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Investigating Impact and Viability of Hostile Weather Conditions on Solar Farm Establishment in Nigeria: A Case Study

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INVESTIGATINGIMPACTANDVIABILITYOFHOSTILEWEATHERCONDITIONSONSOLARFARMESTABLISHMENTINNIGERIAACASESTUDY

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Investigating Impact and Viability of Hostile Weather Conditions on Solar Farm Establishment in Nigeria: A Case Study

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I. Introduction

Generating power by converting sunlight into electricity is not a new concept; neither is generating solar power at the utility scale. What is new, however, is the accelerating demand for clean energy, particularly PV solar energy. Solar energy as one of the many sources of renewable energy-based off-grid electricity supply is traditionally considered as an expensive and unreliable source of power. But as technology improves over the years, renewable energy sources are beginning to take the stage of modern energy divide (Omorogiuwa Eseosa and Ekiyor Martin Thompson 2017).The modern surge for solar is, in part, driven by rising demand for electricity and increasing environmental costs associated with conventional fuels. In recent years, large-scale solar energy development has also been invigorated by the economic forces of technological innovation, falling costs of production, and political support in the way of renewable energy standards and goals. As a result, numerous large-scale solar projects have taken root domestically and internationally, and are continuing to grow. However, solar energy usage has not gained much popularity in Nigeria as it is majorly limited to pilot and demonstration projects even with abundant available solar renewable energy. Solar energy applications serve various energy needs among rural dwellers because of obvious deprivation of grid supply. Solar PV technologies are growing, though awareness is relatively low. PV installations are commonly found in street lighting, rural electrification projects as well as low and medium level uses such as solar pumps. PV cells have been installed to serve rural clinic and schools. Understandably, many of the earliest projects were developed in areas where sun shines the most. Northern Region of Nigeria is certainly very viable for solar development for many reasons: land is relatively cheap, environmental impacts tend to be less complex, population is comparatively less dense, high solar irradiance, low humidity, and the weather is predictably cloudless for most part of the year. Though the conditions in the North are rather ideal, large-scale solar power is still very much a viable source of renewable energy in a myriad of conditions and locations. In other regions of Nigeria, particularly in the South, for instance, the conditions are dramatically different from the North—land tends to be expensive, very complex environmental impacts, denser population, solar irradiance is comparatively less, humidity can soar, and the weather is highly variable and extremely difficult to predict. Even though the conditions may not be as ideal as those found in the North, economic forces are spurring the feasibility of PV solar power development in other regions of Nigeria. However, a predictive study of the performance of solar PV system in various locations in Nigeria will result in correct investment decisions, better regulatory framework and favorable government policies. Accurate and consistent evaluation of PV system performance allows detection of operational problem, facilitate the comparison of system that may differ with respect to design, technology, or geographic location and validate model for system performance and cost estimation during the design phase. A comparative analysis of the meteorological Data across regions in Nigeria is necessary to determine variation of solar irradiation and its effect on solar energy utilization in Nigeria. Solar Energy depends on solar radiation which is a lot more complex than human perception of solar potential from sunshine and may require sophisticated instrument for measurement. Moreover, to successfully investigate the distribution of solar resources in Nigeria, more regions than North and South will be under

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studied. Optimum Solar PV system is derived with regard to various designs and technologies, thus resulting to correct investment decision and performance improvement. It will also facilitate comparison of systems that may defer with respect to geographic location among others and validate models for system performance. This work overviews environmental constraint of utility solar PV energy utilization in Nigeria in an attempt to achieve the following:

- Review design and technological criteria for better performance of solar power plants.
- Determination of viability of solar power potentials at different locations in Nigeria
- Modeling of PV systems using RETScreen renewable energy software and make possible recommendation for future work in the field of solar energy

II. Review of Related Work

PV panels have been used to collect photons for decades with the sole purpose of generating power for utilities since the first megawatt- scale solar farm was built in Sacramento, California, in 1984 (Green Energy News 2009) as cited by Robert and Anders (2013). From the location of Nigeria, it can actually produce appreciable amount of solar energy radiation as this value varies across the country from 3.5kWh/m^2 per day in the coaster latitude to 7kWh/m^2 per day in the far North; giving an annual average solar intensity estimated to be 1934.5kWh/m^2. (Akindele, 2014). According to Sambo, 2009 as cited by Akindele (2014), with 1% of Nigeria's land area covered by solar collectors, given prevailing efficiencies and average radiation of 5.5kWh/m^2/day, it will be possible to generate 1850x10^3 GWh of electricity per year, which is over 100 times grid consumption level. However, there is currently no grid input from solar source in Nigeria. In recent years, studies of solar energy technology are on the rise as it becomes more readily deployable as in the case of Ethiopia rural electrification where SPV account for 95% electrical energy of HPS (Zelalem, 2013). In the author's methodology, to obtain PV arrays/size that will satisfy energy demand, parameters used include lifetime PV array of 25 years, 90% derating factor and ground reflectance of 20% and was simulated with homer optimization software. The results showed that the site has tremendous solar resource potential, with average radiation of 6kWh/m^2/day (insolation). This is the reason 95% of electrical energy is from PV array while the rest 5% is obtained from diesel Generator in optimum system. The author also concluded that incentives from state and federal government are critical to the widespread deployment of such system due to high net present cost. The method adopted by Emmanuel (2009) to analytically calculate various losses of PV Park considered in-plane solar radiation, ambient daytime temperature, array DC power as well as park AC output power averaged with 10 min frequency during a typical day per month. The nominal instantaneous array DC power per 10 min and total annual array output energy were computed using solar radiation data as well as technical specifications of photovoltaic panels. Real array output power obtained by gradually adding various losses of array comprising of degradation modulus, temperature and soiling losses. The same method is adopted for calculation of interconnection, inverter and transformer losses by correlating real array power output with PV park power output with a 10 min frequency. This method gives realistic estimate, since various losses are interrelated and directly linked with instantaneous real power output of both PV panels and park.

The efficiency of PV panel depends on the operating temperature and power density of solar radiation. As its temperature increases, efficiency decreases linearly, since peak power PV panels refers to Standard Test Condition (STC). In different temperatures, output power of PV panels depends on difference of panel temperature, STC temperature (TC - TSTC) and power density (G) of the incident solar radiation. The following variables were defined by the researcher; final yield (YF), reference yield (YR), performance ratio (PR) and capacity factor (CF) and were calculated as defined by IEC Standard 61724. The final yield is annual, monthly or daily net AC energy output of the system divided by peak power of installed PV array at STC of 1000 W/m^2 solar irradiance and 25-degree cell temperature.

$$YF = \frac{E[KWh_{A,C}]}{P_r[KW_{DC}]} \quad (1)$$

Reference yield is the total in-plane solar insolation Ht (kWh/m^2) divided by the array reference irradiance (1 kW/m^2); therefore, the reference yield is the number of peak sun-hours.

$$Y_R = \frac{Ht[\mathrm{KWh/m^2}]}{1\mathrm{KW/m^2}} \quad (2)$$

Performance ratio is the final yield divided by reference yield. It represents the total system losses when converting from name plate DC rating to AC output. The typical losses of PV park include losses due to panel degradation(ɧdeg), temperature(ɧtem), soiling(ɧsoil), internal network(ɧnet), inverter(ɧinv), transformer (ɧtran), system availability and grid connection network (ɧppc), Therefore, PR can be expressed as

$$p_R = \frac{Y_F}{Y_R} = \text{ɧdeg}.\text{ɧtem}.\text{ɧsoil}.\text{ɧnet}.\text{ɧinv}.\text{ɧtran}.\text{ɧppc} \quad (3)$$

Array yield (YA) is defined as annual or daily energy output of the PV array divided by the peak power of the installed PV. System losses (LS) are gained from the inverter and trans- former conversion losses, and the array capture losses (LC) are due to the PV array losses

$$Y_A = \frac{E_A}{Pr} \quad (4)$$

$$Lc = Y_R - Y_A \quad (5)$$

$$Ls = Y_A - Y_F \quad (6)$$

Finally, capacity factor (CF) is defined as the ratio of actual annual energy output to the amount of energy PV Park would generate if operated at full power (Pr) for 24hr/day for a year.

$$C_F = \frac{Y_F}{8760} = \frac{E}{P_r \text{ x } 8760} = \frac{\text{Ht x } p_R}{\text{Pr x } 8760} \quad (7)$$

Performance ratio and various power losses associated with 5MW Grid connected solar PV power plant in Karnataka were evaluated over 7-months period. Manually extracted parameter through SCADA system was compared with simulated result from PVsyst software. The closeness of the result proves the method satisfactory for determining possible plant capacity for an arbitrary chosen area. (Bharathkumar and Byregowda, 2007).

Hakeem in 2013 categorized PV systems on the basis of their functional operational requirements, component configuration and equipment connection to other power sources and electrical loads. On these basis, PV systems are rather classified as grid–connected/utility–interactive systems and stand–alone systems. Marion et al (2005) presented a paper to illustrate the extent to which the performance parameters of grid connected solar PV plant might be influenced by weather. PV system performance was modeled using PV form for 30-year period. The hourly solar radiation and meteorological data input to PV form was for the boulder, CO, Station in the National solar radiation Data base. Final yield (Yf) shows the greatest variability and the PVUSA rating at PTC shows the least. The variability of the reference yield (Yr) is similar to the final yield because of Yr dependence on solar irradiance. Performance Ratio (PR) values exhibit the influence of temperature, with smaller values in summer than winter for every yearly values. Both PVUSA, AC power rating at PTC and yearly PR values should be able to detect degradation of system performance over time.

Dirk and Sarah (2012) presented a report on 40-year field test on module degradation rate. Nearly 2000 degradation rate measured on individual module or entire system, have been assembled from literatures and showed mean degradation rate of 0.8%/year and a median value of 0.5%/year. The majority (78%) of all data reported a degradation rate of <1%/year. Significant differences between module and system degradation rates observed earlier on has narrowed, implying that substantial improvement towards stability of the balance of system components has been a choice. Despite the progress achieved in the last decade, linearity and precise impact of climate have not been satisfactorily determined.

III. Methodology

RET Screen is the choice software used for the study. It is clean energy project analysis software used in energy decision making and allows engineers, architects, and financial planners to model and analyze any clean energy project. It allows five step standard analyses. These include energy analysis, cost analysis, emission analysis, financial analysis and sensitivity/risk analysis. RETScreen is used in this report to predict the output from 10MW power plant using satellite data from National Aeronautics and Space Administration (NASA) in the absence of real time measurement from solar plant and metrological site in Nigeria. In order to determine environmental hostilities of solar PV performance in Nigeria, information and data from a wide variety of sources (primary and secondary) such as Data from solar radiation was obtained from NASA and analyzed using RETScreen software to determine irradiation levels from different sources, and power output from solar plants.

a) Data Collection

The following data were collected from NASA.

- ✓ Geographical and environmental variables associated with solar PV Module in the locations. These include: Latitude & Longitude, Climate Zone, Elevation, Heating Design Temperature, cooling design temperature, Earth Temperature Amplitude, Air Temperature, Relative Humidity, Precipitation, Daily Solar Radiation, Atmospheric Pressure, Wind Speed, Earth Temperature, Heating Degree-Days and Cooling Degree-days.
- ✓ Manufacturers' specification Data for two different PV Module (mono crystalline silicon & amorphous silicon) of 10MW each.

b) Data Analysis

RET Screen software was used to simulate the geographical, environmental and solar PV module parameters. Data for six locations which uses radiation data from NASA and Ground measurement was obtained and analyzed. It was found that NASA source data varies over a wide range depending on whether it is collected from monitoring stations, extrapolated, or derived from satellite information. In order to evaluate the environmental factors associated with Solar PV performance, technological and design factors are kept constant while factors that are specific to geographical locations are varied. One Location is taken from each of the six geographical zones in Nigeria as climatic variation is minimal within a region. The latitudes at the locations are used as the optimum tilt angle for the PV module in fixed tilt orientation to maximize Irradiation and to ensure same condition for all locations. Simulations was done for both Fixed tilt and Single axis tracking Scheme, leading to a total of 24 simulations with 4 in each location. These include Abuja, Birnin-Kebbi, Enugu, Lagos, Port Harcourt and Maiduguri as highlighted in Figure 3.0. Assumption used in RETScreen for Mono-Silicon and Amorphous Silicon modules are given in Table 3a and 3b respectively.

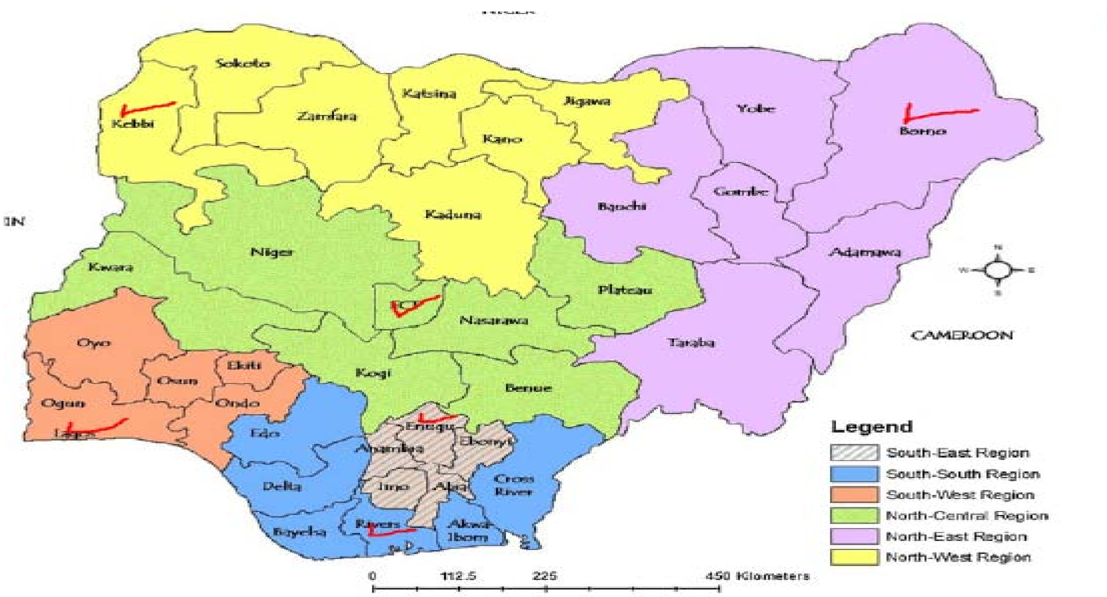


Figure 3.0: Regional Map of Nigeria

Table 3a: Mono-Silicon Module and inverters parameters

Photovoltaic		
Type		mono-Si
Power capacity	MW	10
Manufacturer		BP Solar
Model		mono-Si - BP 1210
Number of units		1,000,000
Efficiency	%	7.75%
Nominal operating cell temperature	°C	45
Temperature coefficient	% / °C	0.4%
Solar collector area	m²	129,032
Miscellaneous losses	%	7.5%
Inverter		
Efficiency	%	96%
Capacity	kW	10,000
Miscellaneous losses	%	0%
Resource Assessment		
Solar Tracking Mode		Fixed and one - Axis
Slope		Latitude of the location
Azimuth		0

Table 3b: Amorphous Silicon and inverter parameters

Parameter	Unit	Value
Photovoltaic		
Type		a-Si
Power capacity	MW	10
Manufacturer		BP Solar
Model		a-Si - BP Millenia MST 50 MV
Number of units		200,000
Efficiency	%	6.1%
Nominal operating cell temperature	°C	45
Temperature coefficient	% / °C	0.11%
Solar collector area	m²	163,934
Miscellaneous losses	%	7.5%
Inverter		
Efficiency	%	96%
Capacity	kW	10,000
Miscellaneous losses	%	0%

Resource Assessment	
Solar Tracking Mode	Fixed and one - Axis
Slope	Latitude of the location
Azimuth	0

IV. Result and Discussions

RET Screen Simulation result in Table 4.0 shows the trend of improvement CUF from fixed tilt to single axis tracking and from mono-silicon to amorphous silicon module

Table 4.0: CUF and annual output for tilt and one axis tracking method at various locations

		Annual Average Radiation KWh/m²/d		Mono Silicon Annual Output MWh		Amorphous silicon Annual Output MWh		m-Si CUF		a-Si CUF				
S/N	location	Fixed Tilt	One - Axis Tracking	Fixed Tilt	One - Axis Tracking	Fixed Tilt	One - Axis Tracking	Fixed Tilt	One - Axis Tracking	Fixed Tilt	One - Axis Tracking	Amb Temp °c	Wind Speed(M/s)	Optimum Tilt Degree
1	Abuja	5.45	6.88	16,460	20,423	17,555	21,791	18.8	23.3	20	24.9	24.7	2.4	9.2
2	Birnin Kebbi	5.97	7.75	17,758	22,599	19,199	24,436	20.3	25.8	21.9	27.9	27.6	2.3	12.5
3	Enugu	4.92	5.97	14,804	17,795	15,733	18,917	16.9	20.3	18	21.6	25.2	2.1	6.3
4	Lagos	4.74	5.69	14,260	16,962	15,155	18,032	16.3	19.4	17.3	20.6	25.7	2.8	6.5
5	Port Harcourt	3.96	4.48	11,907	13,435	12,603	14,222	13.6	15.3	14.4	16.2	26.7	2	4.9
6	Maiduguri	5.89	7.63	17,599	22,313	18,974	24,059	20.1	25.5	21.7	27.5	27	3.8	11.9

The trend is also repetitive in the average radiation across the locations. Average radiation is directly proportional to CUF. Air temperature does not have linear relationship with solar radiation (irradiation) as seen in cases of Port Harcourt and Lagos with lower irradiation despite having higher air Temperature than Abuja and Enugu. Other geographical factors like location latitude, elevation from the horizon and wind velocity also affect the irradiation level. From the meteorological resource data in Appendix A and B, Port Harcourt and Lagos have the lowest elevation with values of 18m and 32m respectively. The irradiation is also observed to have direct variation with the nearness of the latitude to north with exception to Enugu and Lagos. Lagos is 0.2 degree more elevated than Enugu but 155m lower from the horizon. Their latitudes are 6.5 degree and 6.3 degree due north respectively. The irradiation of Enugu is higher than Lagos despite trailing Lagos by 0.2 degree north. The pattern is sustained as the difference in their latitude is small as compared to the difference in their elevation from the horizon.

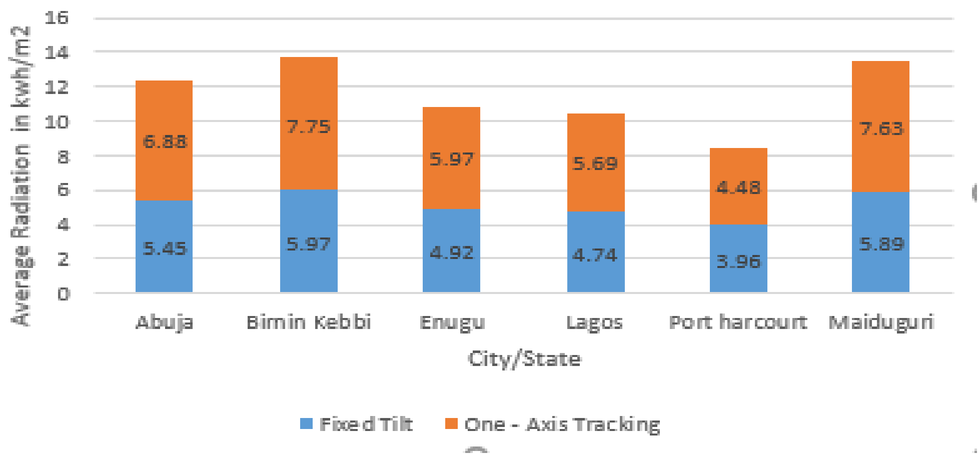
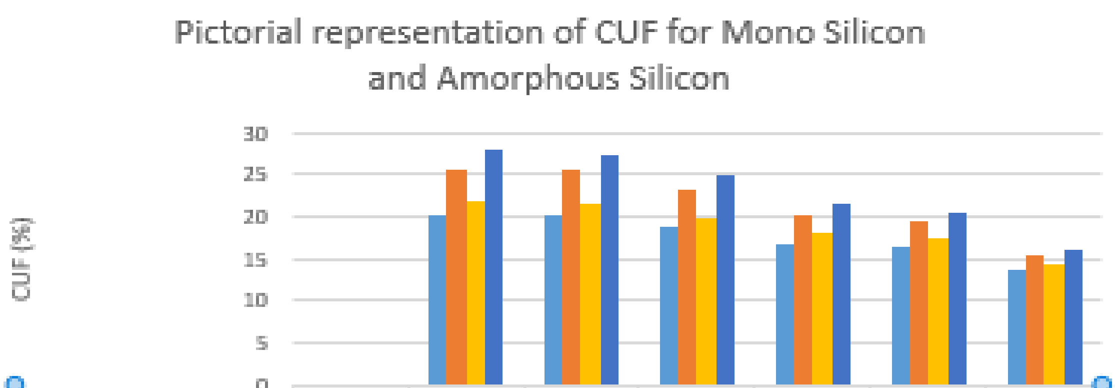


Figure 4.0: Average Radiation for fixed tilt and one axis tracking system on the various locations

There is significant improvement on the annual average radiation by the used of one axis tracking control method in all location as shown in Figure 4.0. Port Harcourt recorded 13.1% increase while Birnin Kebbi shows an increase of 29.8%. Percentage increase is seen to rise from the least average radiation to the highest average radiation. The increase obtained by the use of one axis tracking control is proportional to the magnitude of the fixed tilt average radiation.



	City/State	Birnin Kebbi	Maiduguri	Abuja	Enugu	Lagos	Port harcourt
m-si fixed tilt	0	20.3	20.1	18.8	16.9	16.3	13.6
M-Si single axis tracking	0	25.8	25.5	23.3	20.3	19.4	15.3
A-Si fixed tilt	0	21.9	21.7	20	18	17.3	14.4
A-Si single axis tracking	0	27.9	27.5	24.9	21.6	20.6	16.2

m-si fixed tilt ■ M-Si single axis tracking ■ A-Si fixed tilt ■ A-Si single axis tracking

Figure 4.1: Shows CUF for various location, PV Module type and tracking mechanism

The difference of CUF brought about by PV module type is minimal compare to change in CUF due to the use of tracking scheme. Figure 4.1 shows variation of CUF from the highest to the least across different locations and variations of CUF due to tracking technique and PV module type within a location. Birnin-Kebbi has the highest CUF while Port Harcourt has the lowest CUF. The initial cost, operational and maintenance cost for fixed tilt and single axis tracking scheme are shown in Table 4.1. From the investigation, tracking scheme is more expensive than fixed tilt system both in terms of cost and maintenance.

Table 4.1: Economic Analysis

Cost Summary	Fixed Tilt	Single Axis tracking
Initial cost/KW	$ 2800	$ 3400
O & M cost/KW-Year	$ 38	$ 44
10MW Initial Cost	$28,000,000	$38,000,000
10MW O & M Cost/year	$380,000	$440,000

V. Conclusion and Recommendation

Solar Farm investment will play an important role in the overall energy supply in Nigeria because of its great potential in most location. Among the six towns selected from each of the geopolitical zones only Port Harcourt and Lagos shows low solar potential as determined from their CUF. This depends on several factors including Solar Radiation, Temperature, Air Velocity, apart from technological and design Parameters like, PV Module type and quality, angle of tilt (or tracking), Cable losses, efficiencies of Inverter and Transformers. Amorphous Silicon PV Module performed better than Mono Silicon PV Module in all the locations but did not improve the CUF as much as the variation of tracking mechanism, from fixed tilt to single axis tracking scheme. Annual output of Solar PV farm can be improved considerably by increasing the capacity of Solar PV Module and reducing losses in cable, inverter, transformer and soiling. In the case of Port Harcourt, to achieve an output of 28,444MWh/year, Solar PV Module capacity will be increased to 20MW, which is twice the initial capacity. Simulation results for 20MW in Port Harcourt are shown in Appendix C and D. This will require an additional initial and maintenance cost of $38,000,000 and $440,000/year respectively. The overall effect results in increasing cost. Furthermore, the use of storage facility to compliment the output in period of low solar irradiation will also attract additional cost, thereby making solar farm in hostile environment feasible but costlier.

It will be desirable to monitor solar radiation data from ground base weather station in order to determine the inaccuracies associated with satellite measured data such as that provided by NASA, NREL and WRDC. This work is essential in providing useful proposition to the application of solar energy technology to meet the millennium development Goal (MDG) of clean energy deployment in Nigeria. This paper is limited to investigation of Environmental factors affecting Solar PV performance in Nigeria. The factors considered are those specific to a given geographic location. It also encompasses models for system comparison, performance analysis and cost estimation during the design phase. It does not include other factors like module degradation, capture losses, and losses in system inter-connectivity. It is also recommended to carry out detailed study for several locations with active involvement of existing Solar plant in the region.

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Appendix A

Enugu, Port Harcourt and Lagos Meteorological Resource Data

RETScreen - Climate database			
Country		Nigeria	
Province/State			
Climate data location	See map	Enugu	
Latitude	°N	6.3	
Longitude	°E	7.5	Source
Climate zone	1A	Very hot - Humid	NASA
Elevation	m	187	NASA
Heating design temperature	°C	20.2	NASA
Cooling design temperature	°C	31.1	NASA
Earth temperature amplitude	°C	10.5	NASA

RETScreen - Climate database			
Country		Nigeria	
Province/State			
Climate data location	See map	Port Harcourt	
Latitude	°N	4.9	
Longitude	°E	7.0	Source
Climate zone	0A	Extremely hot - Humid	Ground+NASA
Elevation	m	18	Ground
Heating design temperature	°C	22.3	NASA
Cooling design temperature	°C	28.3	NASA
Earth temperature amplitude	°C	4.2	NASA

RETScreen - Climate database			
Country		Nigeria	
Province/State			
Climate data location	See map	Lagos	
Latitude	°N	6.5	
Longitude	°E	3.5	Source
Climate zone	1A	Very hot - Humid	NASA
Elevation	m	32.2	NASA
Heating design temperature	°C	22.4	NASA
Cooling design temperature	°C	29.0	NASA
Earth temperature amplitude	°C	5.2	NASA

Appendix B

Meteorological Resource Data for Maiduguri, Birnin Kebbi & Abuja

RETScreen - Climate database			
Country		Nigeria	
Province/State			
Climate data location	See map	Maiduguri	
Latitude	°N	11.9	
Longitude	°E	13.2	Source
Climate zone	0B	Extremely hot - Dry	NASA
Elevation	m	337	NASA
Heating design temperature	°C	17.4	NASA
Cooling design temperature	°C	36.8	NASA
Earth temperature amplitude	°C	18.5	NASA

RETScreen - Climate database			
Country		Nigeria	
Province/State			
Climate data location	See map	Birnin Kebbi	
Latitude	°N	12.5	
Longitude	°E	4.2	Source
Climate zone	0B	Extremely hot - Dry	NASA
Elevation	m	263	NASA
Heating design temperature	°C	18.3	NASA
Cooling design temperature	°C	37.7	NASA
Earth temperature amplitude	°C	18.1	NASA

RETScreen - Climate database			
Country		Nigeria	
Province/State			
Climate data location	See map	Birnin Kebbi	
Latitude	°N	12.5	
Longitude	°E	4.2	Source
Climate zone	0B	Extremely hot - Dry	NASA
Elevation	m	263	NASA
Heating design temperature	°C	18.3	NASA
Cooling design temperature	°C	37.7	NASA
Earth temperature amplitude	°C	18.1	NASA

RETScreen - Climate database			
Country		Nigeria	
Province/State			
Climate data location	See map	Abuja	
Latitude	°N	9.2	
Longitude	°E	7.2	Source
Climate zone	1A	Very hot - Humid	NASA
Elevation	m	573	NASA
Heating design temperature	°C	18.3	NASA
Cooling design temperature	°C	32.8	NASA
Earth temperature amplitude	°C	13.6	NASA

Appendix C

Port Harcourt Simulation Parameters for 20MW

Photovoltaic		
Type		a-Si
Power capacity	MW	20
Manufacturer		BP Solar
Model		a-Si - BP Millenia MST 50 MV
Number of units		400,000
Efficiency	%	6.1%
Nominal operating cell temperature	°C	45
Temperature coefficient	% / °C	0.11%
Solar collector area	m²	327,869
Miscellaneous losses	%	7.5%
Inverter		
Efficiency	%	96%
Capacity	kW	20,000
Miscellaneous losses	%	0%
Summary		
Capacity factor	%	16.2%
Initial costs	$/kW	3,400
	$	68,000,000
O&M costs (savings)	$/kW-year	44
	$	880,000
Electricity export rate		Electricity exported to grid - annual
	$/kWh	0.10
Electricity exported to grid	MWh	28,444
Electricity export revenue	$	2,844,393

Appendix D

Port Harcourt simulation Result for 20MW

Resource assessment

Solar tracking mode		One-axis
Slope	°	4.9
Azimuth	°	

Show data

Month	Daily solar radiation - horizontal kWh/m²/d	Daily solar radiation - tilted kWh/m²/d	Electricity export rate $/kWh	Electricity exported to grid MWh
January	4.13	4.90	0.10	2,639.005
February	4.32	5.06	0.10	2,456.673
March	4.23	4.81	0.10	2,591.109
April	4.29	4.84	0.10	2,521.848
May	4.13	4.61	0.10	2,482.108
June	3.82	4.19	0.10	2,185.119
July	3.51	3.76	0.10	2,034.927
August	3.29	3.46	0.10	1,873.910
September	3.79	4.17	0.10	2,180.834
October	3.89	4.39	0.10	2,372.921
November	3.98	4.64	0.10	2,423.037
December	4.15	4.98	0.10	2,682.441
Annual	**3.96**	**4.48**	**0.10**	**28,443.934**

Annual solar radiation - horizontal	MWh/m²	1.44
Annual solar radiation - tilted	MWh/m²	1.64

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