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SOLAR ENERGY SYSTEMS FOR RURAL DEVELOPMENT*

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ABSTRACT

This Keynote paper attempts to bring into focus some of the elements that play an important role in the use of solar energy for development in rural areas. The role of the energy crisis in galvanizing developing countries into action are discussed, pointing out that third world countries in Africa have not yet made substantial impact in the rural areas with the use of solar energy, partly due to their earlier dependence on industrialized countries to define their energy problems. It is stressed that, a knowledge of local conditions and needs, an accurate assessment of energy resources, proper problem definition, interdisciplinary collaboration and human interaction, technical and economic viability, and social acceptability, are prerequisites for solar energy systems to play a successul role in rural development. Areas where an immediate impact of solar energy can be felt are; agriculture, health and education.

AWARENESS OF SOLAR ENERGY UTILIZATION

The Oil Crisis and Industrialized Countries

Oil producing countries, for several complex reasons which no attempt will be made to outline in this paper, caused a world-wide reaction by deciding to increase the prices of crude oil in the early 1970's. It is not an over-exaggeration to say that these oil-rich countries enjoyed a tremendous economic uplift, whereas other non oil-exporting and non oil-producing countries were faced with substantial economic problems. Third-world countries without any fuel oil reserves were soon spending up to one-third or at times close to fifty percent of their foreign earnings to import crude oil or petroleum products inorder to maintain oil-based industries and public utilities. Industrialized countries in the western world and in Asia were also hard hit by the high oil prices.

Realizing the vulnerability of their economies to decisions taken by oil producing countries, developed countries in North America and Europe were galvanized into action; they started looking at "alternate sources of energy" and at conserving conventional energy. One therefore noted that in industrialized countries, although energy consumption was expected to increase by about 5 percent annually, substantial changes were achieved in energy consumption patterns. For example: automobiles in the United States used 25 percent less fuel in 1984 compared to 1974; oil-fired electricity generating stations are being phased out, such stations now accounting for only about 6 percent of total electricity production; passenger aircraft carried 50 percent more people in 1984 compared to 1974 but used the same amount of fuel [1]. In addition, the use of energy in the commercial, industrial, governmental and residential sectors have been substantially reduced due to public education and the development and installation of control systems to improve equipment performance.

Both research institutions and industries in industrialized countries have also focused their attention on the development of technologies that utilize non-conventional sources of energy, resulting in a large information source being developed. Buildings using solar energy for nearly 100 percent of their heating and cooling loads are now in existence in several temperate countries [2]. Many developments have been cited in the literature on, improved air and liquid solar collectors, heat pumps, photovoltaics, thermal and chemical storage, photosynthesis and other topics, which have boosted knowledge on solar energy utilization

ARCHIV BASSEY no. 6

Now, as a result of such intense action in the industrialized countries, there has over the past five years been a drop in the demand for fuel oil; prices have dropped drastically causing economic chaos in many oil exporting countries. Support for the development of renewable energy activities have also been curtailed in many industrialized countries, leaving researchers without employment or causing them to retrain. Several companies have also been forced to close their businesses as the market has also experienced a slump in the demand for solar equipment. It would appear that a substantial proportion of energy needs are presently being met by hydro, nuclear and coal in these countries.

Commonsense should however indicate that the attendant ecological problems associated with nuclear and coal powered plants cannot be quickly solved. The increase in world demand for energy, expected to increase over the next 15 years by up to 2.5 percent annually, will create a substantial strain on existing energy sources. Thus it is incumbent on the responsible segments of societies throughout the world to continue to develop alternate sources of energy.

Third world countries

The pertinent question may now be asked concerning what developing countries have been doing in the area of combating the important problem of the depletion of energy resources. The author feels that Asian, Latin American and Carribean countries have tackled it better than African countries in general. There has been a tendency for Third World countries to follow the wave of solar energy activities which took place in the seventies. Many governments, not having funds to support energy research and/or not having the will to tackle this problem, found it convenient to ignore the flurry of activities mentioned above. International development agencies, donor countries, non-governmental organizations developed strategies for developing countries and used their funds to support the development of solar energy systems for these countries. Thus the type of projects undertaken were often determined by non-nationals who had a tremenduous amount of goodwill but often had little knowledge of the specific needs of the rural areas where efforts were concentrated. When nationals were involved in renewable energy work, they either were "forced" into doing work for which funding was available, priorities having been set by the donors, or they acted as counterparts to non-nationals who managed the project. All of these situations led African countries to follow the trends in developed countries in the area of solar energy development but also created a substantial number of technologies which where not appropriate for use in rural areas.

The end result is that there has been little application of the results obtained in the target countries. Unlike developed countries mentioned earlier, developing countries in Africa have not managed to substantially reduce their dependence on fuel oil; in fact the situation has worsened as it is not surprising to experience power blackouts and to see automobiles queueing for fuel in some countries these days. At the same time, it is noted that traditional fuel resources are not well managed due to the continued use of old and inefficient equipment or useful energy is allowed to waste due to unavailable technology to exploite it. (Table 1 for example shows that 80 percent of the gas associated with oil is flared in Africa, an energy equivalent to about 265 million barrels of oil, during 1978. While this fuel wastage may have improved in other parts of the world, it is quite possible that it has not changed in most of Africa.)

Table 1. World Associated Gas Production for 1978.
(Million barrels of oil equivalent)

	Production	Flared	% of Production Flared
Africa	330	265	80
Asia/Middle East	1300	770	59
Latin America	390	120	31
Eastern Europe	620	130	21
North America	770	40	5
Western Europe	80	60	75
Total	3490	1385	40

Source: Energy in Developing Countries, World Bank, August 1980.

Although solar energy activities have been carried out by many researchers in African universities and other institutions, their impact in rural areas have generally been negligible. However, these efforts have not been in vain as a substantial number of governments are at least now aware of the possible benefits of developing appropriate solar energy technologies. A substantial number of the population are now also aware of this energy source and are often willing to try out various systems, if they do not have to pay for them. The conditions for introducing solar energy as an alternate source of energy appears to be right and the author feels that if existing knowledge is used to develop economically and technologically viable solutions the population at large will adopt them.

Aim of Paper

In view of the above, this paper is intended to present the author's perception of the use of solar energy for development in rural areas, with particular reference being made to Africa, bearing in mind that rural areas throughout the world have common characteristics but also have location specificity due to social, cultural, and economic differences, and technological capacities. An attempt will be made to give an overview of the various constraints to the utilization of solar energy, how they may be overcome, and what actions have promises for adoption in the near future. The paper will also present the role of human interaction, between technologists, social scientists, policy makers, entrepreneurs, scientists and the target population.

KNOWLEDGE OF LOCAL CONDITIONS

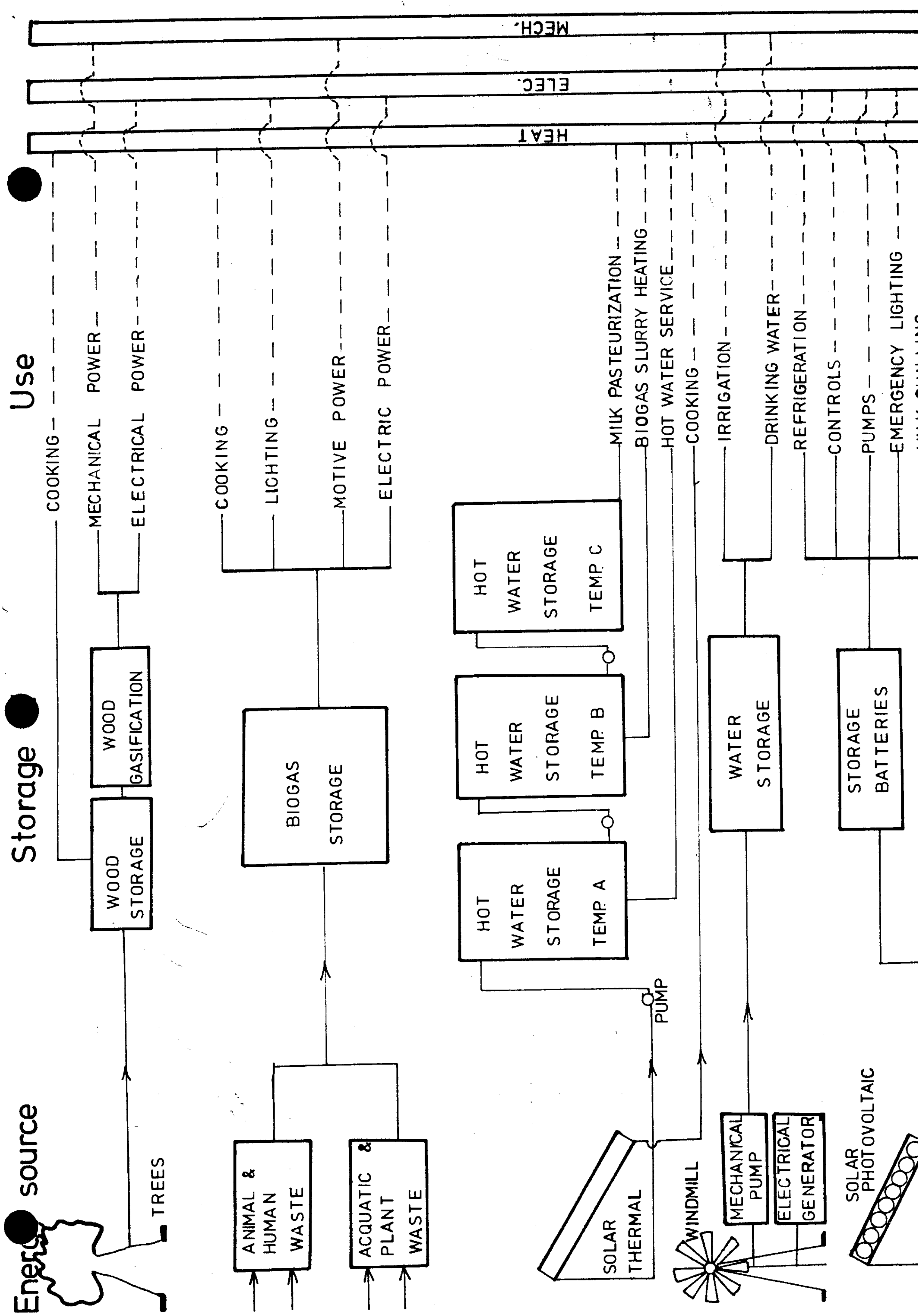
The failure of the introduction of solar cookers in Asian and African countries, due to their non-acceptance by the rural population, has been widely cited by development promoters in defence of the need to clearly identify the energy problem before proposing a solution. Present results on, and analysis of, the introduction of energy technologies, support the thesis that insufficient knowledge of rural energy needs is one of the main reasons for difficulties in the diffusion of energy technologies. A good review of the arguments for identifying rural energy needs and proposing solutions within the social, economic, political and technological context of the specific location has been well presented in the literature [3], giving examples of forestry, woodstove and general energy diffusion programs [4].

A shortcoming of methods used to introduce solar energy systems in rural areas is the lack of the involvement of the target population in the activities, from conception to implementation. This is in the author's opinion mainly due to either one or both of the following; the lack of knowledge on the part of the introducers of the technology of how to involve the intended users, the feeling that the introducers know what is best for the intended users. Given the complexity of introducing technologies, it is therefore not surprising to find interesting solar technologies which remain in laboratories of several research institutions, their cost being too high, and/or they do not meet the needs of the users, due to social and cultural reasons. It is in some cases questionable whether such technologies are the right type of interventions, for, as pointed out in [3], the solution to a perceived energy problem may not lay in the introduction of a technology but in solving an economic problem.

Although knowledge exists on the prequisites for the adoption of technology (including those using solar energy), no methodology is universally applicable, due to the location specificity of problems. It is therefore in many cases frustrating for developers and introducers of solar energy, as guidelines are not available which would suit the needs of every project. Efforts have however been made in the past years to pay close attention to identifying; energy consumption patterns, energy bottlenecks, appropriate technologies or actions to be taken, mechanisms for involving the intended beneficiaries, follow-up activities, etc. Such interaction of activities would ensure the development of a realistic strategy, using knowledge of local conditions.

The use of solar energy to enhance development should not only be seen as a process involving one technology to solve a given specific problem. Rather it should be viewed within a wider context involving the improvement of lifestyles taking into account the availability of food, water, shelter, health, clean environment, education and psychological well- being. This total systems approach has positive repercussions in terms of increasing the chances for success, as activities are initiated based on a clear understanding of the overall problem which should be tackled. In India, for example, this total system concept has been applied with encouraging results. A model which has been reported [5] for an integrated solar energy installation is shown in Figure 1. The three end forms of energy are; heat, mechanical energy and electricity. These are obtained from biomass (fuel wood, animal waste, acquatic waste, plant waste), solar thermal energy, solar photovoltaic energy, and wind energy. It is noted that the end energies can be used for a wide range of realistic activities, such as, cooking, grinding, refrigeration, lighting, etc.

A substantial amount of information on the socio-economic aspects of introducing solar energy in an environment can be obtained from integrated systems similar to that shown in Figure 1. Experience shows that the capital cost per capita of such an integrated system is, for an Indian village population of 1000, about US $56.40 [5]. Considering the benefits that such an investment can bring to a developing country, it is surprising that African countries, especially those with various forms of solar energy, have not yet taken steps to undertake similar studies. It is in fact not possible to determine the viability of using solar energy for development if serious investigations under real-life conditions are not undertaken.


Energy source
Storage
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MECH.
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TREES
WOOD STORAGE
WOOD GASIFICATION
COOKING
MECHANICAL POWER
ELECTRICAL POWER
ANIMAL & HUMAN WASTE
ACQUATIC & PLANT WASTE
BIOGAS STORAGE
COOKING
LIGHTING
MOTIVE POWER
ELECTRIC POWER
SOLAR THERMAL
PUMP
HOT WATER STORAGE TEMP. A
HOT WATER STORAGE TEMP. B
HOT WATER STORAGE TEMP. C
MILK PASTEURIZATION
BIOGAS SLURRY HEATING
HOT WATER SERVICE
COOKING
WINDMILL
MECHANICAL PUMP
ELECTRICAL GENERATOR
WATER STORAGE
IRRIGATION
DRINKING WATER
SOLAR PHOTOVOLTAIC
STORAGE BATTERIES
REFRIGERATION
CONTROLS
PUMPS
EMERGENCY LIGHTING

AVAILABLE SOLAR ENERGY RESOURCES

Definition of solar energy

The author has assumed that solar energy refers to certain sun-based energy resources; wood, agricultural and animal wastes, direct energy from the sun (thermal and photovoltaic), wind and hydro. These energy sources can be used within integrated decentralized systems, whereas other energy sources, such as fuel oil and coal, belong to more centralized energy producing systems. Since these energy sources are directly dependent on the sun's existence, the question may be legitimately posed as to the accuracy of refering to them as "renewable"; the sun will, according to scientists, eventually die. This should however not be made an issue as a few hundred years, or even few thousands of years, are quite insignificant compared to to the predicted life of the sun in the range of tens of millions of years. Before then, man, continuously in the process of developing his scientific capabilities, will have been able to find another habitat or another energy sources for survival.

Knowledge of Resources

Solar energy exists in abundant forms throughout the African continent. In the dry northern and southern parts of Africa it is manifested in the form of solar radiation; biomass and hydro being in relatively short supply due to the semi-arid conditions. Countries in the more humid and forest regions generally have less solar insolation compared to the drier countries but are endowed with more biomass resources. Thus, each country, and indeed each geographic location in a country, exhibits its own particular solar energy resource characteristics.

A close study of the formal and informal literature on the available resources in developing countries in Africa is disquieting; there has still not been significant systematic efforts to obtain and assemble the available information. Many countries have collected solar radiation data in the form of sunshine hours for over thirty years, and some total solar radiation measurements are available for specific locations, many of these readings being irregular and/or dubious in nature. In cases where substantial information is available, errors caused by lack of proper maintenance of equipment or inaccurate record-keeping and lack of analysis of data present the potential user with difficulties [6].

Despite the above, good attempts have been made by several researchers to obtain quantitative information on available solar radiation in several countries over the past 10 years. In general, total solar radiation would be expected to be between 8 and 25 MJ/m2/day in African countries, its magnitude depending on the season of the year and location. Such levels of insolation are suitable for solar utilization but certain important points should be considered before any system is developed. For example, a clear distinction is usually made between direct and indirect solar radiation, and the nature of atmospheric conditions should be understood (i.e., cloudy versus clear skies, and the effect of dust). The author has noticed attempts being made to use concentrating type collectors in locations where diffuse solar radiation is prevalent and where the relationship between the amount of direct to total solar radiation is not known. Furthermore the effect of dust on the actual amount of solar radiation available for use during various seasons is often unknown, a factor which affects sizing and thus the economics of technologies.

Wind availability is even more difficult to generalize. Data on wind is available for certain locations in many countries in the form of wind direction and magnitudes, but are not usually analyzed. Due to its location specificity and its variation with time, measurements over a reasonable period are necessary inorder to determine the size of an appropriate machine which could be installed. Although wind energy is available in many locations, it is not widely available in easily exploitable amounts as solar radiation.

Biomass resource assessment is relatively new in Africa. Existing resources are not known for most countries, although attempts have been made in some cases [7]. The main bottleneck in obtaining the required information is associated with the reliability of the methodology used. However, active work in this area has provided useful information, for countries such as Mauritius [8], Nigeria [9], and Sierra Leone [10], that can be used to plan for the future. Inorder to work in a given location such as a village, the biomass resource available in or close to the village determines the viability of the activity. Thus country-wide resource assessments should only be taken as guidelines for general policy actions whereas specific applications would depend on results obtained for that location.

POSSIBLE SOLAR ENERGY TECHNOLOGIES

Potential solar energy technologies that can be used for development have been described in [11, 12, 13]. Individual technologies which can have an impact are those that have the potential to solve pressing problems being experienced by a substantial cross-section of the population. Some of these are:

* Solar cookers which take into account cultural and social traditions;
* Solar water heaters for hospitals, clinics, residences and industry;
* Solar dryers appropriately scaled for rural use;
* Solar stills for potable water;
* Solar refrigeration of medical supplies;
* Solar space cooling to offset the dependence on fuel- oil- produced electricity;
* Solar pumps using photovoltaic cells;
* Improved stoves using available biomass;
* Production of mechanical power using biomass in biogas digesters and gasifiers;
* Windmills for pumping, electricity generation and mechanical energy;
* Small turbines for electrical power;
* Electricity production to operate equipment for education and communication.

Specific systems which have been developed for use in Africa are reported in many reports and publications. One recent publication which presents results of relevant solar energy technologies is Renewable Energy Development in Africa in two volumes containing about 60 papers [14]. It is noted that research and development activities involve the above mentioned systems. It would therefore not be difficult for progress to be made in introducing them in rural areas as the technical base presently exists.

As mentioned earlier, substantial impact can be made if a group of solar systems are introduced in a given location instead of a single technology. Within a village setting food, health and education are basic prerequisites for development. Thus introduced solar systems should provide improvements in food processing, better health care, clean drinking water, better access to information, improved education, better lighting, improvement in social activities, etc.

Many of the above technologies are usually viable when used by groups of people instead of by individuals. However, some of them, such as cookers, cannot be shared amongst users due to social customs, even though it would be economically profitable. Information on the interaction between people sharing solar energy technologies and their reactions to them are not available for countries in Africa. This is not unrelated to the little amount of introduction of potentially useful systems amongst the various populations.

In view of the foreign exchange difficulties being experienced by almost all African countries, it is advisable not only to develop and build equipment locally but to also minimize the cost of imported parts used. In addition, the importance of having technical expertise to properly manufacture, install and maintain equipment cannot be overstated. Unfortunately very few countries produce any form of solar equipment in substantial quantities. To the author's knowledge Niger is the only country in West Africa where solar equipment (water heaters and stills) have been manufactured industrially. However a major constraint has been the availability of manufacturing materials, nearly all of which have to be imported. In order to make any meaningful progress in the area of manufacture, considerable efforts have to be made in using cheaper and more locally produced raw materials without sacrificing quality; a very difficult task.

Since a major constraint to having a viable technology is cost, due to the lack of liquidity in developing countries, small but economically sound energy systems within a decentralized system are advisable since more people would have access to them. Thus it is reasonable to assume that not all rural groups will benefit from the same range of technologies in an introduced integrated solar energy system.

Taking into account the wide range of exising technologies, cultural groups, financial resources, manpower, specific needs and available resources in a given location, etc, it would be quite presumptuous for the author to present sets of solar technologies which can be generally used for rural development. The vast amount of technical information available in the literature, coupled with a knowledge of the socio-economic conditions and solar resources can be used by a competent team to develop appropriate solar energy technologies, provided that funds are available.

HUMAN INTERACTION AND COLLABORATION

There cannot be effective transfer of solar technology to the target population in a decentralized system if the interaction between them and the introducers of the technology is poor. Based on this observation, social scientists as well as technologists have stressed the importance of the exchange of ideas before the decision is made to introduce any technology. Although approaches used do vary, the main purpose of this interaction is to make a right choice of technologies, thus minimizing the chances of their rejection by the intended users. Simple discussions, interviews and even observations can produce valuable information which can be of vital importance to an intervention. Continuous contact between both parties is necessary during various stages of the introduction of a technology to enable the introducer to assess what changes to make in order to alleviate or eliminate any problem. Examples of reasons why such contacts are useful are many: climatic factors may affect the performance of an equipment, making them perform poorly; there may be breakdowns which if not remedied will cause disenchantment amongst the users, etc.

Of vital importance in the use of solar energy for development is the early involvement of the private sector, i.e., potential manufacturers. This relationship has been shown in other instances to be a positive one; it provides feedback to the developer of the technology as well as strengthens the expertise of the manufacturer, creating an opportunity for a good quality product to be manufactured. The developer of the technology is at the same time made aware of the practicality of producing the design in a production line, and making him conscious of the unit cost.

An important relationship which is often ignored during the development and introduction of solar energy systems is that between the researcher/developer and socio-economist. Based on the author's experience this can be attributed to several reasons; both parties being unaware of how to interact, lack of trust of the value of each other's input, none of either party wishing to be "dominated" by the other, the feeling by the developer that the socio-economist "is not needed at this stage". Conscious effort is often needed to surmount some of these barriers so that a team spirit can be developed, to the benefit of the activity. The input of the social scientist in determining the right entry points in a village and the evaluation of the impact of the intervention are as essential as the technical performance of the equipment. Thus, both technical and socio-economic expertise should be recognized by all concerned.

Collaboration between researchers within a country and between countries is often non-existent. Considering the limited resources available, duplication of effort cannot be afforded. It is through societies such as the Solar Energy Society of Africa, conferences, journal articles, etc, that permanent relationships can be established. Not only are these media useful for information sharing, they allow the quality of work to improve through constructive criticisms and scientific cooperation. Examples of such collaboration have taken place between solar energy researchers in Africa with the support of the International Development Research Centre and the Commonwealth Science Council, within which research results have been shared at conferences and during other activities. African organizations such as the OAU, ECOWAS, CEAO, etc, have a major role to play in this area of fostering collaboration.

However, for the results of solar energy to be used for development, dialogue should exist between the researchers, policy makers and manufacturers. Researchers need to convince both entrepreneurs and the responsible people in government of the potential use of the developed systems. Manufacturers may for example need to obtain special incentives such as reduced taxes on imported materials so as to provide cheaper products. All of this would entail discussions between the parties concerned. It is the author's opinion that the developer of a solar technology is the catalyst in the overall activity and must take certain steps beyond his/her laboratory to "sell" it or it may not be used.

SOME RESEARCH DIRECTIONS

The type of work carried out by a researcher depends on his expertise and interest. Also, the role of solar energy in contributing to the solution of development problems is not identical for various countries, due to several factors, one of which is the availability of various forms of energy. It is thus difficult in a paper of this type to cover all possible research activities that should be carried out to help promote solar energy for development. However, based on knowledge of the availability of manpower and technology, social and economic conditions, existing solar energy resources, and constraints to their use, certain areas for future work will be pointed out.

There is a need to carry out research on the availability of solar radiation. Countries can benefit from accurate and comprehensive measurements of solar radiation in strategic locations within each country, from which reliable predictions can be obtained for other locations where data are not available. From these, various components of solar radiation (e.g., diffuse, direct and inclined surface values) can be deduced. A good starting point may be through collaboration between meteorological departments and developers of solar energy systems to analyze existing climatic data inorder to present them in a form useful to solar technologists. Such activities could bring about inter-country collaboration through the preparation of iso-radiation maps for certain regions and the setting-up of a solid base for the effective utilization of solar radiation.

Detailed assessment of the availability of biomass in specific locations are lacking for most countries in Africa. Since the economic viability of many developed systems depend on the cost of transporting the fuel source, decentralized applications dictate that biomass should be available close to the location. Thus techniques for reliably assessing biomass resources are needed. Work available should be strengthened to obtain present and future estimates of fuel-wood and agricultural wastes in areas where possibilities exist for their use. Consideration should be given to the urban sector's need for fuels such as charcoal and wood as this has an important contribution to rural incomes and environmental problems. On the whole it is difficult for any government to establish effective energy policies for development if the availability and use of the traditional energy source, i.e., biomass, is not well documented.

Work should continue on existing technologies such as solar water heating, cooking, pumping, drying, salt production, improved stoves, windmills, cooling and refrigeration. For many of these technologies, such as solar heaters and dryers, information is lacking on the durability of local designs, their technical performance under real-life conditions, social acceptability and economic viability. Cookers which meet the requirements of the potential users are needed, taking into account cost and efficiency. Solar dryers for rural applications with drying times comparable to traditional methods, and capable of drying substantial quanties of crops without electric fans, will rapidly promote the use of this technology.

Development in rural areas is strongly linked to the availability of energy for heat, light and mechanical power. As such, the neglected area of studying decentralized systems for power production deserves attention. Processing of agricultural products in cottage industries can be stimulated if various forms of power are available in rural areas resulting in substantial economic gains for the population. Thus, the development of methods of efficiently converting, especially biomass, to useful mechanical and heat energy with the least ecological consequences appears to be a priority.

Storage is a constraint to the utilization of solar energy in many applications such as; electricity production using photovoltaics, water heating on a large scale for industry and institutions, heat storage for food drying, power production and cooling. It has been a neglected area perhaps due to the investment needed to carry out research.

In order to assess the technical and socio-economic viability of solar energy systems, their use under real life situations should receive much more attention. Integrated systems specially designed for given localities have not been seriously studied in Africa. In this case, the need for an interdisciplinary team consisting of social scientists and technologists is crucial. The author strongly feels that a careful design of even a single experiment of this type in a given country could provide results which can drastically change the attitude of all sections of society. Most important, it would provide scientific information on the cost versus benefits of such systems and provide policy makers with reliable data that would help them to make decisions relevant to the role of solar energy in development.

CONCLUSIONS

Solar energy in all its diverse forms can play a significant role in the development of rural areas. Positive changes can be anticipated in agriculture (food processing and preservation), health (clean and warm water, solar refrigeration), telecommunications and education (through the use of solar photovoltaics to power electrical equipment). However its effective use depends on research strategies which include R&D activities as well as field studies that involve interdisciplinary collaboration. The participation of policy makers, potential manufacturers and users of the developed technologies cannot be overemphasized.

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