Solar Energy Utilization in Lesotho

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ABSTRACT

Lesotho is a country lacking indigenous energy resources, but having a considerable amount of solar irradiation. The availability of solar radiation, along with other meteorological data necessary for evaluating the performance of solar devices, is discussed. The prospects of solar energy usage, as an alternative power source, is considered. It is concluded that solar devices have a potential market in the country. Some ways of improving the utilization of solar energy technology in Lesotho are also discussed.

INTRODUCTION

Lesotho is a small country in Southern Africa, surrounded by South Africa on all sides. It is situated roughly between 28°S and 31°S latitude and 27°E and 30°E longitude. It covers an area of 30,335 square kilometres. Three-quarters of the land is mountainous and one-quarter constitutes the foothills and the low lands. Only one-tenth of the land is suitable for arable agriculture. The highest mountain in Lesotho is 3482 m above sea level. Lesotho has no navigable rivers and it must rely on its neighbour for access to the sea.

The population of Lesotho is between 1.5 to 2.0 million and has been increasing at an annual growth rate of 2.3 percent over the last decade. About 50 percent of the male labour force is exported to South Africa. About 90 percent of the population in Lesotho live in the densely populated low land areas. The country has no proven energy resources and coal, oil and electricity are imported from outside. There are at present no natural resources being exploited but plans are underway to export water and hydroelectricity to South Africa.

Lesotho lies entirely outside the tropics and the altitude ranges from about 1500 to 3500 metres. The winter months in Lesotho are June, July and August and the summer months are December, January and February. In general, the winter months in Lesotho are cloudless or very nearly so and the summer months much more cloudy with most of the rainfall occurring in this season. The rainfall, brought by the prevailing winds occurs mostly between October and April. It is variable, averaging about 700 mm a year over most of the country. Temperatures in the low lands vary from about 32°C in the summer to –7°C in the winter. In the high lands the temperature range is much wider and below zero readings are common. Hail is a frequent summer hazard.

The driving force for the development of new sources of energy in a developing country like Lesotho is self-evident. There are no known indigenous sources of energy and the current fuel import bill is a burden on the national economy. Remote villages suffer from the absence of an efficient energy supply system. The hardest hit sector is the rural poor, who are unable to meet their domestic fuel requirements. Energy consumption in the country will further increase in the future as the population and the degree of urbanization increase. Economic developments in agriculture and industry as well as improvements in transport facilities will result in more commercial energy consumption. Thus, there is a growing demand for energy and the exponential increasing cost of energy necessitates the search for cheaper energy sources. This demand can be satisfactorily met by tapping as many alternative energy sources as possible.

RENEWABLE ENERGY RESOURCE SURVEY

Lesotho's geographical location and climate make it a unique place for research and development activity in alternative energy sources. Lesotho possesses abundant solar, wind and biomass energy resources that could be utilized for both household and industrial purposes. These renewable energy sources could be harnessed, with relatively moderate capital investment, using existing technology. The country receives a tremendous amount of energy from the sun each year. The small population, an almost exclusive reliance on imported oil for the energy needs and the high cost of electricity make renewable energy options, particularly solar energy, extremely viable from the technical, social and economic point of view. In Lesotho, the available information indicates that the solar insolation is sufficiently high to justify the development of solar energy devices as relatively cheap sources of energy.

The major factors affecting the utilization of solar energy as a power source are the level of insolation and its distribution, the technology and economy of collection, conversion and storage. Thus in analyzing a solar energy system it is necessary to consider the input into the system which is the solar radiation incident on it. All renewable energy sources including biomass are dependent on climatic data of solar radiation, wind, temperature, humidity and rain. Meteorological data collection is therefore, the first and most important step in the resource survey.

Solar Radiation

Important data needed for estimating the efficiency of various solar energy devices are the daily global and diffuse radiation on a horizontal surface, the daily global and diffuse radiation on tilted planes and the hourly data on global, beam and diffuse irradiation. Measured data on solar radiation are not available for most of the locations in Lesotho. There is only one station, Roma in Maseru, where global and diffuse radiation measurements have been carried out from 1984 onwards. However, long term data on sunshine duration, temperature, humidity and rainfall are available for many locations. Theoretical estimation of solar radiation for the country has been carried out by Gopinathan [1-3] and the estimated data, on global, diffuse, and beam irradiation, are available for many locations. Figure 1 represents the locations in Lesotho, for which estimated data on solar radiation are available. Measured monthly average daily global and diffuse radiation data for a typical station, Roma in Maseru, are presented in Fig. 2. Monthly mean daily percentage of maximum possible sunshine duration along with the mean value of maximum temperature, for Maseru, are presented in Fig. 3. Measured variations of beam and diffuse irradiation with solar time on a typical summer day, for Maseru, are presented in Fig. 4. Figures 1-4 clearly demonstrate the abundance of solar energy in Lesotho. Lesotho is exposed to an average of 8.5 hours of daily sunshine all the year round. The annual total radiation for the country, as reported by Gopinathan [3] lie between 5700 MJm^{-2} and 7700 MJm^{-2}. Most of the locations receive more than 6750 MJm^{-2} of irradiation per year. The insolation is very high throughout the summer months for all the stations. The global radiation values drop only by 40-50 percent during the winter months of June and July. However, even during June and July the monthly mean daily global radiation

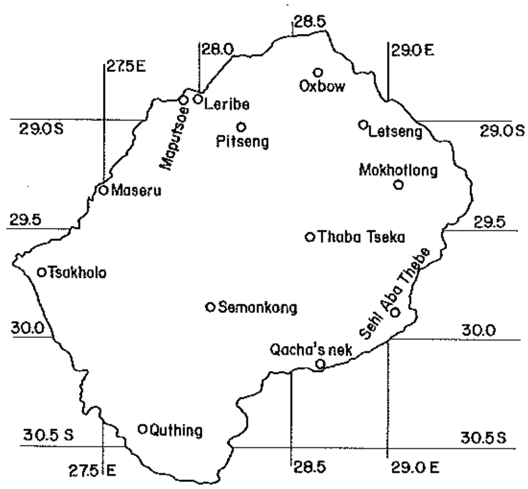

Fig. 1. Geographical locations of the stations in Lesotho for which solar radiation data are available.

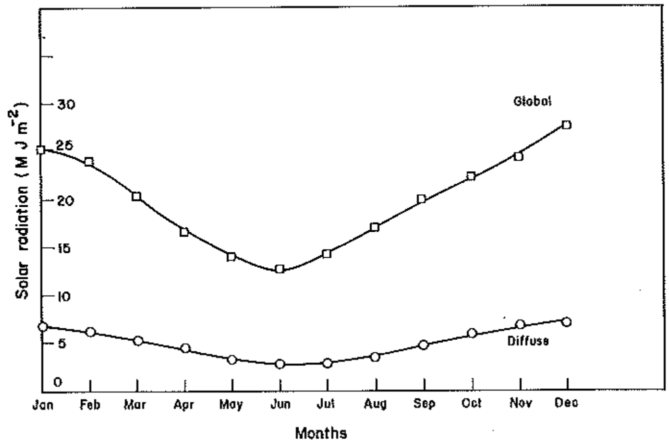

Fig. 2. Monthly mean daily global and diffuse radiation on a horizontal surface for Maseru.

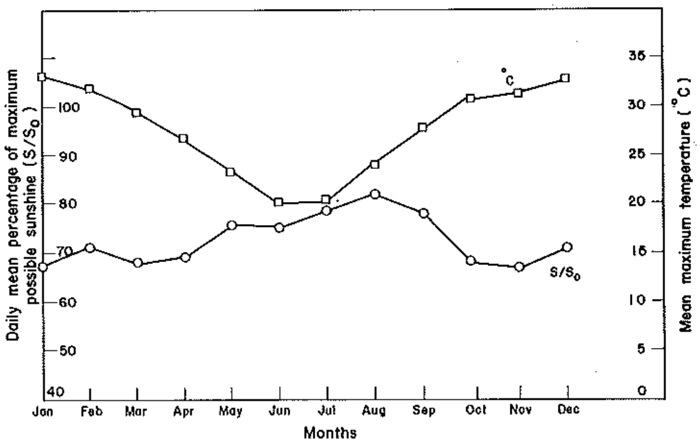

Fig. 3. Monthly mean daily percentage of maximum possible sunshine duration and maximum temperature for Maseru.

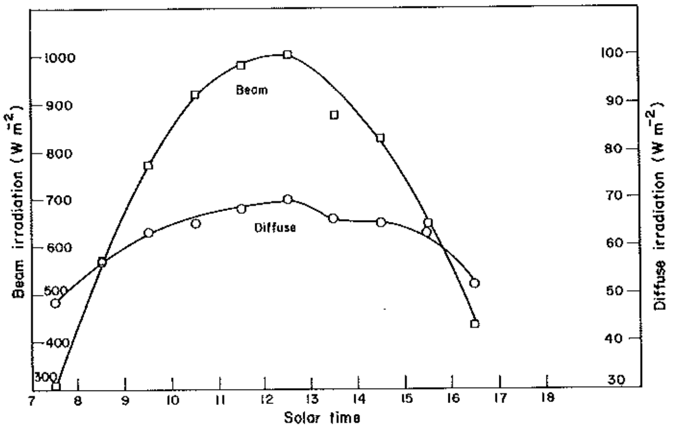

Fig. 4. Measured variation of beam and diffuse radiation with solar time on a horizontal surface for Maseru - 9th December 1984.

values are never below 10 MJm^{-2}. For only a few months the average daily irradiation is below 15 MJm^{-2}, while the annual average, in general, is higher than this value. Thus the statistical analysis has shown that all parts of Lesotho enjoy a very sunny climate and the long periods of bright sunshine and the high amount of insolation can help in making solar energy a viable option.

PROSPECTS OF SOLAR ENERGY

Solar energy can be utilized for a variety of applications. Particular solar energy applications, using simple technology, may include:

1. Heating water for domestic and industrial purposes,
2. Drying of agricultural and industrial products,
3. Refrigeration for preservation of food materials,
4. Desalination of water,
5. Cooking of food with solar cookers, and
6. Electricity production.

In the above applications, water heating, drying of agricultural products, refrigeration and electricity production can find immediate applications in Lesotho.

Solar Water Heating

The most promising application of solar energy in Lesotho is for water heating for domestic and institutional purposes. The economic feasibility of solar water heaters depends upon efficient collection, conversion and storage of energy. The most important goal in a solar energy application is the ability to calculate the output from a proposed design and establish the value of the energy delivered. Prior to installing a solar collector we should know the availability and variation of solar radiation intensity, optimum tilt of the collector for the period of use and the instantaneous efficiency of the collector, which type and model to be used and the monthly heating load to be met by the solar energy. Water in Lesotho, even in the low land areas, is always cold and hot water supply is necessary throughout the year, for domestic consumption. In urban areas electric water heaters or gas heaters (LPG) are commonly used. A common practice in the country is to use electric water heaters of 40 litre capacity for hot water supply or to use LPG gas cylinders for cooking and water heating. As most of the country is mountainous, it is virtually impossible to construct electricity transmission lines or even maintain a regular supply of oil and gas in remote areas. For calculating the cost effectiveness of solar devices we should calculate the cost involved in using conventional energy devices. A 48 kg gas cylinder (LPG) costs around M70.00 (US$35) in the market and will last only for 4-5 weeks, for an average family of 4-5 members if used for cooking and water heating. A family of the same size will spend about the same amount if electricity is employed for these purposes. At present, a complete solar water heating unit, with a collector area of 1 m^2, is sold at M 425.00 (US$210) in the local market. A house owner installing a hot water system, at the present cost, can recover his initial expenditure in about 6-7 months time by saving on gas or electricity. Even for large area collectors, the initial expenditure involved for installation can be recovered in about a year. The market for hot water solar heaters need not be urban-based and hot water installations in remote mountain areas have the added advantage that no conventional energy sources are available to compete with.

The problem of solar energy storage in hotels is serious as most of the energy must be collected during the day and used at night and morning. A fairly large hotel or hostel (100 guests) would consume about 2000 litres of hot water (at 50-60°C) per day. To serve this size, the hotel would require a storage tank of about 3000 litres. Although this would require large area solar collectors, it is still an attractive investment. Studies conducted by Lof and Tybout [4] indicate that the storage tank capacity resulting in minimum cost of solar heat is in the range of 50-75 kg of stored water per square metre of the collector area. On the basis of this finding, and using the upper limits of the findings, the total collector area required to store about 3000 litres of hot water, at 50-60°C, at the minimum cost is about 40 m^2. At a cost of approximately M300.00 (US$150) per m^2, the total investment will come to only M12000.00 (US$6000). The cost here is mainly the capital cost of the collectors and the invested amount can be recovered in a few months time. Thus the low temperature devices (below 100°C) with their higher conversion efficiency, low cost, and almost zero maintenance can easily compete with electricity or gas, at the present prices. Except for a few types of collectors, like the vacuum type, flat-plate collectors can be manufactured in the country and thus the prices reduced further. Materials like copper and galvanized iron sheets, insulating materials, glass windows are all locally available. Non-selective paints can be used as the absorbing material. The passive thermo-syphon type of solar heater could become very popular in Lesotho. Thus, solar water heaters have several unique features that place them in an advantageous position for utilization in Lesotho.

Intermediate temperature devices, for the production of steam, for industrial purposes for example, may face some problems concerning economic feasibility as there are not many industries in Lesotho which can absorb many units for steam generation. Hospitals also need steam for cooking and sterilization of surgical and other instruments but the prospects for using solar energy for the supply of hospital steam is also remote due to the difficulties of storing steam for use during non-sunny days.

Photovoltaic Devices

The current cost of photovoltaic converters, whilst lower than a decade ago, is still far too expensive to provide power for industry. But they can prove extremely useful where small quantities of energy are needed, at sites remote from power lines. In a mountainous country like Lesotho it is extremely difficult to extend power cables to remote areas.

Farming as in most developing countries is an important occupation in Lesotho. Usually, the farm lands are based in rural areas where organized water supply is lacking. Consequently most water supply schemes in these areas are to be derived from bore wells. Pumps powered by photovoltaic devices may be used to pump water from these bore wells for farm irrigation and domestic consumption with market prospects to be found among rural farming families and cooperative units. At present, a solar pump using a photovoltaic device, costs about M2045.00 (US$ 1020) in the local market. This price would be still higher if more powerful pumps were installed and would certainly be outside the financial means of small farmers in remote areas. It is clear that only large farm owners can be considered as potential consumers of this product. The more promising applications of photovoltaic devices are for refrigeration, telecommunication, community television, radio units, etc. for remote areas. An equally optimistic view is held for the application of photovoltaic devices as sources of power for the operation of educational, audio-visual equipment in schools in areas without rural electrification schemes.

As mentioned earlier, while considering solar energy for water pumping and refrigeration, our main interest centres on rural areas where no conventional power source exists. A realistic cost comparison of solar versus conventional energy in these areas must necessarily include initial capital investment in conventional power installation in these areas. An imported photovoltaic device sold at M32.00 per watt (US$16) in the local market can find many consumers in the remote areas. If we assume a useful life of 5 years for the cells, and 365 day operation per year, the daily cost of solar energy would be comparable with the conventional form of electricity.

Solar Drying

Solar drying is extensively practiced throughout the world and has a special significance for rural populations. Family farming units can use solar drying to preserve seeds for the next farming season and surpluses against rainy days. The cost here is only the capital cost of the dryer. Estimates show that a small cabinet dryer can be made from local material at less than M150.00 (US$75) for 2 m^2 of drying surface area. Solar agriculture dryers can have even higher potential than the solar water pumping because of the relatively cheaper unit cost of the former.

The commercialization of solar powered air-conditioning and space heating units in Lesotho appears much less viable. The reason is purely economical. Potential consumers this time are largely urban based hotels and commercial houses and solar energy would have to compete with conventional energy systems.

Energy Efficient Building Design

Another important aspect to be discussed, along with solar energy utilization is the design of energy efficient buildings. The availability of solar radiation in winter is an important consideration in residential building design for a country like Lesotho. Some minimum distance must be kept between buildings, taking into account their orientation and height, so as to provide direct solar radiation to all the residents.

WIND AND BIOGAS

While discussing the utilization of solar devices it is appropriate to mention briefly other available types of renewable energy resources in the country. Wind energy can be harnessed for various purposes including water pumping and electricity generation. Wind power utilization, at least in water pumping for irrigation purposes, can be achieved without many technical difficulties or financial burdens.

Biogas plants can also be developed in most parts of the country particularly in semi-urban areas. A large animal population, close to 3 million, could produce abundant organic material that could be used in digesters to produce combustible gas for cooking and lighting purposes. Additionally, constructing digesters in the villages would benefit farmers in terms of environmental sanitation and also could contribute to soil fertility through the application of decomposed slurry. Sufficient quantity of biogas to meet the household energy requirements of almost all the villages can be produced. There are, at present, about 24 biogas digesters, operational in the country, that have been constructed with the help of UNDP or FAO. A common problem that can occur to any digester in Lesotho is that the gas production can drop sharply in winter due to low temperature and frost. To counter this, biogas fermenters can be heated with solar collectors.

ENERGY EDUCATION

Although alternative energy resources, especially solar energy, seem to hold promise in relation to rural development, research and development work in alternative energy sources is still in its infancy in Lesotho. The rate at which solar energy will become widely used depends on research and development efforts to overcome the technical and economic barriers. Questions of cost, material requirement, efficiency and reliability need to be answered. Different energy strategies suit different countries of the world. They will depend on many factors including the economic system, the level and priorities of development, available energy resources and the financial and technical capabilities of the country. The following suggestions may contribute to the formulation of a comprehensive energy strategy for Lesotho:

1. Popularize solar energy application through the mass media,
2. Include energy studies in school education,
3. Hold training courses, seminars, discussions, demonstrations of solar energy utilization for farmers, village chiefs and others,
4. Encourage schools and other institutions to acquire solar energy technology,
5. Encourage research and development in the field of solar energy,
6. Provide incentives to owners of solar energy devices,
7. Install water heaters in all government buildings,
8. Provide commercial bank loans to all house owners wishing to purchase solar water heaters,
9. Allow materials imported for use in the manufacture of solar water heaters and on photovoltaic devices to enter duty free, and
10. Set up a government sponsored small-scale manufacturing industry for fabricating solar water heaters and assembling other solar devices. This unit can also act as a training centre for solar energy application.

CONSTRAINTS

Because of its low level of development as well as its limited economic and technological resources, Lesotho faces a number of barriers in adopting a comprehensive energy policy. The most important of these are shortages of indigenous experts, technical know-how and material resources. Lesotho is not economically strong enough to establish and run centres for solar energy research and development. Almost all equipment will have to be imported and subsidies and incentives and technological facilities can not be financed internally. The local technologists and industries may not be in a position to meet the national demand for solar energy equipment. The nation's small number of technicians and skilled craftsmen are already fully engaged. There may also be some resistance against solar energy utilization from many fossil fuel oriented members of the public accustomed to using fossil fuels.

CONCLUSION

The available meteorological data along with the estimated solar radiation show the abundance of solar energy in Lesotho. The typical solar energy devices that can be economically employed in the country have been indicated. Qualitative economic assessment indicates that solar water heaters, solar dryers and photovoltaic devices are commercially attractive. It is felt that the economic burdens of importing oil and electricity will force the country to accept renewable energy technologies.

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