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Evidence of Global Warming In Nigeria and Recommended Responses

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ABSTRACT

Hourly dry-bulb temperatures for 14 locations were obtained from the Nigerian Meteorological Agency (NiMet) Oshodi for the periods 1995-2009. Statistical analyses were carried out on the data using Microsoft Excel 2007 version to obtain average hourly temperature for each month of the year and their standard deviations, average temperature for each month and the average temperature for the four warmest months and their standard deviations. The 1%, 2½% and 5% normal probability confidence values of dry bulb temperature obtained from the average temperature and standard deviation for the four warmest months were compared with the results obtained by earlier workers for the period 1951-1965. It was found that both the design month mean monthly dry bulb temperature and the 2 ½ confidence values for the dry bulb temperature were higher in the present work based on 1995-2009 data than results obtained by earlier workers based on 1951-1965 data, for all the fourteen locations. The increase of dry bulb temperatures for all the locations is an evidence of global warming in Nigeria and necessary policy should be put in place to combat it either for adaptation to global warming and mitigation of its effects in Nigeria. Global warming increases power consumption in a refrigeration and air conditioning systems. Some of the measures taken to combat the effects of global warming include using "cool roof" for buildings, planting trees to provide shade around air-conditioned buildings to reduce cooling load, choosing a building orientation that will minimise air-conditioning cooling load, equipping air-conditioning systems with economizers, application of off-grid renewable energy sources in homes, using low energy appliances, and using compact fluorescent lamps (CFLs) and light emitting diode (LED) bulbs to replace incandescent bulbs.

Key words: Dry bulb temperature, global warming, evidence, normal probability confidence values.

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1. INTRODUCTION

From several surface and upper air weather stations spread all over Nigeria, the Nigerian Meteorological Agency (NiMet) has been gathering weather data since 1896 (Nnodu, 2011). The outside air design condition usually specified for calculating air-conditioning cooling load for a building is the 2½% normal probability confidence value for dry-bulb temperature and the mean coincident wet-bulb temperature for the place where the building is located. The 2½% dry-bulb temperature is the temperature exceeded for 2½% of the hours of the four warmest months in a year, assuming the dry-bulb temperature is normally distributed during those four months. The mean coincident wet-bulb temperature is the average of the wet-bulb temperature occurring at the 2½% dry-bulb temperature (Stoeckers and Jones, 1982). The interest of a mechanical engineer in weather data is not just limited to his involvement in the field of refrigeration and air-conditioning alone. The operation of an air breathing engine is controlled so that aspiration of surrounding air at different temperatures and moisture content will not significantly affect power output, fuel efficiency, combustion stability and exhaust gas emissions (Valo & Paasima, 2009).

There are observed evidences from all the continents and most oceans of increase in temperature which has effect on many natural systems (Fagbenle, 2010). Shoboyejo and Shonubi (1974) using the meteorological data collected for twenty-eight location in Nigeria during the fifteen-year period (1951-1965) and assuming the data are normally distributed, obtained the 1%, 2½% and 5% normal probability confidence values for dry-bulb temperature, wet-bulb temperature and vapour pressure for the four warmest months in the year for each location. Ariyo (1997) did a similar analysis on the hourly weather data for fifteen years (1978-1992) for Ikeja and Ilorin to obtain 1%, 2½% and 5% normal probability confidence values for dry-bulb temperature and relative humidity for the two locations. He found the corresponding normal probability confidence values in his work for the two locations higher than those obtained by Shoboyejo and Shonubi from the period 1951to1965.

Olorunmaiye et al (2012) obtained the hourly meteorological data of Ilorin and Ikeja for 1995 -2008 to obtain outside air design temperature for air conditioning cooling load calculations. The results were compared with results obtained by the earlier researchers mentioned above and it was concluded that the part of sensible infiltration/ventilation and heat transmission components of air conditioning cooling load have increased for both Ikeja and Ilorin in Nigeria, as a result of global warming. It has been observed and reported that there is an increase in global surface temperature and that the twelve hottest years since 1850 occurred between 1995 and 2006 (Wilson and Law, 2007). Hagglund (2009) observed that “climate debate has reached a stage where greenhouse effects are considered facts that have to be taken into account”.

In order to combat the menace of climate change and global warming, several papers have been written by researchers on what to do. The two methods of fighting the problems which are mitigation and adaptation have been discussed. It was reported by Orlove (2005) that Intergovernmental Panel on Climate Change (IPCC) has defined adaptation as “adjustment in natural or human systems in response to actual or expected climatic stimuli or their effect, which moderates harm or exploits beneficial opportunities”, whereas mitigation is “an anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases”. Mitigation is reduction of the principal cause of the problem and adaptation is accommodating the problem and many of the activities toward adaptation can influence the sources and sinks of greenhouse gases (Orlove, 2005).

Tol (2005) observed that adaptation may affect mitigation by giving the example of using air conditioning as an adaptation method to summer heat which increases emission of greenhouse gases.Klein et al (2005), clearly stated major differences between mitigation and adaptation as follows: first, mitigation has global benefits while adaptation at best has only regional benefits and mitigation activities carried out today will be evident in several decades to come because of the long residence time of greenhouse gases in the atmosphere, while adaptation measure would be effective immediately and yield benefits by reducing vulnerability to climate variability. Secondly, the cost of mitigation measure is higher than adaptation measures. Lastly, Mitigation is focused on energy and transport in industrialised world and largely energy and forestry sectors in developing countries. Equally, agriculture plays a prominent role in mitigation whereas adaptation covers several sectors such as agriculture, tourism and recreation, human health, water supply, coastal management, urban planning and nature conservation.

Buob and Stephan (2011) were of the opinion that mitigation cannot be the only policy response to global climate change. They wrote that an alternative is reducing vulnerability by adapting to global warming and examples of adaptation measures include early storm warning and investment in infrastructure such as dam. Olorunmaiye and Awolola (2016) observed that more can be achieved in Nigeria in mitigating global warming by putting an end to flaring of natural gas in oil producing areas. The aim of this work is to scrutinize the results obtained for outside design conditions for estimating cooling load for air conditioning systems for fourteen other locations apart from Ilorin and Ikeja, to see if they provide further evidence of global warming in Nigeria and to present response to it.

2. MATERIALS AND METHODS

Hourly dry-bulb temperature data based on Greenwich Mean Time (GMT) were obtained for fifteen years (1995-2009) from Nigerian Meteorological Agency, Cappa, Oshodi, Lagos state for Bauchi, Benin-City, Calabar, Enugu, Ibadan, Jos, Kaduna, Kano, Maiduguri, Minna, Ondo, Port-Harcourt, Sokoto and Yola. The locations of these towns on the map of Nigeria are shown in Figure 1.

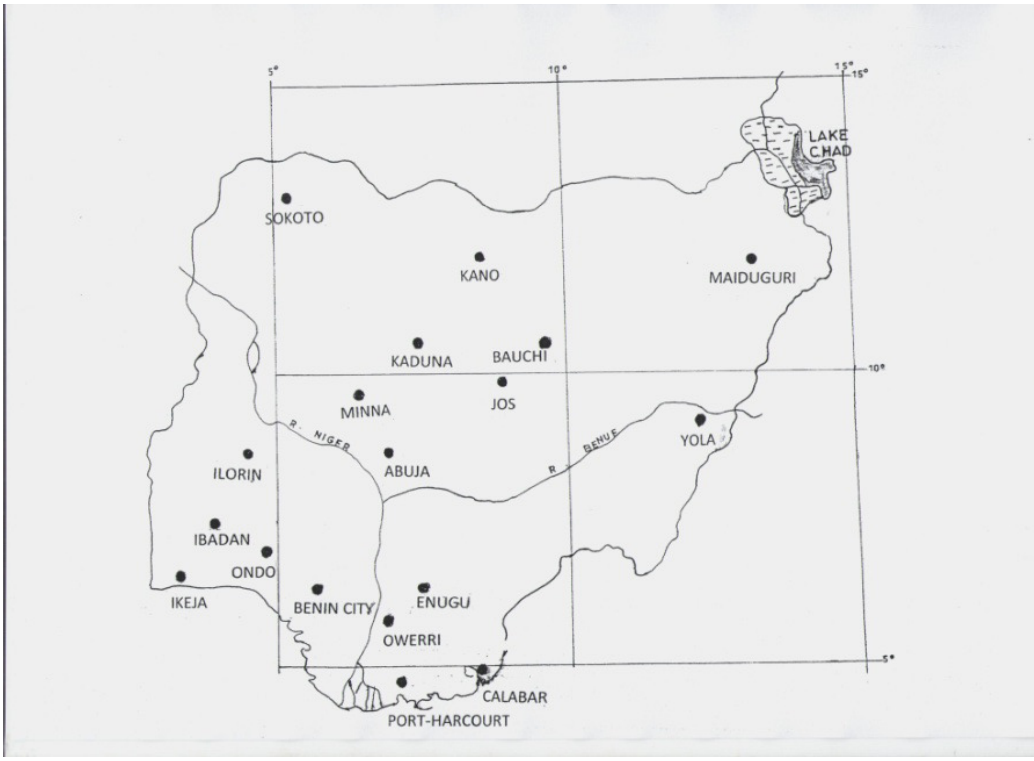

Figure 1: Map of Nigeria showing the fourteen locations

These data were analysed using 2007 version of Microsoft excel office software. The Average dry-bulb temperatures were obtained for each of the 24 hours of the day for each month of the year. Average daily temperature range was also obtained for each month of the year.

3. RESULTS AND DISCUSSIONS

The average monthly temperature and standard deviations obtained in this work are presented in Tables 1 to 5.
The outside design conditions for cooling load calculations for the locations were determined from the data for the four warmest months for the fourteen locations. The mean and the standard deviations were determined from the hourly data for the four warmest months for each of the fourteen locations. Assuming the data follow the Gaussian or normal distribution, the 1%, 2 ½ % and 5% normal probability, confidence values were determined from normal distribution table as done by Shoboyejo and Shonubi (1974) and Olorunmaiye et al (2012). Tables 6 (A) to (E) show the results obtained as compared with the previous results obtained for the same locations by Shoboyejo and Shonubi (1974). From Tables 1 and 4, the month with highest average temperature is April for Kaduna, Kano, Sokoto, Maiduguri, Yola and Bauchi. The coldest month for the above mentioned locations is January excerpt Yola which was in December. Tables 2 and 3 show that highest average temperature for Benin- City, Calabar, Port-Harcourt, Ondo and Ibadan occurred in February and the coldest month was August for the locations. The month which has highest average temperature for Enugu, Minna and Jos was March. See Tables 3 and 5.

From Table 6, both the mean temperature and 2½% confidence values for dry-bulb temperature for the four warmest months were higher in the present work (based on 1995-2009 data) than the results of Shoboyejo and Shonubi (based on 1951-1965 data). The increase in the mean temperature in this work is lowest in Ondo which is 4.79%; this may be as a result forest vegetation in the area. The highest increase in the mean temperature is 17.92% at Kano. This appears to be an evidence of global warming in Nigeria. The International Panel on Climate Change setup in 1988 by UN World Meteorological Organization and UN Environmental programme ascribed this observed warming to human-induced emissions (Wilson & Law, 2007).

4. CHALLENGES FACED IN THIS WORK

One challenge faced in this work was the long duration of the time used to key in the data from the photocopied data sheets from NiMet. Efforts were made to ensure the data keyed into the computer were accurate. If the soft copies of these data were available the time used for typing the data and checking their accuracy would have been saved. Another challenge faced was incomplete data for some the locations. For Ibadan, Kaduna and Yola, the year 2009 data were incomplete and the fifteen year period that was used was 1994 to 2008. For Owerri, the data for 1995 to 1998 were incomplete and so the statistical analysis for Owerri was based on the eleven-year period 1999 to 2009.

5. ENGINEERING RESPONSE TO THE OBSERVED RISING OUTSIDE AIR TEMPERATURE

Energy consumption for running air-conditioning systems in buildings depends on the climate in which the building is located. The results of this work shows that the thermal transmission component of air-conditioning cooling load is increasing due to global warming. Since global warming is caused by energy consuming devices like air-conditioners, whatever can be done to reduce energy consumption in air-conditioning systems will help to mitigate global warming. Planting of trees around air-conditioned buildings will reduce the cooling load due to the shade provided by trees. The shade reduces temperature gradient across the building fabric as well as reducing direct exposure of the building fabric to sunlight. The Placing of a building on a site alters the microclimate of that site Marku & Morris (1980) Architects and engineers can work together to choose the orientation that will give minimum air-conditioning cooling load.

Energy consumption of an air-conditioning system can be reduced by equipping it with an economizer (Natural Resources, Canada, 2010). An economizer consists of dampers, sensors, actuators, control and links. It may be installed on a new air-conditioning system or retrofitted on an old air-conditioning system. It is used to determine how much outside air to bring into a building. During the period, June to September when the outside air temperature is between 23°C and 27°C most of the time in many towns in Nigeria, economizers can save energy by using outside air to cool the building without the compressor running. An adaptation measure that will make it possible to run refrigerators in cooler rooms is using “cool roofs” for buildings. Cool roof reduce heat transmission into a building either by using solar reflective roof coatings on top of the roofing material (U.S. Department of Energy, 2011), or by using polyurethane lining as insulation under the roofing sheets (The Guardian, 2011a).

The National Centre for Hydropower Research and Development (NACHRED), University of Ilorin recently destroyed one million Naira worth of incandescent bulb rated 60W collected from homes in which they had been replaced free of charge with Compact Fluorescent Lamps (CFLs) rated 14W (The Guardian, 2011b). Some renewable energy companies are also selling 5W alternating current Light Emitting Diode (LED) bulbs to replace incandescent bulbs. Although these CFLs and LED bulbs are more expensive than the incandescent bulbs they are replacing, their use is being promoted to encourage consumers of electricity from the national grid to save energy and pay less. And thereby contribute less to global warming. A few years ago some renewable energy companies started operating in Nigeria promoting the use of solar energy instead of electricity generating sets running on fossil fuels.

Table 1: **Average monthly temperature, standard deviation and range of dry bulb temperature for Kaduna, Kano and Sokoto *(Computation from NiMet data)***

	Kaduna			**Kano**			**Sokoto**		
Month	Mean Tdb	STD	Range	Mean Tdb	STD	Range	Mean Tdb	STD	Range
January	23.12	5.69	14.73	21.72	5.81	15.21	24.59	5.78	14.90
February	25.67	5.70	14.59	24.56	6.02	15.33	27.18	6.01	15.20
March	28.78	5.14	13.83	28.69	5.69	15.11	31.24	5.78	14.73
April	29.04	4.45	11.27	31.85	5.03	13.49	34.30	4.89	12.97
May	27.17	3.95	9.45	31.30	4.63	11.60	33.21	4.52	10.87
June	25.23	3.38	7.98	28.72	4.05	9.61	30.91	4.01	9.50
July	24.34	2.87	6.77	26.57	3.40	7.77	28.28	3.45	7.77
August	23.77	2.71	6.16	25.63	3.04	7.00	26.81	3.04	6.82
September	24.36	3.38	8.03	26.72	3.58	8.56	27.86	3.51	8.44
October	25.19	3.89	9.85	27.73	4.42	11.85	30.14	4.61	12.49
November	24.72	5.42	14.98	25.33	5.56	15.31	29.12	5.57	15.56
December	23.27	5.63	15.33	22.30	5.71	15.72	26.19	5.76	15.51

Table 2: **Average monthly temperature, standard deviation and range of dry bulb temperature for Benin City, Port-Harcourt and Calabar *(Computation from NiMet data)***

	Benin City			**Port Harcourt**			**Calabar**		
Month	Mean Tdb	STD	Range	Mean Tdb	STD	Range	Mean Tdb	STD	Range
January	27.38	3.50	9.16	26.80	3.92	10.06	27.18	3.04	8.44
February	28.49	3.52	9.14	27.81	3.86	9.70	28.23	3.17	8.83
March	28.29	3.32	8.04	27.76	3.40	8.16	27.89	3.03	7.34
April	27.65	3.11	7.07	27.32	3.16	7.11	27.23	2.82	6.50
May	27.00	2.93	6.59	26.81	2.97	6.61	26.95	2.69	6.30
June	26.00	2.52	5.53	25.96	2.47	5.36	26.12	2.33	5.24
July	25.09	1.95	4.30	25.34	2.10	4.61	25.19	2.02	4.42
August	24.77	1.85	4.12	25.31	2.03	4.66	24.83	1.76	3.62
September	25.19	2.22	4.69	25.38	2.17	4.81	25.35	2.05	4.68
October	25.97	2.66	6.12	25.86	2.47	5.58	25.86	2.33	5.53
November	27.39	2.98	7.68	26.76	3.01	7.52	26.66	2.57	6.50
December	27.58	3.24	8.611	26.72	3.53	9.07	27.13	2.75	7.68

Table 3: Average monthly temperature, standard deviation and range of dry bulb temperature for Enugu, Ondo and Ibadan *(Computation from NiMet data)*

	Enugu			**Ondo**			**Ibadan**		
Month	Mean Tdb	STD	Range	Mean Tdb	STD	Range	Mean Tdb	STD	Range
January	27.17	4.43	11.53	26.97	3.79	10.31	27.53	3.49	9.70
February	29.03	4.25	11.10	28.06	3.98	10.62	28.82	3.77	10.28
March	29.63	3.61	9.21	27.78	3.65	9.14	28.68	3.61	9.27
April	28.55	3.40	7.86	26.93	3.24	7.57	27.88	3.26	7.65
May	27.21	3.15	7.12	26.39	3.00	7.09	27.16	3.02	7.20
June	26.36	2.69	6.37	25.32	2.70	6.23	25.86	2.67	5.77
July	25.70	2.37	5.44	24.44	2.15	4.99	24.87	2.04	4.78
August	25.57	2.24	5.31	24.08	1.98	4.72	24.54	1.92	4.65
September	25.70	2.53	5.79	24.63	2.45	5.58	25.13	2.33	5.46
October	26.39	2.90	7.21	25.44	2.89	7.02	25.98	2.76	6.76
November	27.26	3.64	9.02	26.86	3.28	8.57	27.07	3.39	9.09
December	26.66	4.56	12.08	27.13	3.48	9.40	27.62	3.27	9.22

Table 4: Average monthly temperature, standard deviation and range of dry bulb temperature for Maiduguri, Yola and Bauchi *(Computation from NiMet data)*

	Maiduguri			**Yola**			**Bauchi**		
Month	Mean Tdb	STD	Range	Mean Tdb	STD	Range	Mean Tdb	STD	Range
January	22.22	6.72	17.83	26.05	5.82	15.39	23.64	6.23	15.77
February	25.21	6.92	17.48	29.07	5.72	14.78	26.83	6.12	15.02
March	29.43	6.60	17.40	32.67	5.21	13.64	29.86	5.58	14.17
April	32.99	5.85	14.84	33.35	4.58	11.20	31.46	4.95	12.54
May	32.90	5.04	12.39	30.93	4.27	9.10	30.12	4.48	10.23
June	30.34	4.31	9.64	28.20	3.48	7.14	27.42	3.89	8.51
July	28.05	3.73	7.74	27.29	2.99	6.37	25.90	3.37	6.87
August	26.46	3.20	6.46	26.43	2.72	5.73	24.97	3.04	6.44
September	27.56	3.76	8.47	26.72	3.01	6.68	25.87	3.53	7.91
October	28.44	5.02	13.19	27.82	3.48	8.50	27.38	4.20	10.72
November	25.87	6.56	17.68	27.47	5.68	15.35	26.41	5.47	14.31
December	22.90	6.78	18.54	25.71	6.01	16.40	24.20	5.94	15.78

Table 5: Average monthly temperature, standard deviation and range of dry bulb temperature for Minna and Jos *(Computation from NiMet data)*

	Minna			Jos		
Month	Mean Tdb	STD	Range	Mean Tdb	STD	Range
January	27.54	4.73	12.57	19.25	5.88	15.15
February	30.06	4.68	12.50	21.66	5.83	14.95
March	31.98	4.19	11.28	24.03	5.13	13.35
April	31.00	4.02	9.85	23.82	4.25	10.23
May	28.57	3.61	7.96	22.35	3.32	7.78
June	26.64	3.00	7.01	21.17	2.98	6.65
July	25.60	2.50	5.90	19.78	2.25	5.09
August	25.11	2.39	5.14	19.73	2.25	5.12
September	25.54	2.78	6.36	20.56	3.06	7.06
October	26.54	3.35	8.38	21.32	3.94	9.63
November	27.69	4.77	12.90	20.37	5.22	13.45
December	27.42	4.96	13.96	19.59	5.69	14.96

Table 6: Comparison of 1%, 2½% and 5% normal probability confidence values of dry bulb temperature, mean Temperature, Daily range, and Design month obtained in this work based on 1995-2009 *(Computation from NiMet data)* with results obtained from 1951-1965 data *(Shoboyejo & Shonubi, 1974)*

A. For Bauchi, Benin City and Calabar

City/research period	**Bauchi**		**Benin-City**		**Calabar**	
	Shobeyejo & Shonubi (1951-1965)	**Present Work (1995-2009)**	**Shobeyejo & Shonubi (1951-1965)**	**Present Work (1995-2009)**	**Shobeyejo & Shonubi (1951-1965)**	**Present Work (1995-2009)**
Design Month	April	April	March	Feb.	March	Feb.
Range	14.44	12.63	11.11	9.15	9.44	8.79
1%	38.33	41.23	32.20	35.86	31.11	34.70
2 ½ %	36.60	39.41	31.11	34.61	30.00	33.58
5%	35.00	37.86	30.00	33.54	29.44	32.63
Mean	27.22	29.72	25.56	27.95	25.56	27.63
STD	5.00	4.95	2.78	3.40	2.22	3.04

B. For and Enugu, Ibadan and Jos

City/research period	Enugu		Ibadan		Jos	
	Shobeyejo & Shonubi (1951-1965)	Present Work (1995-2009)	Shobeyejo & Shonubi (1951-1965)	Present Work (1995-2009)	Shobeyejo & Shonubi (1951-1965)	Present Work (1995-2009)
Design Month	March	March	Feb.	February	March	March
Range	11.11	9.21	11.11	10.35	12.78	13.45
1%	33.88	37.29	32.78	36.21	29.44	34.39
2 ½ %	32.22	35.92	31.67	34.93	28.33	32.62
5%	31.67	34.76	30.56	33.84	27.22	31.10
Mean	26.11	28.64	25.56	28.12	21.11	23.16
STD	3.33	3.72	3.33	3.48	3.33	4.83

C. For Kaduna, Kano and Maiduguri

City/research period	Kaduna		Kano		Maiduguri	
	Shobeyejo & Shonubi (1951-1965)	Present Work (1995-2009)	Shobeyejo & Shonubi (1951-1965)	Present Work (1995-2009)	Shobeyejo & Shonubi (1951-1965)	Present Work (1995-2009)
Design Month	March	April	April	April	April	April
Range	14.44	11.27	15.56	13.49	17.22	14.96
1%	34.44	39.38	38.33	42.00	40.56	44.76
2 ½ %	32.78	37.53	36.11	40.13	38.33	42.65
5%	31.67	35.95	34.44	38.52	36.67	40.85
Mean	23.89	27.70	25.56	30.14	26.67	31.41
STD	4.44	5.02	5.00	5.10	6.11	5.74

D. For Minna, Ondo and Port Harcourt

City/research period	Minna		Ondo		Port Harcourt	
	Shobeyejo & Shonubi (1951-1965)	Present Work (1995-2009)	Shobeyejo & Shonubi (1951-1965)	Present Work (1995-2009)	Shobeyejo & Shonubi (1951-1965)	Present Work (1995-2009)
Design Month	March	March	February	February	February	February
Range	12.77	11.28	10.56	10.69	11.11	9.69
1%	35.56	40.43	32.22	35.87	31.11	35.85
2 ½ %	34.44	38.84	31.67	34.53	30.56	34.52
5%	32.78	37.48	30.56	33.38	29.44	33.38
Mean	26.67	30.38	26.11	27.36	25.56	27.43
STD	3.89	4.32	2.78	3.66	2.78	3.62

E. For Sokoto and Yola

City	Sokoto		Yola	
	Shobeyejo & Shonubi (1951-1965)	Present Work (1995-2009)	Shobeyejo & Shonubi (1951-1965)	Present Work (1995-2009)
Design Month	April	April	March	April
Range	15.00	13.06	15.56	11.28
1%	41.67	44.03	38.33	43.74
2 ½ %	39.44	42.19	36.66	41.81
5%	37.78	40.62	35.00	40.16
Mean	29.44	32.38	27.22	31.53
STD	5.56	5.01	5.00	5.25

6. CONCLUSIONS AND RECOMMENDATIONS

The rising temperatures of the fourteen locations in Nigeria have been presented as evidence of global warming in Nigeria. Several steps taken to combat it were presented, prominent among them being adoption of solar technologies to provide off-grid renewable energy sources.

7. DIRECTION FOR FURTHER RESEARCH

The Statistical analysis of weather data reported in this work should be extended to locations not yet covered. It will be necessary to choose a location in each of the following states: Jigawa, Kebbi, Yobe, Gombe, Kogi, Benue, Taraba, Ogun, Osun, Ekiti, Delta, Akwa-Ibom, Bayelsa, Anambra, Ebonyi, Abia and Zamfara to see further evidence of global warming in these new locations.

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