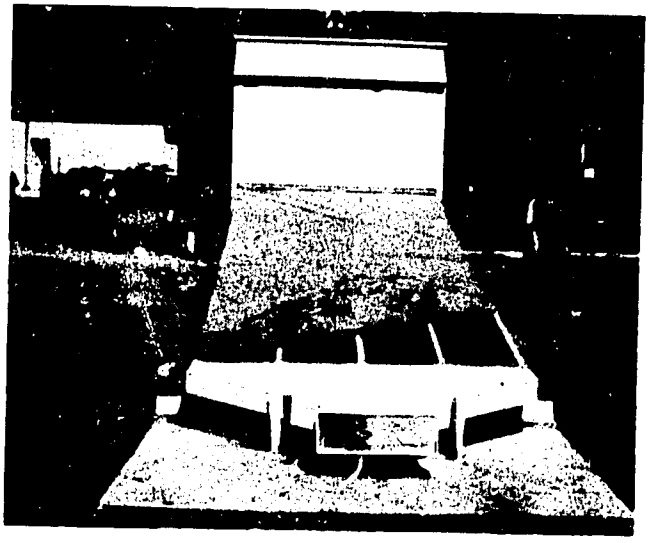

Figure 22: Solar Cabinet Dryer at Institut de Physique et Meteorologique, Dakar Senegal.

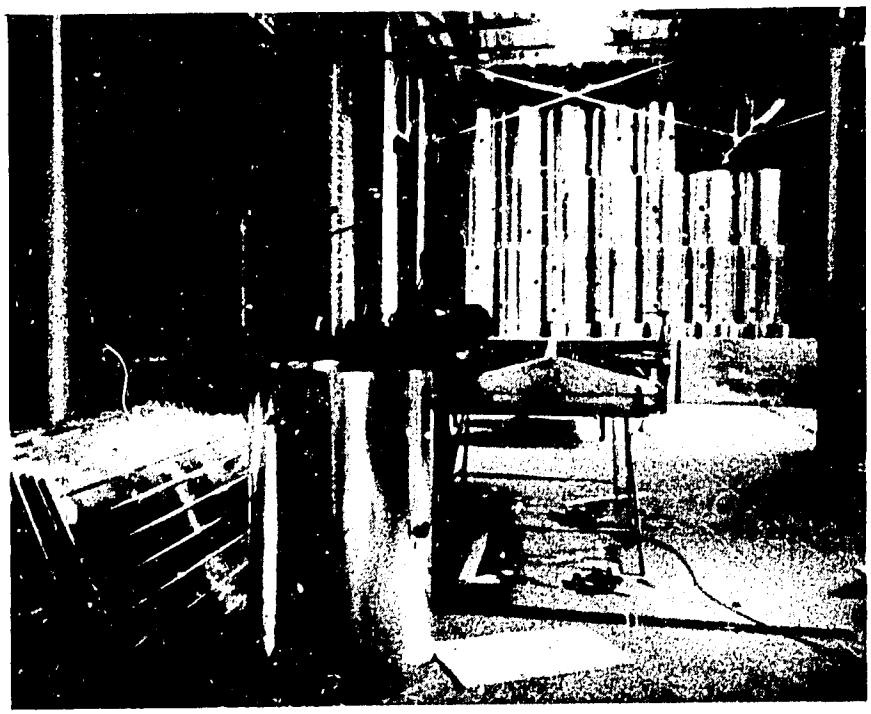

Figure 23: ONERSOL Plant for the manufacture of Hot Water Tanks, Solar Stills and Solar Collectors, Niamey, Niger.

Figure 24: Wood-fired Brick Kiln near Niamey, Niger, illustrating industrial use of wood fuel.

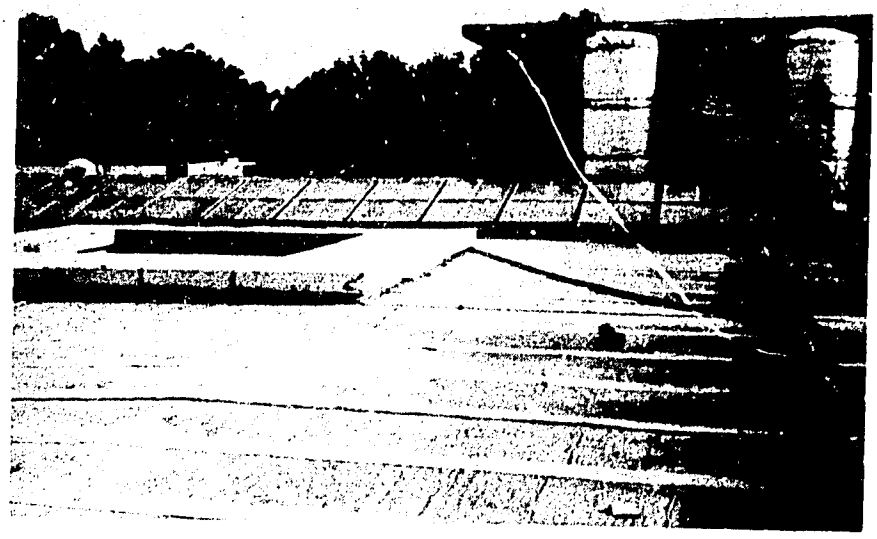

Figure 25: Solar System used to supply hot water for the Hotel Independence, Ouagadougou, Upper Volta.

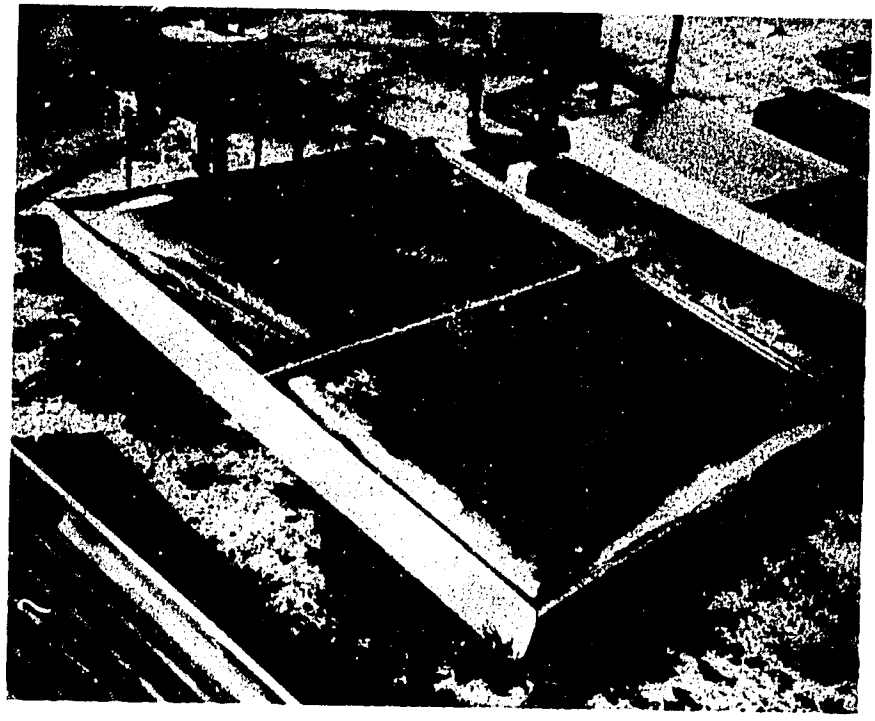

Figure 26: Solar Steam - Cooker at the Interstate School for Rural Engineers (EIER), Ouagadougou, Upper Volta.

B. EASTERN AND SOUTHERN AFRICAN STATES

BOTSWANA

Presentation made by Phillip Mauco and Frank Taylor

Botswana is a semi-arid, land-locked country with an area of 581,000 square kilometers and a population estimated at 800,000, and an estimated GNP growth rate of 3 percent per annum. Eighty percent of the land is covered with Kgalagadi sand, supporting savannah-type thorn bush vegetation. Rainfall is erratic, averaging 700 millimeters in the extreme north to 200 millimeters in the extreme southwest. Drought years are common with an apparent twenty-years cycle.

Petroleum products are wholly imported in refined form. Since 1974-1975, Botswana's imports of petroleum products have grown at an average annual rate of 16 percent compared to an average annual growth rate of 18 percent of the gross domestic product. The expenditures on imported fuel is, therefore, causing a severe strain on the country's foreign reserves. Coal mining is now in operation, but the coal produced is suitable only for industrial plants, and is used mainly by the copper-nickel mine at Selebi-Phikwe and the electric power stations of the Botswana Power Corporation at Gaborone and Selebi Phikwe. The rural population and the urban poor depend mainly on wood for cooking, warmth, lighting and water-heating -- for beer brewing. Given the fragile ecological balance of Botswana, the uncontrolled exploitation of the woodlands is having a deleterious effect on the environment. Surveys in the rural areas have revealed that provision of water is the number one problem facing the people in these areas. Other needs or problems identified include the increasing scarcity of firewood, long cooking times for traditional foods, and lack of employment. The energy-related need identified in the urban household is also the availability of firewood for cooking, water heating and space heating.

Solar insolation is relatively high, averaging 1.8 calories per square centimeter per minute in mid summer, while the mean annual sunshine duration is around 3300 hours. Little comprehensive data are available on wind-regimes, but it is known that windruns vary substantially around the country. Two sites in south Botswana show average windruns of 3.2 kilometers per hour and 7.4 kilometers per hour. Biogas is a potential source of energy, particularly for pumping water, since Botswana has a herd of over 3 million head of cattle, most of which stay around bore-holes in remote areas during the dry months. The government of Botswana, through its Ministry of Agriculture, has embarked upon a reforestation scheme, while development of solar energy devices has been undertaken mainly by non-government organizations. A rural-based center which has taken a leadership role in solar energy experimentation in Botswana is the Rural Industries Innovations Center. This center has developed solar cookers, ovens, stills, biogas units and windmills, some of which are now being tested in the field. Most of the work has involved adaptation of proven technology to meet local needs which is then introduced into villages through extension workers. Some of the needs of the urban population have been met by one commercial organization which fabricates solar heaters of the conventional design type. Another rural-based group is now in the process of establishing a renewable energy technology unit which will concentrate on the development of solar pumps.

ETHIOPIA

Presentation made by Ghebru Wolderghiorghis

Ethiopia's estimated population is about 30 million, about 88 percent of whom are farmers with only 12 percent living in the urban areas. Present commercial energy consumption is characterized by the consumption of oil and hydroelectric power, mostly in the urban areas, and by the absence of almost any commercial source of energy in the rural areas. In the urban areas, oil is used for transportation and electric power production. There are supposed to be some oil and gas deposits in the country but currently all oil is imported, and, although it constitutes only four percent of our estimated energy consumption, we spend about 30 percent of our foreign exchange earnings on it. Some of the estimated 50 million gigawatt-hours hydro potential of the country has been developed, and there are also plans to develop some of our geothermal fields, reputedly among the richest in the world.

Most of the energy consumed in the rural areas is obtained from firewood, charcoal, agricultural wastes and cow dung. Ethiopia is very rich in livestock, and most of the people in the rural areas use dung cakes for cooking and heating -- which has disasterous effects because the fertilizer value of the dung is thereby lost. Most of the areas in the northern and northeastern part of the country have become deforested because of over-grazing and the alarming rate of consumption of firewood, estimated at 20 million cubic meters per year. Even with reforestation programs, the estimated annual loss of forested land is 700,000 hectares.

With regard to solar energy, we have just begun to collect the relevant radiation data to enable us to effect proper planning with respect to its development. We also intend to test some solar pumps to see what adaptive research needs to be undertaken in the Ethiopian context. The wind-regime is favorable in some areas. Some very encouraging results have been obtained with the use of simple Cretian sail windmills in some remote areas of the country. We think that windmills could make a substantial contribution in some of the rural areas if they are suitably adapted to local conditions.

Since, on the one hand, energy is one of the fundamental instruments for the development of any country, and on the other hand, only twenty percent of the Ethiopian people would be reached by the year 2000 if we were to proceed with the current pace of electrification which started as far back as 1941, the government of Ethiopia is now giving top priority to the development of the energy sector of the economy. With the help of friendly countries, we plan to undertake a comprehensive energy survey which would help us to develop the energy sector in an integrated manner.

KENYA

Presentation made by A. Dondo and F. Onyango

Kenya has a population of over 14.5 million people with a land mass of 225,000 square miles, about a fourth of which consists of the most extensive highland zone in Africa. These highlands include several extremely high sections, such as the Aberdares Mountains and Mount Kenya, as well as the lower lands in the Eastern Rift Valley.

Economic development in Kenya has largely been dependent on hydro-power, oil, wood and human muscle power. The modern urban sector consumes most of the imported oil and coal. Oil supplies 85 percent of the total energy in this sector, hydro-electricity 12 percent, and coal 3 percent. The annual rate of increase in energy consumption over the past decade was approximately 8 percent. Between 1972 and 1976, oil import expenditures rose to $21 million, representing over 25 percent of our foreign exchange earnings.

The main sources of energy in the rural areas, where about 90 percent of the population lives, are firewood, human labor, animal power, agricultural wastes, and to a limited extent, oil. This energy is used for domestic needs like cooking, heating, and lighting and for village level industries like grain-milling, brick-making, and farm level processing -- including drying and curing of agricultural products. The estimated annual per capita energy consumption level in the rural areas is about 400-500 kilograms coal equivalent. The efficiency of utilization of these energy resources, however, is extremely low. For instance, a popular charcoal stove, called "Jiko", was found to be only 15 to 20 percent efficient, resulting in a waste of charcoal. Firewood is the most important of the energy sources which have been mentioned. It provides an estimated 90 percent of the total energy requirements. A survey is being taken to provide more accurate data but conservative estimates show that the annual consumption of firewood and charcoal is well in excess of 10 million tons. This is an alarming figure, especially when viewed in the light of the country's population growth rate of 3 percent. If this growth rate is not curbed, the country's population will reach 31 million by the year 2000. In the light of these facts, the government of Kenya, institutions and private firms have begun to show interest in the development of alternative energy resources. A conference was just held in Kenya under the auspices of the Kenya Academy of Sciences in cooperation with UNEP and the Royal Swedish Academy of Sciences through the Beijer Institute.

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

MAURITIUS

Presentation made by Suresh Hurry

Mauritius is situated some 500 miles to the southeast of Madagascar, with an area of about 700 square miles and a population of about 950,000. The main product of Mauritius is sugar, about 650,000 tons of which is produced annually. Mauritius has no oil, coal, or gas resources. The country is almost entirely electrified, with installed electric power generation capacity of 15 MW, mainly produced by diesel-fueled plants. There are a few hydro-power stations; the largest having a capacity of 10 MW. A new 24 MW hydro-power station is planned with financing by the Arab Bank of Development and other international agencies. Cooking in the villages is done mainly with kerosene, although previously it was done with firewood. There is a reforestation program now being undertaken on the slopes of the island mountains which, it is hoped, would help to halt soil erosion as well as replenish wood supplies.

A remarkable use of sugar cane fiber residue (bagasse) during the crop season is to burn it in thermal plants to produce electricity. Other uses of sugar products and bagasse which are being contemplated include livestock feed, newsprint and alcohol production. Following the lead of Brazil, molasses can be fermented to produce alcohol which can be mixed with gasoline to give gasohol. Concerning direct applications of solar energy, water-heaters are in use in a few houses and hospitals. These heaters are licensed by Australian manufacturers. We are also investigating the use of small solar stills to produce distilled water for car batteries.

Furthermore, we plan to evaluate the wind power potential in Mauritius with the cooperation of a French company. The wind-regime in Mauritius is sufficiently favorable to allow the installation of fairly large aerogenerators which can be integrated into the existing electric power grid. We also have underway a wave-energy power project which was just commissioned with assistance from the Ministry of Overseas Development of the United Kingdom.

RWANDA

Presentation made by Charles Ntakirutinka

Rwanda is a land-locked country in the heart of Africa, more than 2000 kilometers from the closest seaport. Therefore, Rwanda suffers not only from the ever-increasing world prices of oil but also from the high cost of transportation. The country imports all of its oil and other petroleum products, much of them for electric power generation. We do not expect any relief from this critical situation until 1981 when an 84 MW hydro-electric power plant will be completed. The rural population, which is about 95 percent of the population, obtains most of its energy in the form of wood, mainly for cooking purposes.

Wood is being consumed so rapidly that it is feared that the country will be completely deforested within eight years if no immediate action is taken. Because of this alarming situation, the government of Rwanda has initiated a reforestation program and has also encouraged the development of promising alternatives. A Center for the Study and Application of Energy for Rwanda within the National University of Rwanda was created in 1974. This center has been working since then on development

of energy resources such as peat, animal wastes, wind-energy, and solar energy. The staff is comprised of five researchers and ten technicians working on design and fabrication of solar devices. The work of the center is financed by the national development budget.

Within a year of its creation, the center was able to complete the construction of solar water-heaters which were installed in a hotel in one of the national parks. We started work on modular construction of collectors some time ago and are now marketing a commerical product made with locally available materials. The base of the collectors is made with cement fiber instead of sheet metal, and the insulation is made of wood chips. So far, we have installed more than one-hundred heaters in hotels and private homes at prices competitive with electric heaters. Other research conducted in the solar energy field by the center includes solar refrigeration, drying, distillation, heating, and photovoltaic systems. Our work on solar refrigeration was inititated in 1975 when we built an intermittent absorption-type refrigerator with a solution of ammonia and water as a working fluid. The energy for the operation was provided by a parabolic collector which could reach up to 300 degrees Celsius with the temperature of the cold chamber at 5 degrees Celsius. We have discontinued this project because of the low efficiencies and the cost of replacing the mirrors.

We are also constructing low-cost solar dryers for agricultural products such as corn, coffee, and tea. Solar cookers were also tested, but we were disappointed with the results; presumably they may have to be redesigned. Work is also in progress to build solar stills and improved wood-stoves, and to test photovoltaic pumps, especially in the eastern part of the country where the insolation reaches up to 6 kilowatts per square meter.

SOMALIA

Presentation made by Ali Hagi Adan

Somalia is a country of about 3.8 million people, three-fourths of whom are nomadic and semi-nomadic pastoralists, and about 15 percent are engaged in small-scale agriculture, fishery, and forestry. The country is considered to be in the semi-arid zone, with an annual rainfall below 300 millimeters in many areas. No conventional sources of energy like oil or coal exist in the country and the potential of hydro-electric power remains uncertain. The country imported about 104,000 metric tons of petroleum products in 1977, at heavy costs in foreign exchange earnings. However, the majority of the population depends on firewood and charcoal to meet its domestic fuel requirements.

Among the alternative sources of energy, solar may be considered a good prospect for many of the small rural settlements in Somalia. However, despite its great potential, little solar research and development work was initiated in the past, and it is only recently that a few interesting attempts have been made. With the assistance of the United Nations Children's Fund (UNICEF), a solar distillation plant with a capacity of 5000 liters per day has been installed in a village in the southern part of the country to provide drinking water for fishermen resettled from other places. Smaller, one-square meter stills will also be installed in ten different locations. The preliminary findings from this project show that solar distillation techniques could make a significant contribution because most of the materials of

construction are available locally and the climatic conditions are favorable. However, there is a lack of technical personnel who will be needed to construct the stills and a training program would have to be initiated. The Faculty of Engineering of the Somalia National University is also planning to undertake theoretical and experimental studies in solar energy. It is expected that the scientists and engineers involved in the project will make use of the research and development experience gained in other countries with, of course, the necessary modifications made to suit local conditions.

An especially promising area of solar energy utilization in Somalia is the solar water-pump which is used to augment water supplies for domestic needs in remote villages and arid regions. The use of diesel-operated pumping equipment is unreliable due to factors such as cost and supply of fuel, difficulty of maintenance, and lack of skilled mechanics. Provision for solar pumping as a part of the community development program may be a practical way of assuring adequate water supplies for villages. The nomads, who constitute the mainstay of the economy of the country, are constantly on the move to watering places to sustain themselves and their cattle. But watering places have become fewer in number, so that the nomads now gather around a few inadequate places where crowding leads to social problems. Drought conditions are not uncommon and acute shortages of drinking water prevail in some areas of Somalia. One possible solution to this problem is solar distillation of sea water or brackish water to obtain drinkable water. Sun drying of grains, fruits, vegetables, meat, fish, hide and skin is an age-old practice. Somalia could very well adapt the more efficient scientific methods of solar drying. There is need for small as well as large-scale systems for the dehydration of agricultural products. Individual farmers with small holdings, and meat producers and fishermen, who are mainly concerned with sale of their modest surplus in the local and nearby markets, need inexpensive and small-scale systems. On a larger scale, there is a need to find alternative sources of energy for processes such as dehydration of food and the processing of livestock and marine products. This is especially important from the point of view of our export markets.

SUDAN

Presentation made by Yahia H. Hamid

The Sudan is Africa's largest state, covering a land mass of nearly 970,000 square miles (2.5 million square kilometers) with a population of about twenty million people. With the vastness of its territory comes also a great variability in its physiography, from the desert north to the moist savannah of the extreme south. The Sudan is not a producer of any fossil fuels and imports all of its fossil fuels. The country did embark upon an ambitious development program in the early 1970s but this has now been revised and in many ways has been reduced in scope because of the large increases in expenditures on fossil fuels. The Sudan consumes energy in a rather specialized fashion: 75 percent of the energy consumed is for direct heat conversion, 17 percent for transportation, agricultural machinery and water pumping, 6 percent for engineering construction and only 2 percent for electric power generation. Ninety percent of the direct heat energy is obtained from firewood and charcoal (78 percent of this for domestic uses and 22 percent for industrial). Sixty-two percent of the electrical power is obtained from hydro-power sources, with the remainder from thermal plants which mostly use diesel fuels. The hydro-power potential is known to be high, and many dams could be built along the length of the two Niles. However, the

cost of building these dams, at over $2 million per installed megawatt, will be rather prohibitive for the country in its present state of development. There is a growing demand for petroleum fuels and the current annual consumption of 1.2 million metric tons is expected to double by 1985 and triple by 1990.

The Sudan has vast resources of wood fuel, but these resources are not being utilized well for the following reasons: first, the population distribution does not coincide with the distribution of these resources since areas of deficit are linked with areas of surplus by a poor network of earthen roads; and second, the present mode of utilization is inefficient. The consumption of wood fuel is unorganized with only 40 percent of wood regulated by strict controls of the Forestry Administration. There are agricultural wastes (more than 12 million tons per year) which unfortunately are not being used. For example, cotton stalks, over 8 million tons per year of which are produced annually, are burnt in the fields to avoid infestation of the soil; in contrast, bagasse is burnt in sugar factories to produce process steam and power. Ecologically and socially, the energy situation borders on disaster, whereby problems of deforestation of marginal regions, desert creep, and the search for domestic sources of energy have long become preoccupations of both government and citizen alike.

The geographic and economic setting of the central and northern provinces of the Sudan favor the utilization of solar energy. The first application which would be expected to have an immediate impact is in the pumping of water from surface or underground reservoirs for community use and for the irrigation of small fields. We think that the preservation of food and agricultural products by either solar refrigeration or drying is another application which could be very important to farmers and households. We expect that photovoltaic systems for telecommunications could also stimulate the social development of the rural areas. Another area that could be mentioned is in industrial factories around the urban centers. Furthermore, we can see its use in air and water heating, refrigeration, air-conditioning, and production of process steam for light industries such as sugar refineries, textiles, oil pressing and agro-processing. Our solar energy experience at the University of Khartoum dates back to the mid 1950s. In 1973, the Institute of Energy Research, incorporating solar energy as the main area of activity, was established within the National Council for Research. Activities of this Institute in solar energy research include development of solar stills for large scale application, low-cost solar water-heaters, flat-plate steam generators, solar refrigeration -- developed jointly with the Technical Institute of Denmark in Lumbe, and development of forced-circulation solar vegetable dryers. We have also engaged in training, technical exchange and testing of solar equipment made in France.

A basic issue confronting African energy scientists continues to be that of meeting rural energy needs from renewable sources. The importance of this stems from simple demographic and economic facts that the majority of the population is rural and that the economics are agro-based. In the Sudan, field experiments and tests on solar energy devices confirm, to the surprise of none, that local skills, social, cultural and ecological factors must be considered as primary inputs in the evolution of locally-bred African solar technologies. International support, we hope, would be directed towards the establishment of solar technological bases in Africa, capable of interaction and mutual enhancement during this process of evolution.

SWAZILAND

Presentation made by Linda Vilakati

Swaziland has a land area of 6700 square miles (17,300 square kilometers) and a population of 600,000 people. It lies along the Transvaal escarpment and, even though small in size, has a great topographical and climatic diversity. The country has a proven resource base and appears to have a great potential for growth. The economy depends at the present time on mining and agriculture with some manufacturing activity involved in the processing of local raw materials.

The country is rich in minerals, and exports iron ore and asbestos. It also possesses coal fields which are now being mined for export to Mozambique and Kenya. It does not have any oil deposits and has to import its petroleum products through South Africa. However, over 90 percent of the population lives in the rural areas and meets its energy needs mainly from wood and other agricultural sources; which is causing concern about deforestation. A vast private reforestation scheme is being undertaken at Piggs Peak. The Village Technology Unit was formed just under two years ago with the aim of building and testing all kinds of devices, including solar devices, which are appropriate to the needs of the people. The project is a joint venture between the government and UNDP with other financing from UNICEF. The project itself has three areas of concentration: first, pre-school education; second, income generation activities; and third, village technology, with a focus on improving the quality of life of women.

We started the field-test of appropriate technology devices with a demonstration to which eighty-three senior chiefs were invited. Four devices were demonstrated, namely, a mud stove, a solar water-heater, a solar cooker and a solar dryer. The chiefs were very interested in the mud stove and the dryer because they felt that the mud stove could be of assistance to their wives in improving cooking, was more hygenic and less smoky, and that the solar dryer could be used to dehydrate vegetables for better preservation. The solar water-heater was also well received although the chiefs from the more rainy areas were dubious about it. There was little enthusiasm for the solar cooker, since it was felt that it would diminish the role and the status of the women. A survey conducted later showed that the villagers did not comprehend the solar devices. We have, therefore, started to focus our attention on training extension workers. So far, we have trained over two-hundred people from the Ministry of Agriculture and forty-eight community development officers who are required, in turn, to stage a demonstration workshop, to be attended by school teachers from surrounding areas. We have also been working with women and church groups and have generated a great deal of interest in many devices, such as groundnut shellers, solar water-heaters, wooden washing machines, a wooden maize grinding machine, charcoal cookers and hand pumps (which were found to be very popular among farmers).

We have just received an offer from the United States Agency for International Development to start another village technology unit. This project would involve university personnel, an American research institute, and a small-industry entrepreneurship project.

TANZANIA

Presentation made by Simon Nkonoki and M. J. Mwandosya

The Republic of Tanzania has a land area of about 365,000 square miles (945,000 square kilometers) and a population of nearly 18 million people, with a per capita income and mid 1975 commercial energy consumption of $175 and 20 gallons oil equivalent, respectively. The country currently imports all of its petroleum products. There has been some exploration for gas deposits over the past few years and a strike has been made which is estimated at 30 billion cubic meters. Negotiations are now underway to exploit this resource. Plans are also being made to develop a 600 MW hydroelectric project as a joint venture with Rwanda and Burundi, and we also have the Rufiji Basin hydro-electric project with a potential generating capacity of 1100 MW. All the electric power generated is consumed by less than 8 percent of the population living in the urban centers. The government initiated a rural electrification scheme in 1965, but so far only forty villages and small towns have been covered by this project. Tanzania also has proven coal reserves of over 300 million tons and an estimated potential of 1,240 million tons, but only one very small colliery, with an annual production of only 3,000 tons, is being worked at the present time. The annual demand for coal is expected to rise to 30,000 tons by 1980 and to 150,000 tons by 1983, when some new cement, paper and pulp factories would be operating at full capacity.

Nearly 90 percent of the population live in rural areas. The great majority of these rural people depend, on one hand, on muscle energy to perform their day to day activities -- which include cultivation, tilling, planting, weeding, grinding and harvesting, and, on the other hand, on firewood and other vegetation or animal wastes for cooking, heating and lighting. This heavy dependence on wood is causing a severe strain on the woodlands. It is estimated that the country has been incurring a forest deficit of over 18 million cubic meters per year.

In recognition of the serious situation facing the country in the energy sector, work is in progress on the research, development and field-test of a number of solar devices. Solar stills have been tested in the laboratory in Dar es Salaam. The cost of distilled water by this process was found to be 20 percent of the current commercial price. A solar cooker was tested in 1977 and 1978 and it was found to be adequate to cook certain Tanzanian dishes like Ugali (maize or cassava stiff porridge). Phillips Electronics of Holland has donated a photovoltaic water pumping system to Tanzania which will soon be installed for testing. Some regions of the country have favorable wind-regimes which could be exploited to produce mechanical and electric power. The Arusha Appropriate Technology Project (AATP), financed by the Swedish International Development Agency and the Portola Institute of the United States, has started production of windmills at a current unit cost of $2,000. A promising alternative energy source for Tanzania is biogas. Tanzania has nearly 15 million cattle and over 18 million goats and sheep; already, over fifty rural health centers have installed biogas plants for cooking, lighting and water-heating. The plants cost from $680 for a cubic meter unit to $4,000 for a 10.5 cubic meter unit. However, the Arusha Appropriate Technology Project has designed a unit using oil drums which costs 700 Tanzanian shillings (US $90). Another developmental work which deserves mention is the work of the Faculty of Agriculture of the University of Dar es Salaam on improved charcoal stoves.

We have no illusion that solar technology alone can solve the entire energy problems of Tanzania, so there is no exclusion of large energy systems, at least for the time being, while these sources exist. We hope to launch a large scale research project in solar technology which will include surveys of rural energy consumption, training, fabrication and field-testing and evaluation of specific technologies. We have recognized the need to develop both long-term and short-term energy policy, and so a nation-wide committee on energy has been formed within the National Scientific Research Council. We do hope and call for increased cooperation and linkages between African research institutions as well as with public and private organizations. We would like to call on donor countries and international organizations to allow for more flexibility in the funding mechanism, as has, for example, been initiated by the International Development Research Center (IDRC) of Canada.

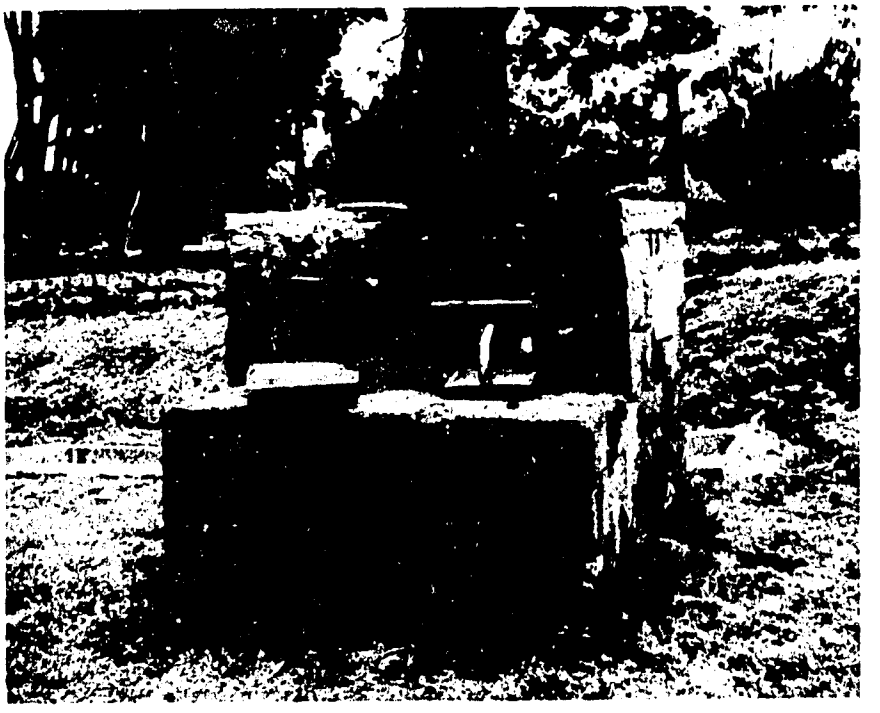

Figure 27: Lorena Mud - Stove; UNICEF Project, Kenya.

Figure 28 Crop Drier; UNICEF Project, Kenya.

Figure 29: Experimental Solid Absorption Solar Refrigeration System at the University of Khartoum, Sudan.

Figure 30: Dr. Yahia Hamid examining Prototype Solar Still at the Soba Station field site of Institute of Energy Research, Khartoum, Sudan.

Figure 31: Biogas for cooking at Majengo Village, Tanzania.

Figure 32: Passive Solar - Cell System, University of Dar Es Salaam, Tanzania.