NBRRI

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# SOLAR RADIATION DISTRIBUTION MAPS OF NIGERIA

NIGERIAN BUILDING AND ROAD RESEARCH INSTITUTE

## Foreword

Nigeria lies in the tropics and receives a tremendous amount of solar energy radiation which can be usefully tapped for various economic purposes. To effectively utilise the solar energy, it is necessary to have adequate knowledge of solar energy radiation levels in Nigeria in the form of tables and meaningful solar radiation maps.

The solar radiation maps presented in this report are based on direct solar radiation measurements and analysis of the data from the Nigerian Meteorological Office records . In 1982, the Nigerian Building and Road Research Institute established thirty experimental stations to measure the hourly and daily global solar radiation in various parts of Nigeria for a period of five years. Concurrently, climatic data from twenty stations of the Nigerian Meteorological Office for thirty six years (1951 — 1986) were analysed by means of empirical formula to convert into solar radiation data. The solar radiation maps are drawn from these two groups of data.

It is my firm conviction that these maps will be invaluable not only to architects, engineers and building technologists in the design of energy efficient buildings but also to solar energy scientists, engineers and technologists engaged in energy supply system in rural areas, design and fabrication of efficient solar devices and agricultural potential studies.

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## ABSTRACT

Measurements, analysis and subsequent production of long term solar radiation data in the form of tables and maps are presented in this paper.

In one of the largest surveys ever introduced in Nigeria, the Nigerian Building and Road Research Institute (NBRRI), measured and recorded the global solar radiation on a horizontal surface for a network of 30 stations widely spread throughout Nigeria for the period 1982 to 1986. The integrated values of the hourly and daily sums of the measured global solar radiation were recorded with LN–3000/10 solar recorder. The mean monthly values are given wherever the data are available and from these, the iso-radiation lines are drawn. The radiation increases as one goes from the coastal areas to the hinterland during the hot dry season. It ranges from 8.05kWh/$m^2$/day in Nguru to 4.45kWh/$m^2$/day in Calabar for a typical day in May. However, the values decrease to about 3.56kWh/$m^2$/day in Katsina for a typical day in December during the harmattan season.

The mean monthly sunshine hour, the relative humidity, temperature and rain days were also determined from meteorological data for 1951 to 1986. These are correlated with the measured data and used in estimating the global solar radiation where the measured data are not available, especially in remote areas. Regression techniques are used for the estimates. Converted solar radiation data for eleven-year period (1976–1986) are also obtained from the meteorological station. A thirty-six year record (1951–1986) of global solar radiation is used in the production of the solar maps.

The solar radiation maps of Nigeria are produced from the above data for the minimum, the maximum and the yearly average solar radiation and also for all the months of the year. Maps are also produced for the diffuse and direct solar radiation.


## 1. INTRODUCTION

Information on solar radiation availability at a given location and its variability over the geographical region is essential in the utilization of solar energy. A detailed knowledge of the solar radiation level is required for the optimum design and study of solar energy conversion systems and devices. It is also required for the design of energy efficient buildings, weather forecasting, agricultural potential studies and in the forecast of evaporation from lakes and reservoirs. The use of solar energy as an alternative source can provide energy for about 100,000 communities in Nigeria whose connection to the national grid electricity supply may not be economical due to their remoteness from the National Grid Lines.

The use of distributed (roof top) or centralised solar power plants will aid the growth of small scale industries and social amenities thereby stemming the rural-urban drift for young school leavers who go to the urban centres in search of employment.

Measured solar data are available only in few places in Nigeria due to the high cost of the measuring equipments and its periodical up-keep. Attempts are also being made to provide empirical relations for estimating solar radiation from climatic data (1–7).

Long term solar data in forms of tables and maps are of utmost practical significance in the design of solar energy conversion systems. Such maps and data analysis are presented in this paper. Measured data are obtained from the meteorological office, Oshodi, Lagos and the Nigerian Building and Road Research Institute (NBRRI) (6, 7).

The Nigerian Building and Road Research Institute (NBRRI) measured and recorded the global solar radiation on a horizontal surface for a network of 30 stations in one of the largest surveys ever introduced in Nigeria. The stations, shown in Fig. 1, are widely spread throughout the country. Nigeria has an area of 923,768km$^2$ and occupies a geographical zone, lying in the tropics and stretching from the Atlantic Ocean in the South, latitude 4$^o$N to the Sahara Desert in the North, latitude 14$^o$N. It also stretches from longitude 3$^o$E to longitude 15$^o$E.

The integrated values of the hourly and daily global solar radiation on a horizontal surface are recorded using the LM 3000/10 solar recorder and the MR–5A pyranometers. The mean monthly and annual solar radiation are determined from these records.

Iso-radiation lines on solar maps presented here are drawn using accurate data from any one of these four methods: the measured global solar radiation on horizontal surfaces; the estimated global solar radiation from empirical formulae using meteorological data especially sunshine hours, relative humidity, temperature, rain days; the converted solar radiation data from the meteorological station for eleven years (1976 – 1986); and the transposing of one set of data for a given location to another of a similar latitude, altitude and surroundings (8–10). Based on the thirty-six years solar data, solar maps are produced for the maximum; minimum, yearly average and the mean monthly global radiation for all the months of the year. Maps are also produced for the diffuse and direct solar radiation.

## 2. SOLAR DATA COLLECTION AND ANALYSIS

### 2.1 Sunshine hours

This parameter, measured with a Campbell-Stokes recorder at the Lagos station, is one of the most important climatic factors in the estimation of solar radiation. It is used in almost all empirical formulae for estimating solar radiation. The campbell-stokes sunshine recorder which is based on concentrating direct solar radiation on a specially prepared paper and thereby producing a burnt line on it, is the most popular apparatus being used by the Nigerian Meteorological Office. The monthly average of the daily sunshine hours for 34 towns in Nigeria over a period of 36 years (1951–1986) is shown in Table 1. The daily annual average of sunshine hours is shown in Fig. 2.

### 2.2 Solar Radiation Data from NBRRI Measurements.

The solar recording equipment installed at the thirty stations by NBRRI, is the LM–3000/10 solar integrators and the MR–5A pyranometers, obtained from Hollis Observatory, U.S.A. It records both the instantaneous and the integrated values of the global solar radiation simultaneously on the same chart. The integrated values of the global solar radiation are determined from the time scale and the event marks on the charts. The hourly, daily and monthly average solar radiation in Watt-hour/m$^2$ are prepared and tabulated for all days and months (7) for which the charts seem to be good throughout the five years (1982–1986).

The experimental sites include all the state capitals and some other locations characterised by low or high altitude (e.g. Obudu in Cross River State and Serti in Gongola State). The recorders are put under the supervision of personnel having research orientations especially in the Universities and Polytechnics. Tables 2a and 2b show typical records of monthly average of the hourly global solar radiation for Azare (Lat 11.8$^o$N) and Lokoja (Lat 7.78$^o$N).

The monthly mean daily global radiation for all the stations is shown