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GENERATION OF TYPICAL METEOROLOGICAL YEAR DATA FOR A CITY IN SOUTH-WESTERN NIGERIA

S. O. Oyedepo [1]*, J. A. Oyebanji [2], S. N. Ukponu [1], O. Kilanko [1], P. O. Babalola [1], O.S.I. Fayomi [1], J.O. Dirisu [1], C.O. Olawole [3], R.O. Leramo [1], I.S. Dunmade [4], U.K. Efemwenkiekie [1] and O.O. Shopeju [1]

[1]Mechanical Engineering Department, Covenant University, Ota, Nigeria
[2]Mechanical Engineering Department, Bells University of Technology, Ota, Nigeria
[3]Physics Department, Covenant University, Ota, Nigeria
[4]Earth and Environmental Sciences Department at the Mount Royal University, Calgary, Canada
sunday.oyedepo@covenantuniversity.edu.ng, oyedeposo@yahoo.com, +2348055537865

Abstract

Weather data is essential in determination of the performance of energy systems such as HVAC and solar energy systems. Weather data therefore, can be employed in designing more energy-efficient systems. This work focuses on the generation of a Typical Meteorological Year (TMY) Data for Abeokuta (7°7′1″ N, 3°22′13″E), a state in South-Western Nigeria by the use of a modified Sandia method. It makes use of seven weather parameters obtained over 29 years (1984 - 2012) in the construction of the TMY. Sandia method is highly affected by solar radiation even if its weight is reduced by half. The weights of other parameters such as temperature, wind, and relative humidity have less impact on the selection of TMY. The results of this study show that the weather pattern of Abeokuta follows the general diurnal variation of dry/harmattan season and wet/rainy season, typical to Nigeria. In this work also, the effect of general rise in temperature and solar radiation, indicative of global warming, is highlighted. Higher solar radiation values are majorly typical of a low cloud cover, and high clearness index. Suggestions were also made as to the preferable type of sustainable energy system to make use of in this location, as well as in the development of energy systems and data collection in Nigeria. The relevance of this work is that it would help to strengthen building energy standards, understand the local climate of Abeokuta and hence facilitate building energy system performance.

Keywords: TMY, Weather data, sustainable energy, wind speed, solar radiation, relative humidity

1. Introduction

Energy demand is at high Increase due to the high population, consumption rate and industrialization which calls for Energy production and Energy generation in many developing countries such. Growing world population, global warming evidence, fuel depletion and environmental degradation have made renewable energy resources increasingly attractive as alternative energy sources [1]. Renewable energy sources (wind, solar, hydropower, etc.) are inexhaustible, clean, free and offer many environmental and economic benefits; accurate assessment of weather data is thus vital in the choice of a profitable location for proper harvest of any of these energy sources. In Nigeria, for example, the Government and other reputable institutions are presently investing on projects that would harness solar and other renewable forms of energy to support life and industry [2].

Typical Meteorological Year (TMY) data are used to facilitate proper performance comparisons of energy systems whose performance depends on weather conditions. A potential building

owner and developer would be increasingly concerned with energy costs due to environmental and economic factors. Knowledge of weather data such as dew point temperature, dry bulb temperature, relative humidity, is essential in proper simulation of HVAC (Heating Ventilation and Air Conditioning) Systems and also in Solar Energy systems design, such as solar thermal systems and solar hot water systems for domestic use. Since weather conditions can vary significantly from year to year, there is a need to derive a customised weather data set that can well represent the long term averaged weather conditions over a year [3]. Typical year files are commonly used in building simulation to estimate the annual energy consumptions [4]. This typical year can be generated by several methods, as has been evident from many past attempts.
TMY is a collation of selected weather data for a particular location, generated from a data bank much longer than a year in duration. It presents a range of weather phenomenon and also gives annual averages that are consistent with the long-term averages for that location [4], [5]. Several TMY methods has been developed in literatures [5] and has been developed in many regions/countries (such as Ankara, Athens, Belgium, Italy, Spain, Canada, Damascus, Japan, China, Nicorsia, Saudi Arabia, Hong Kong, and Macau), the concept is not widely developed in Nigeria, only scanty work had so far been carried out on few locations across the country viz: TRY generation for Ibadan [6], TMY for Port-Harcourt zone [7] and TMY generation for Sokoto [8]. Fagbenle, (1995) present TRY for Ibadan which focused on global solar radiation, selection of each month and year with minimum value of FS is selected.
In this research a range of data for a 29 year period (1984 - 2012) was used, in order to approximate an accurate representation of typical year with a span of a climatic period. The aim of this work is therefore to develop TMY for Abeokuta (7°7′1″ N, 3°22′13″E), South-Western geopolitical zone Nigeria using Modified Sandia method with Filkenstein–Schafer (FS) statistical analysis for long duration hourly data capturing. The meteorological data (global solar radiation, dry-bulb temperature (mean, maximum and minimum), relative humidity, precipitation, and wind speeds) captured by the Nigeria Meteorological Agency (NIMET) located at Oshodi, Nigeria were used.

2. Experimental Methods

2.1. Data treatment and site location

The 29-years daily weather data (from 1984 - 2012) are obtained and treated before being used for the TMY generation. Sandia method were used in this study for data acquisition from NIMET, Meteorological Station, Oshodi, Lagos for the selected sites (Abeokuta, South Western Nigeria, located at 7°7′1″ N, 3°22′13″E) and experimentally, seven (7) parameters were used, which are: Maximum, Minimum and Mean Dry bulb temperatures; Dew point temperature; Relative humidity; Global solar radiation and Wind speed. Also, some of the equipment used in measuring weather data, as observed in NIMET, Oshodi Lagos include: Campbell-Stokes Sunshine recorder which employs the burning card method to record the hours of bright sunshine, wet and dry bulb thermometers, maximum and minimum thermometers housed in the Stephenson screen, Piche evaporimeter, soil thermometers of varying lengths, rain gauge, cup anemometer and wind vane as shown in figure 1.

Figure 1: Equipment at NIMET a, Campbell-Stokes sunshine recorder b, Stephenson screen thermometers c, soil thermometers d, anemometer

2.2. TMY Procedure

Modified Sandia method is employed in the development of TMY for a given zone. The procedural steps of the method considering each month in a year at a time are outlined as follows, Global Solar Radiation raw data were taken in kWh/m^2/day and converted to MJ/m^2/day, sorted and unsorted daily mean values for each of the parameters were considered as shown in table1 and 2, typical month for each of the twelve calendar months from the long-term data base was chosen and then those 12 months TMMs are concatenated to form TMYs. Monthly statistics were calculated for each index. Month/year combinations which had statistics that were ‘close’ to the long-term statistics were candidates for typical months. The daily global solar flux and long term mean (both unsorted and sorted) for Abeokuta from January 1984 to 2012 are shown in table 3.

Table 1: Weighting Factors for Finkelstein-Schaffer Statistics

PARAMETER	WEIGHT (WF)
Dry bulb temperature (minimum)	1/20
Dry bulb temperature (maximum)	1/20
Dry bulb temperature (mean)	2/20
Dew point temperature	2/20
Relative humidity	2/20
Wind speed	2/20
Global Solar radiation	10/20

Table 2: Short-term daily average mean temperature values for December, 1990 (Abeokuta)

Day	**Unsorted values**	**Sorted values**	**Corresponding days**
1	26.51	23.23	31
2	25.87	25.59	26
3	26.91	25.64	30
4	28.18	25.87	2
5	28.81	26.51	1
6	27.06	26.52	25
7	28.32	26.62	27
8	29.39	26.91	3
9	29.97	27.06	6
10	29.71	27.07	29
11	28.38	27.28	28
12	27.4	27.4	12
13	28.55	28.18	4
14	29.31	28.32	7
15	30.15	28.34	24
16	30.41	28.38	11
17	29.25	28.55	13
18	29.93	28.68	22
19	29.2	28.81	5
20	28.87	28.87	20
21	29.38	28.88	23
22	28.68	29.2	19
23	28.88	29.25	17
24	28.34	29.31	14
25	26.52	29.38	21

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26	25.59	29.39	8
27	26.62	29.71	10
28	27.28	29.93	18
29	27.07	29.97	9
30	25.64	30.15	15
31	23.23	30.41	16

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Table 3.3: The unsort 3 hrt-term daily global solar flux and the unsorted and sorted long-term values for January over the years (1984-2012): Abeokuta Data

	YEAR																													LONG TERM	
DAY	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	Unsorted	Sorted
1	18.00	20.20	20.05	20.20	18.50	22.82	21.64	16.60	17.06	21.92	20.56	21.56	20.48	19.91	22.14	22.36	22.64	20.63	20.38	16.34	18.97	21.85	22.64	18.04	20.95	21.71	22.14	21.13	19.12	20.36	19.82
2	19.87	19.62	21.67	21.53	19.26	22.36	19.40	16.52	16.70	21.82	21.31	22.43	19.76	21.85	22.90	22.10	22.00	23.62	21.74	17.53	19.98	23.26	22.07	16.45	20.99	21.56	22.14	20.74	21.46	20.78	19.89
3	20.84	19.84	21.17	21.82	19.40	20.66	20.09	21.49	16.96	20.88	17.28	21.60	20.41	22.28	22.75	20.63	20.45	19.98	22.54	16.81	21.31	19.40	19.44	18.83	21.20	21.20	22.21	19.80	21.78	20.45	20.00
4	19.84	20.99	20.30	21.42	19.48	22.07	18.58	21.53	16.56	22.39	16.60	19.12	20.63	21.92	20.02	21.31	18.50	21.13	18.76	16.60	21.56	20.20	20.99	20.81	19.76	21.53	21.92	20.99	21.74	20.25	20.09
5	20.81	21.60	21.35	21.60	18.79	19.69	22.07	21.82	15.70	22.72	16.99	21.38	20.45	21.92	18.79	18.32	19.98	21.31	22.75	18.22	22.64	20.16	19.22	23.15	21.24	21.60	21.78	21.17	21.67	20.65	20.16
6	21.17	21.13	20.92	19.37	19.91	20.63	22.68	22.57	16.63	20.12	17.68	20.02	20.16	20.95	17.35	16.96	18.50	21.71	22.75	16.78	22.54	15.73	20.34	16.99	21.35	21.85	21.74	21.17	20.38	20.00	20.25
7	21.56	21.10	20.81	20.41	19.66	19.62	23.15	21.06	16.92	22.21	20.02	21.31	20.48	20.52	16.99	20.84	19.73	21.02	19.22	16.96	16.88	18.97	22.28	18.43	21.31	21.24	21.78	21.24	21.64	20.25	20.25
8	21.74	21.20	20.74	20.20	19.73	18.61	17.24	22.50	17.96	21.78	16.52	23.44	21.71	20.16	17.96	19.30	21.13	22.21	20.48	16.81	16.56	16.88	20.88	18.22	21.28	21.78	21.92	21.64	21.96	20.09	20.27
9	23.11	21.06	20.88	17.53	19.48	22.39	15.88	19.19	16.99	18.14	21.24	23.33	19.94	19.80	19.37	16.92	20.12	23.00	20.52	22.36	16.06	16.81	17.35	17.68	20.09	21.46	22.10	22.00	22.10	19.89	20.30
10	20.92	21.78	21.74	18.58	19.15	18.54	16.42	17.57	17.39	20.99	18.58	23.40	19.19	21.17	16.70	19.48	18.58	23.00	20.77	22.72	16.49	18.18	22.75	20.81	21.42	21.74	22.28	22.14	22.14	20.16	20.36
11	21.60	21.38	21.20	22.32	18.50	20.95	16.63	17.78	20.02	19.62	16.52	21.89	19.80	17.32	17.60	21.89	20.38	22.25	16.60	19.48	22.32	19.87	21.20	21.28	21.38	22.28	22.03	22.25	22.32	20.30	20.39
12	19.08	19.55	21.17	19.51	19.73	20.59	18.07	17.28	18.18	18.90	17.60	20.92	21.42	18.94	18.54	20.52	21.06	22.28	17.82	20.99	18.79	18.79	18.36	17.71	20.92	22.00	22.03	22.32	21.71	19.82	20.41
13	20.99	21.53	21.17	20.34	19.80	20.56	20.92	17.24	16.92	16.67	18.97	22.75	21.89	22.32	16.81	18.97	21.92	22.68	17.39	19.51	20.09	17.57	23.36	17.42	21.78	22.90	22.10	22.14	21.17	20.27	20.45
14	21.53	21.56	18.43	20.92	20.38	20.70	21.60	20.84	17.14	21.60	17.06	23.18	22.75	22.82	18.79	18.29	22.14	23.18	20.48	17.53	19.48	17.17	19.19	18.47	22.03	22.28	20.59	21.82	22.39	20.50	20.46
15	21.60	21.82	20.05	23.98	19.94	19.40	20.88	21.64	21.35	20.59	16.96	23.08	20.30	22.72	17.50	18.14	22.07	24.30	19.40	18.18	16.38	16.92	21.56	20.56	21.89	22.57	21.74	22.93	22.36	20.72	20.50
16	19.98	21.13	19.84	21.17	19.84	21.31	21.24	22.61	22.18	22.64	19.12	19.44	21.85	22.14	18.36	18.18	20.95	24.08	19.69	18.14	17.89	18.43	23.76	18.90	22.25	22.32	21.78	22.97	21.64	20.82	20.53
17	20.59	20.05	21.71	21.67	20.05	21.42	19.80	23.15	19.76	20.92	21.13	18.32	16.92	18.00	18.43	19.98	20.30	23.00	22.79	17.21	18.76	19.37	19.58	22.64	22.46	21.85	22.28	22.86	20.84	20.55	20.55
18	20.74	20.23	22.32	22.46	20.41	21.60	22.03	20.41	19.98	20.30	23.47	16.67	20.12	22.18	21.71	16.92	19.62	22.61	20.99	18.07	19.12	20.23	21.17	20.27	22.36	21.20	21.56	22.90	20.74	20.77	20.61
19	22.93	18.79	21.28	22.00	20.30	22.03	20.63	17.46	23.26	19.51	20.56	16.99	21.24	20.27	18.36	16.74	21.28	18.29	19.73	18.79	20.30	20.88	22.75	18.58	22.28	22.18	22.93	22.57	22.57	20.53	20.65
20	22.57	20.45	21.53	22.61	18.65	21.60	20.27	22.93	22.82	21.35	19.04	17.06	20.59	21.60	19.66	20.23	19.26	22.00	20.34	18.22	23.36	19.22	20.23	23.04	21.85	21.64	22.82	22.50	22.50	21.03	20.67
21	21.82	19.33	20.05	20.56	20.63	21.60	19.55	18.00	24.08	18.29	16.45	17.17	22.68	19.94	19.26	22.75	21.02	20.99	16.92	18.36	18.29	20.63	22.82	22.50	22.28	19.66	23.51	22.00	22.32	20.46	20.72
22	21.10	20.59	22.07	21.85	20.66	22.64	18.97	19.94	20.38	17.89	17.78	17.14	19.58	20.70	23.29	21.89	21.38	24.19	17.60	24.23	18.58	21.60	23.58	20.84	20.81	20.20	23.36	22.25	23.33	20.98	20.77
23	22.57	21.17	22.57	22.54	20.48	20.59	21.64	17.78	18.00	17.75	17.14	21.49	19.44	17.57	23.69	20.16	22.39	21.02	18.25	22.97	19.66	19.37	18.79	20.74	21.64	21.38	23.36	22.54	22.86	20.67	20.78
24	23.26	21.13	19.30	22.07	21.92	21.53	18.29	17.64	18.94	17.60	18.47	20.77	19.37	17.50	20.95	19.91	20.81	18.29	16.99	21.42	16.70	20.20	19.98	24.41	22.72	22.21	23.22	22.68	23.18	20.39	20.82
25	23.22	21.38	19.33	21.85	21.02	21.60	17.86	19.80	16.09	17.60	19.01	17.32	21.31	17.64	20.52	19.33	18.94	18.14	17.14	23.22	18.14	20.81	22.03	23.33	23.26	22.10	23.76	22.82	23.18	20.41	20.92
26	23.15	21.10	19.76	21.92	20.52	22.36	17.39	19.58	16.45	17.93	21.06	17.60	20.23	17.28	20.59	21.71	19.98	19.80	17.32	19.15	21.42	22.14	19.91	23.11	23.87	22.97	23.44	22.93	23.11	20.61	20.98
27	22.93	20.88	21.46	22.79	21.46	22.93	18.47	17.24	22.50	19.48	19.76	22.25	20.70	18.68	20.02	21.64	20.81	21.02	20.41	18.14	19.62	20.30	22.25	22.21	23.47	22.64	22.82	21.28	23.33	21.09	21.03
28	22.75	21.42	21.92	23.15	21.17	23.18	19.58	18.11	23.98	19.30	19.84	22.18	20.63	20.16	20.23	18.40	19.58	22.64	17.53	18.86	18.40	20.05	20.92	21.67	23.51	22.90	22.64	23.00	22.61	21.05	21.05
29	22.57	22.57	23.51	22.64	21.17	23.04	19.19	20.05	23.94	19.66	21.31	19.66	21.60	20.30	19.66	21.49	21.89	21.96	19.19	17.89	19.80	19.94	18.22	22.18	22.90	23.26	20.70	23.54	23.18	21.28	21.09
30	23.69	21.13	22.57	23.29	21.28	22.64	18.04	20.12	19.84	20.99	19.19	20.02	20.95	20.27	20.81	21.20	20.48	23.98	18.90	17.89	17.57	19.66	18.25	19.04	23.22	23.18	21.56	23.33	23.58	20.92	21.28
31	24.05	22.21	21.78	22.68	23.47	18.58	18.22	18.25	19.26	19.40	22.25	18.97	20.45	21.35	18.97	23.40	20.59	25.16	22.00	19.04	18.79	19.91	18.94	23.00	23.44	23.80	23.44	22.54	23.62	21.29	21.29

2.3. Statistical analysis of Finkelstein-Schafer (FS)

Seven weather parameters (or indices) were used for the statistical analysis to establish long-term cumulative distribution functions (CDFs). Finkelstein-Schafer (FS) statistical method is used for generating typical weather data [9], [10], [11]. In the present study, FS methodology is used for the generation of typical solar radiation year and the weighting indices values for the 29 years examine for all the month were considered as presented in table 1. According to FS statistics [12], if a number, n, of observations of a variable j are available and have been sorted into an increasing order X_1, X_2,. . .,X_n, the cumulative frequency distribution function (CDF) of this variable is given by a function, which is defined as follows:

$$CDF_j = \frac{1}{n} j \tag{1}$$

Finkelstein-Schafer (FS) statistic for index *j, j=1,2,3,..., no. of indices considered,* using the following formula (Finkelstein and Schafer, 1971):

$$FS_j = \frac{1}{n}\sum_{i=1}^{n}\delta_i \qquad i = 1,2,..., no. of\ days\ in\ month \tag{2}$$

Where:

δ_i = absolute difference between the short-term and the long-term CDFs for day ***i*** in the month, **n** = number of days in the month**, j** = the weather index considered.
A weight is assigned to each index and a weighted sum (WS) of the FS_j statistics for the month is calculated using the following formula:

$$WS = \sum_{j=1}^{n} w_j FS_j \tag{3}$$

Where:

n = no. of indices (parameters / elements) considered

w_j = weight for index j
FS_j = FS statistic for index j.

2.4 *TMY Selection and Assembly*

A weight is assigned to each index and a weighted sum (WS) of the FS_j statistics for the month is calculated using equation (3). The weights assigned in this work are given in table 1. The weighted sums for the months of the year for all years considered are shown in table 4. The values highlighted represent the cases corresponding to the lowest values of the weighted sum of the FS statistics, the typical month to be included in the TMY are selected from each month as the month with the smallest weighted sum are highlighted in the table 4.

Table 4: Weighted Sum (W.S) for the F.S statistic over all 7 parameters for each month of the years in record

	MONTH											
YEAR	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
1984	1.08	1.30	2.37	4.17	4.41	2.97	1.89	2.80	2.06	3.40	1.47	1.48
1985	1.18	1.92	5.05	2.77	5.12	3.40	1.81	2.50	2.43	2.95	1.07	1.18
1986	1.20	0.96	3.03	2.60	3.41	4.07	3.17	2.61	2.69	2.66	1.44	1.07
1987	1.21	1.10	2.35	4.78	4.47	2.47	2.65	2.96	1.74	3.21	1.48	1.98
1988	1.16	1.03	1.85	2.61	2.78	3.34	2.59	2.35	2.75	2.91	1.13	2.23
1989	1.80	1.80	1.95	3.01	3.79	3.27	1.58	2.10	1.63	3.06	1.18	1.20
1990	1.69	0.98	1.99	2.54	2.91	2.53	2.19	2.51	1.87	3.22	2.13	2.42
1991	1.66	1.15	1.67	2.21	4.78	1.94	1.41	2.15	3.59	3.75	1.83	1.65
1992	2.44	1.21	2.48	2.36	2.57	2.55	1.92	1.73	2.08	3.07	1.78	1.56
1993	1.67	1.45	1.37	2.02	2.32	2.11	1.75	2.20	2.48	3.06	1.66	1.49
1994	1.99	1.41	1.70	2.67	2.23	1.69	1.95	2.30	2.62	3.46	1.86	1.71
1995	1.36	1.63	2.01	2.70	2.59	2.73	2.12	2.45	1.58	1.97	2.28	1.07
1996	0.79	1.20	2.67	2.33	2.44	2.93	1.26	1.98	2.25	2.52	1.57	1.51
1997	1.34	2.01	1.95	4.64	2.95	3.06	1.84	2.49	1.59	2.57	2.05	1.18
1998	1.67	1.17	1.49	3.18	1.97	2.70	2.48	2.20	1.64	2.64	1.18	1.73
1999	1.55	1.84	1.96	2.38	2.49	3.03	2.19	2.13	2.66	3.76	1.30	1.66
2000	1.36	1.59	2.77	1.31	2.78	2.51	1.98	2.22	1.94	3.70	2.13	1.57
2001	1.93	1.32	1.58	3.12	2.92	2.28	2.50	2.08	1.60	3.80	1.61	1.29
2002	1.46	1.19	1.57	1.58	3.17	3.03	2.08	1.76	2.15	3.29	2.05	2.20
2003	2.07	1.21	1.49	4.64	4.42	3.31	1.84	2.77	1.73	2.08	1.85	1.71
2004	1.64	1.08	2.04	1.83	4.15	2.85	2.30	2.55	2.51	3.34	2.07	1.55
2005	1.68	1.74	2.35	3.64	3.66	3.50	1.93	2.22	1.95	2.75	1.52	1.75
2006	1.79	2.59	1.62	3.79	2.11	4.04	4.26	1.83	2.12	1.95	1.80	1.65
2007	2.01	0.87	1.83	2.65	4.05	4.47	3.98	4.04	6.29	4.48	2.57	1.83
2008	2.45	2.48	3.37	3.46	2.10	2.26	2.19	2.02	2.55	3.34	2.04	2.48
2009	2.38	2.76	3.13	3.00	2.27	2.79	2.08	2.74	2.34	4.75	3.76	1.87
2010	1.80	2.47	3.59	2.57	2.51	2.62	2.87	2.82	2.58	4.77	5.06	3.02
2011	2.24	2.66	2.96	4.22	3.48	2.83	3.03	2.62	2.32	3.19	2.10	1.56
2012	2.15	2.16	2.98	2.84	2.42	1.88	2.25	2.58	2.63	4.48	3.29	2.11
min W.S.	**0.79**	**0.87**	**1.37**	**1.31**	**1.97**	**1.69**	**1.26**	**1.73**	**1.58**	**1.95**	**1.07**	**1.07**

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3. **Results and Discussion**

Figure 2. presents quick view of the occurrence of solar flux values in a graphical representation for the cumulative probability distributions of long term and short term global flux for Abeokuta, showing some years between 1984 – 2012 and table 5 present typical meteorological months (TMM) to show an indication of the variation or deviation of the short term of some years selected from 1984 to 2012 from the long term and concatenated months to form the typical meteorological year, trend with excellent relationships between the TMY and the long-term mean of the global solar radiation in the selected site was noticed through all the year except the long term that cut across at global solar radiations (GSR) 21.1MJ/m^2.day while the highest CDF and GSR is in year 1984 (1: 23.3 1MJ/m^2.day).

Tables 6 and 7 presents the result for the month of January (1996) over all 7 weather parameters for all the TMY calendar months. The TMY can be said to be an approximation of the long term values, though not exactly the same, due to the fact that the long term does not account for differences in weights of the different parameters to be considered. Fig. 3 shows the variation of some years with the long term and then with the TMY, indicating that the TMY closely follows the long term, with all the years having good fit.

A comparison is also made between values of Global Solar Radiation of the worst year (that is, whose months have the largest deviation from the long term), the typical meteorological year, and the long term in the Fig 4. It can be seen that while the TMY displays a consistent closeness to the long term, the worst year does not show such a correlation. The TMY and long term show corresponding peaks and troughs (March and August respectively), whereas the worst year only shows corresponding trough at August (16.3 MJ/m^2.day). Its peak occurs at a month different from TMY and the long term in April (25.2MJ/m^2.day).

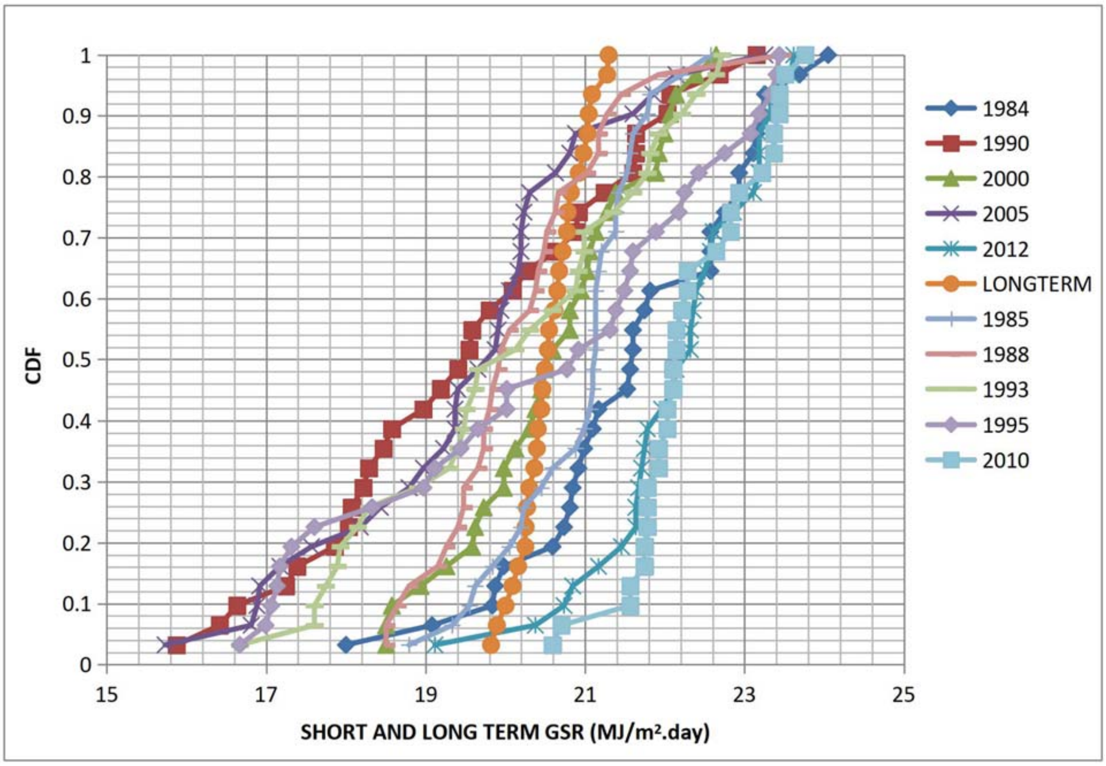

Figure 2: Cumulative Probability Distributions of Long term and Short term global flux for Abeokuta, showing some years between 1984 – 2012

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Table 5: Typical Meteorological Months

Month	Year
The month of JANUARY	1996
The month of FEBRUARY	2007
The month of MARCH	1993
The month of APRIL	2000
The month of MAY	1998
The month of JUNE	1994
The month of JULY	1996
The month of AUGUST	1992
The month of SEPTEMBER	1995
The month of OCTOBER	2006
The month of NOVEMBER	1985
The month of DECEMBER	1986

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Table 6: Typical Meteorological January Month (1996) over all 7 parameters

DAY	GSR(MJ/m^2/day)	TEMP MEAN (°C)	TEMP MIN (°C)	TEMP MAX (°C)	REL HUMID (%)	DEW FROST TEMP (°C)	WIND SPEED (m/s)
1	20.48	21.79	14.6	29.45	18.62	-3.16	3.28
2	19.76	22.1	15.98	30.39	15.64	-5.24	3.48
3	20.41	23.45	16.09	31.29	14.71	-4.98	3.76
4	20.63	23.91	16	33.68	17.81	-2.02	3.51
5	20.45	23.08	16.16	32.67	20.41	-0.86	3.59
6	20.16	23.29	15.48	32.64	19.1	-1.59	2.86
7	20.48	24.01	16.35	32.92	19.22	-0.91	3.75
8	21.71	23.64	15.86	32.08	17.11	-2.79	3.75
9	19.94	22.53	15.92	30.64	15.68	-4.86	3.96
10	19.19	23.01	16.38	30.61	17.28	-3.17	3.2
11	19.80	23.4	16.29	31.71	18.54	-1.9	2.78
12	21.42	23.53	14.39	32.11	20.21	-0.62	2.86
13	21.89	23.7	12.94	32.3	18.97	-1.34	2.45
14	22.75	24.05	16.8	32.68	19.39	-0.75	2.02
15	20.30	24.54	17.46	32.62	17.74	-1.56	2.73
16	21.85	23.69	16.58	29.65	17.08	-2.77	3.6
17	16.92	22.03	15.74	29.25	18.94	-2.73	3.81
18	20.12	20.68	11.38	29.88	20.25	-2.96	3.4
19	21.24	21.78	14.14	31.12	20.33	-1.99	2.79
20	20.59	23.25	14.23	33.22	18.41	-2.12	2.58
21	22.68	26.18	16.97	35.35	19.68	1.21	3.65
22	19.58	26.99	16.43	35.18	21.01	2.78	4.09
23	19.44	25.92	16.8	34.48	19.81	1.08	4.41
24	19.37	24.56	18.45	32.47	18.98	-0.63	3.1
25	21.31	26.01	17.42	35.33	18.17	-0.04	1.93
26	20.23	26.84	17.1	35.16	18.75	1.08	2.26
27	20.70	27.31	16.04	35.53	17.96	0.86	3.43
28	20.63	26.49	19.77	33.39	15.34	-1.98	3.92
29	21.60	25.02	17.91	32.91	15.93	-2.65	3.35
30	20.95	25.78	18.36	34.27	16	-1.97	3.62
31	20.45	26.22	17.16	34.94	17.04	-0.75	3.04

Table 7: Typical Meteorological June Month (1994) over all 7 parameters

DAY	GSR(MJ/m^2/day)	TEMP MEAN (°C)	TEMP MIN (°C)	TEMP MAX (°C)	REL HUMID (%)	DEW FROST TEMP (°C)	WIND SPEED (m/s)
1	22.25	29.8	26.54	34.17	53.98	19.6	3.37
2	19.84	27.23	24.8	30.56	73.6	22.21	3.07
3	23.69	28.32	24.57	32.59	62.32	20.57	1.98
4	24.88	29.56	24.42	34.78	54.6	19.57	2.36
5	25.24	29.31	26.48	33.03	59.68	20.8	2.88
6	20.45	25.85	22.95	28.56	83.39	22.85	3.76
7	22.18	27.11	24.27	30.88	75.25	22.45	3.12
8	18.65	26.86	24.36	30.79	77.06	22.58	4
9	19.76	26.73	24.08	30.46	72.17	21.42	3.89
10	20.09	26.32	22.57	29.86	73.58	21.33	2.79
11	23.08	28.27	23.88	33.12	58.76	19.56	2.31
12	25.34	27.47	24.43	31.39	67.79	21.12	3.46
13	24.95	28.21	23.95	33.48	64.63	21.06	3.01
14	25.02	28.21	24.58	32.5	62.11	20.41	3.94
15	21.35	29.53	25.08	34.01	50.39	18.22	3.21
16	22.28	29.77	25.61	33.99	48.69	17.88	3.58
17	18.97	28.48	26.48	31.74	61.9	20.61	3.32
18	13.82	26.17	24.43	29.35	80.03	22.51	2.96
19	24.73	25.33	20.58	29.13	80.73	21.83	3.07
20	25.16	26.77	21.26	31.64	67.05	20.28	3.14
21	24.84	27	23.06	32.33	64.41	19.85	3.22
22	23.80	28.85	23.79	35.39	46.54	16.3	2.91
23	21.24	29.49	24.91	35.57	46.39	16.83	2.55
24	20.30	27.62	24.8	31.45	64.03	20.34	3.19
25	12.13	27.2	22.4	32.07	65.84	20.39	2.48
26	19.69	27.13	23.03	31.38	65.23	20.18	3.07
27	25.09	28.17	23.97	33.38	57.81	19.2	3.02
28	23.76	27.72	24.23	31.75	58.9	19.08	4.4
29	24.12	26.91	23.77	31.01	68.31	20.71	4.53
30	21.28	26.39	23.4	30.27	75.67	21.84	3.58

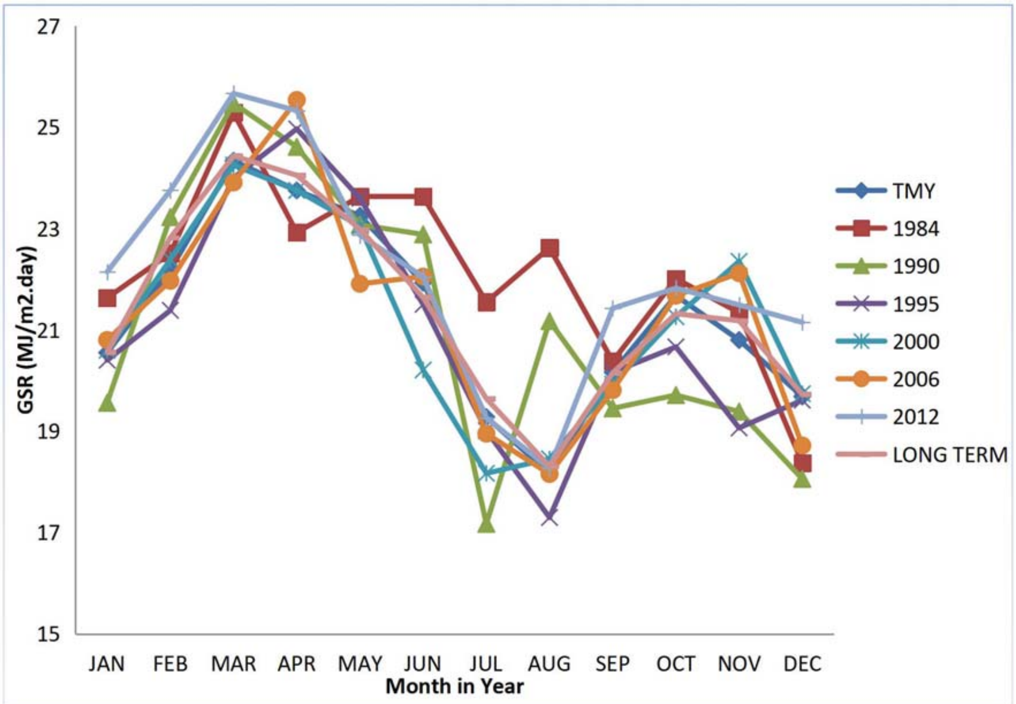

Figure 3: Variation of TMY with long term and other years: global solar radiation for Abeokuta

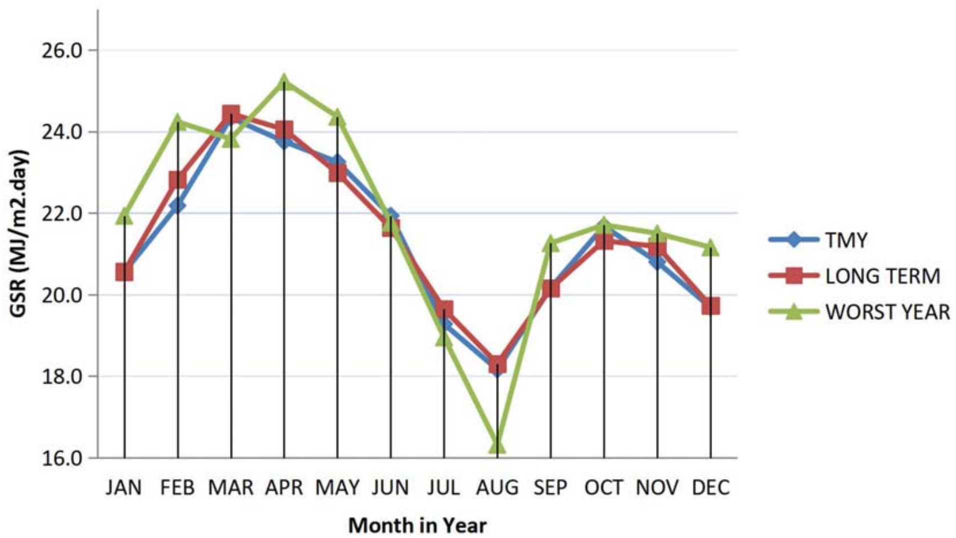

Figure 4: Comparison between TMY, long term and worst year for Global Solar Radiation for Abeokuta

TMY closely follows the long term mean, and with absence of TMY data, the long term mean could be used as a representation of the climatic condition of Abeokuta as presented in Figure 4 is in agreement with findings of Anderson *et al*. (2007) and Yang *et al*. (2008), and Fig. 3 shows increased global solar flux in Abeokuta over the years, indicative of the palpable climate change, and global temperature rise, which is of huge concern in the world today. As much as steps are being made to mitigate the effects of global warming, the benefits of an increased solar flux parameter would be to harness the solar radiation present, to counter the effects of carbon prints, and provide a healthier alternative energy source.

The seasonal variation observed in the solar flux values can be attributed to the important roles that the clouds and water vapour play in the atmospheric radiation budget, which is pronounced during the wet season in West Africa. The presence of convective clouds occurring within a highly humid atmosphere is mainly responsible for the marked reduction of intensive incoming solar radiant energy during the wet months. The dry months have comparatively larger values than the wet months. This is mainly due to the attenuation of the incoming solar radiation by clouds during the wet season, and the harmattan haze during the dry season [13- 19]. Considering the wind speed, it is evident from the TMY that maximum wind speed values exist from December to about March, consistent with the Harmattan season typical to Nigeria, and the West African sub-region. During this period, wind turbine systems would be best utilised. With respect to relative humidity, Abeokuta shows a relatively high level of humidity, hence, discouraging the use of evaporative cooling techniques, especially from May to October, consistent with the rainy season of Nigeria [20 - 23]. However, in order to minimise the effect of increased thermal loads on air-conditioning systems, passive cooling techniques such as shading and solar chimneys could be employed. This would considerably reduce the peak cooling load in buildings, and so reduce the size of the air conditioning equipment and the period for which it is required. This leads to reduction in costs.

Conclusion

In this study, Sandia method (SM) was used to select TMMs and develop TMY for Abeokuta city in south – west region, Nigeria using most recent 29 years (1984- 2012) of the measured data. TMY obtained showed a very slight deviation from the long term values, endorsing the use of this method in obtaining a typical representative year. The generation of a typical meteorological year is very useful for optimal design and evaluation of solar energy and HVAC systems. The result presented in this work will provides a reliable database for engineers who are engaged in design, installation and maintenance of thermo-fluid systems, to strengthen building energy standards, understand the local climate of Abeokuta and hence facilitate building energy performance analysis.

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