EVALUATING THE POTENTIAL OF RENEWABLE ENERGY TECHNOLOGIES FOR BUILDINGS IN NIGERIA

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The impact of greenhouse gas emission resulting from burning of fossil fuel for electricity generation is a global challenge that can be tackled by using renewable energy sources. Nigeria is a fast growing country with population estimated at about 140 million people. Steady economic and population growth is putting significant strain on the country's electricity supply and distribution infrastructure. More than 64% of Nigeria's electricity is generated from fossil fuel sources. However, the direct cost of infrastructure required for generation, transmission and the environmental implication of burning additional fossil fuel will have significant impact on the country's rate of growth and the global carbon dioxide emission. Abundant renewable energy sources all over the country can be utilised to reduce greenhouse gas emissions as well as a strategy for rural electrification. One of the key constraints affecting the use of alternative or renewable energy technologies is the lack of understanding of the factors that affect performance of the system. To remove this constraint, the potential of solar PV systems have been evaluated using the TRNSYS Simulation Environment and RETSCREEN Simulation Tool to establish performance data for a range of solar PV products and locations. Results show that PV systems have significant potential as stand alone applications in buildings and other application.

Keywords: greenhouse gases, renewable energy, RETSCREEN, Solar energy, TRNSYS.

INTRODUCTION

Nigeria is a fast growing country with population estimated at about 140 million people. The steady economic and population growth is putting significant strain on the country's electricity supply and distribution infrastructure, which is currently meeting less than 50% of demand. More than 64% of Nigeria's electricity is generated from fossil fuel and about 34% from hydro plants (World Bank 2001). Having large natural gas deposits, the development of gas fired energy sources seems to be the favoured policy in both medium to long term. However, the direct cost of infrastructure required for generation & transmission of electricity and the environmental implication of burning fossil fuel will have significant impact on the country's rate of growth and the global carbon dioxide emission. Nigeria needs to start considering alternative energy sources, especially with the abundant renewable energy resources available in the country, estimates of total solar energy received on the land mass have

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been put at about 20MJ/m² per day, with little variation throughout the year (Bugaje 1999).

Another important aspect of the electricity infrastructure is the transmission/distribution network. Due to the disperse nature of Nigeria's rural settlements the cost of connecting the entire country to the national grid becomes a big challenge in the both short to long term. This also becomes a bigger challenge in providing power to rural population especially for use in local educational institutions, health facilities and agricultural facilities located in these remote locations of the country. The power sector have high distribution and other system losses of about 30-35% from distribution to billing (Ikeme and Ebohon 2005) one way of reducing such massive losses is to consider standalone renewable energy power systems that are located close to the point of consumption.

Cost of electricity to the consumer is highly subsidised by the Nigerian government, which is less than the actual cost of production. The recently disbundled public electricity generation company (NEPA) generates electricity at about 11US cents per kWh and sells it to consumers at 3-5 US cents per kWh (World Bank 2002). The cost of other private generators are also indirectly subsidised through the subsidy of diesel and other petroleum products, used to privately generate electricity in both private residences and commercial organisations using diesel generators. However, recent privatisation of public enterprises and the removal of subsidies on petroleum products by the government will have direct implication on the cost of both grid electricity and privately generated electricity. All these factors and problems plus the continuous lowering cost of PV systems points to a clear need to integrate the renewable energy systems in private and public developments (in private houses, commercial organisations, schools and hospitals) making it a strategy for rural electrification. Current estimates shows that about two thirds of the population are living in rural areas (Bugaje 2005).

One of the key constraints affecting the use of alternative or renewable energy technologies is the lack of reliable performance data for sizing PV in locations around the country. To remove this constraint, the potential of Photovoltaic systems have been evaluated to establish performance data for a range of Solar PV products. Performance charts that reveal energy outputs for different locations in Nigeria have been developed to enable designers and developers to make decisions at the early design stage on the energy viability of any chosen system. Results show great potential for PV for reducing the energy consumption of grid supplied electricity. It also provides an opportunity for diverse short to long term strategy for reducing the infrastructure cost required to for rural electrification and even the need for new thermal power stations.

METHODOLOGY

System potential has been evaluated using Transient System Simulation Environment (TRNSYS), this is a modular simulation environment for the study of energy systems (Klein et al. 2005) and RETSREEN Renewable Energy Assessment Tool (RETSREEN 2007). Hourly climate data for Nigerian locations have been generated using ten years monthly average of climatic variables of (8) locations using the Meteonorm programme.

Monthly average radiation data have been collected from NASA database of surface meteorology and solar energy (NASA 2006). The radiation and air temperature data has been used to run parametric simulations runs to determine the power generation of series of PV cells. Nigeria is located within 4º and 14º latitude in the northern hemisphere. Table 1 shows the geographical information about the areas studied.

Table 1: List of Locations and geographical descriptions

Station	Latitude (N)	Longitude (E)	Altitude
Sokoto	13.02	5.25	351
Maiduguri	11.9	13.2	378
Kano	12.05	8.53	472
Kaduna	10.5	7.4	575
Bauchi	10.3	9.8	560
Abuja	9.2	7.2	484
Obudu	6.7	9.2	547
Lagos	6.5	3.5	73
Enugu	6.3	7.5	184
Port Harcourt	4.9	7.0	18

RENEWABLE ENERGY RESOURCES

Conventional sources of energy such as gas, coal, oil etc are finite and the generation of electricity from these sources produces greenhouse gases that are detrimental to the planet. There are various infinite sources that can be converted into electrical energy and can be used in the generation of electricity, such as solar energy, wind energy, hydropower, and geothermal energy. The main advantage of these sources of energy is the fact that it does not rely on the scarce and finite resources and does not produce greenhouse gases that pollute the environment. This paper will focus on the potential of Photovoltaic (PV) systems in various regions of Nigeria. Even though the capital cost of these technologies is high at the moment there is clear trend in lowering cost of PV systems (IEA 2007).

Energy generation and the current strength is proportional to the intensity of solar radiation on the surface of the PV panel. The intensity of solar radiation in Nigeria ranges from 4-7 kWh/m²/day across the entire country. Performance of the PV system is affected by many other factors such as, orientation of the panel, area of panels used in the array, effect of temperature on system efficiency, efficiency of the inverter used to concert the direct current from the PV to alternating current (Boyle 2004). Figure 1 shows annual average values of daily solar radiation for 10 locations in Nigeria. Figure 2 shows the monthly values of daily average solar radiation for 3 locations, one each from Northern (Sokoto), Southern (Port Harcourt) and Central Nigeria (Abuja) in order to show the variation of the solar radiation for different regions and time of the year. The two figures shows that there is significant variation in the intensity of solar radiation from Northern to Southern part of the country.

This difference is as a result of difference in the sky clearness index. For Northern and middle parts of Nigeria rainfall is seasonal and far between. Length of the rainy season increases as you move from North to South, there is little variation in rain over the year in far southern part of the country, due to the moist air from the Atlantic Ocean. Cloud cover does have a significant effect on the amount of solar radiation that reaches the earth surface. As shown in Figure 2 the variation of solar radiation in the South is small throughout the year, this is primarily due to very little changes in the climatic conditions throughout the year. In the North the climate is composite, with rainy (June-September) during which cloud cover affects the intensity of solar radiation on horizontal or tilted surfaces and dry seasons (October-May) during this season between November and February there is a period called the 'Hamatan' during which dust in the atmosphere affects the total radiation on horizontal or tilted surfaces.

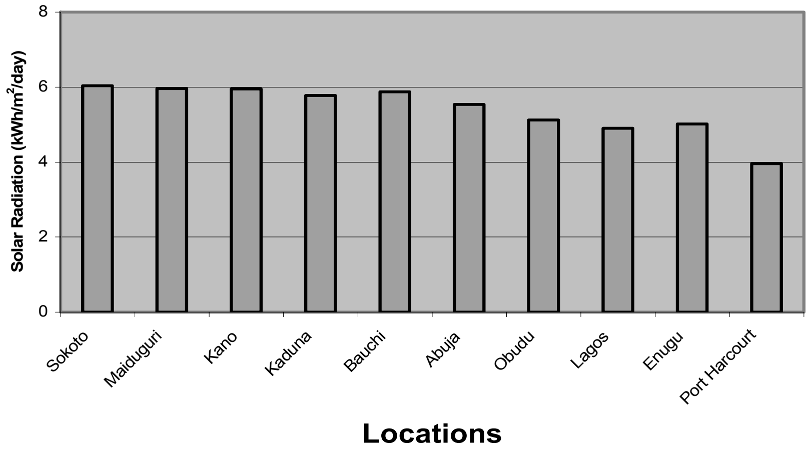

Figure 1: Annual Average daily radiation for 10 locations around Nigeria

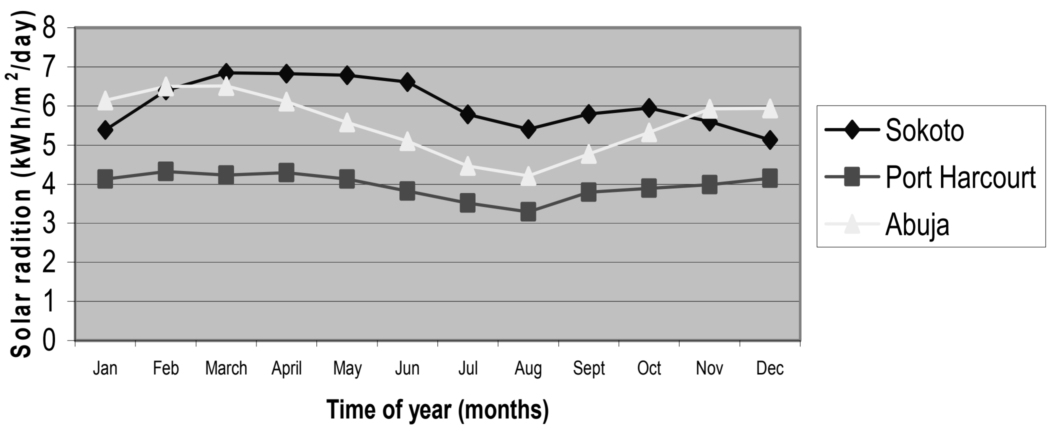

Figure 2: Monthly values of daily averages of solar radiation

Solar radiation from sun can be converted into electricity using PV cells. PV cells can be integrated into building structure such as roof or façade of buildings for small generation, but can also be laid in an open field for larger scale generation. Optimum arrangement of PV cells depends on the location and orientation of the site. PV can be operated in a standalone system to provide power for various application most common applications include small power loads and lighting in buildings, for pumping water, providing power to telephone, radio and television masts or as a means to provide power to remote villages that may not be connected to the electricity grid. Standalone PV power systems require other accessories such as rechargeable batteries to store electricity, an electronic charge and discharge controller, DC/AC inverter to convert direct current generated by the PV into alternating current.

DISCUSSIONS

PV cells technologies

Solar cells are semi-conductors made from silicon. They consist of Mono-crystalline silicon, Polycrystalline silicon and Amorphous silicon. Mono crystalline and poly crystalline silicon cells make of about 80% of the PV cells market (Hausladen *et al.* 2004) Amorphous cells use less materials in their manufacture but have lower efficiency. Table 2 shows the efficiency of three types of silicon solar PV cells. Figure 5 shows the power output for three different PV cells, there is high benefit using the Polycrystalline cells compared to others, this is a directly related to cell efficiency.

Table 2Typical efficiency of solar cells (Hausladen et al. 2004)

Solar cell type	Cell efficiency (%)
Monocrystalline silicon	14-15
Polycrystalline silicon	15-17
Amorphous silicon	5-7

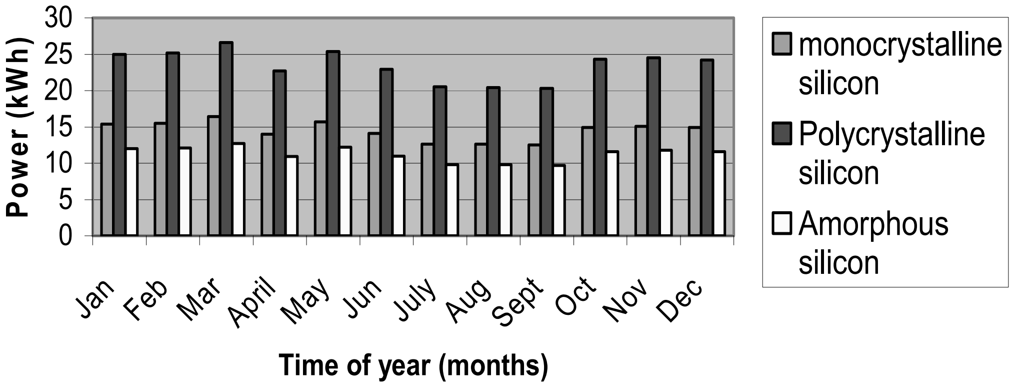

Figure 3: Solar PV output for different PV cells

Solar tracking

The solar radiation collected on the surface of the PV collector can be maximised by reducing the angle of incidence for beam radiation on the surface of the collector (RETSREEN 2007). Tracker devices can be used to rotate the collectors with time of the day and time of the year. Four different solar tracking have been used to simulate the impact of the tracking method on power generation of the PV system. The tracking systems used include Fixed, one-axis trackers, 2-axis trackers and Azimuth trackers. Figure 6 shows the PV power output for the four tracking methods. There is clear benefit of using all the three tracking methods when compared with fixed systems. However one of the greatest benefits of PV systems is the low maintenance cost, by using the tracking systems some mechanical systems are built in that may raise the maintenance cost of the system, some cost benefit analysis need to be carried out when planning to use any tracking strategy.

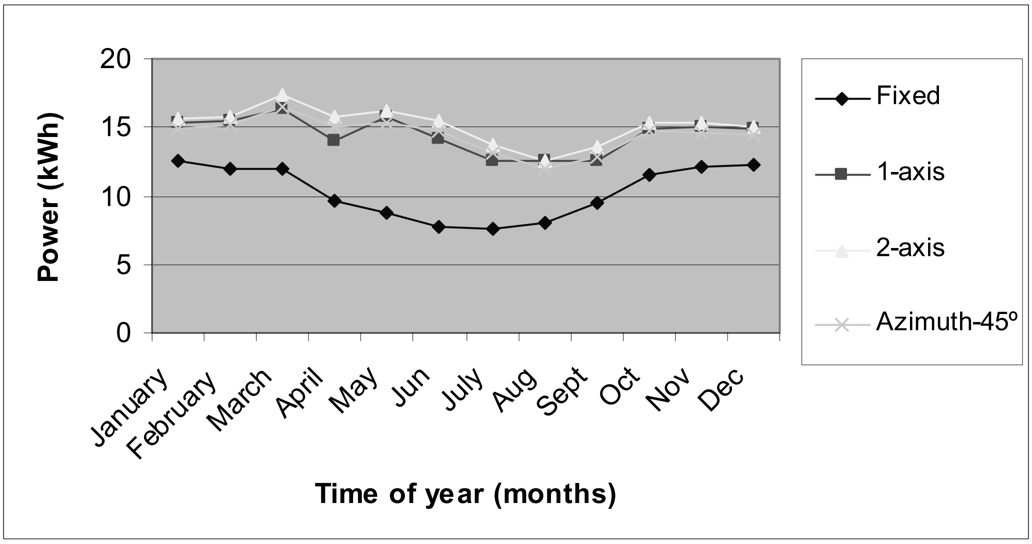

Figure 4:, PV power output for different solar tracking devices

Regional PV power output

The power output of a PV system increases as move from South to North. Figure 5 shows the PV power output for three locations Sokoto (Far North), Kaduna (Central) and Port Harcourt (Far South). It is clear that the performance is higher in the North than in the South, this is because of the low cloudiness in the North compared to the South, which results in lower solar radiation on the horizontal or tilted surface. Figure 6 shows the energy output for one meter square of Polycrystalline silicon and mono-crystalline silicon cells. The results show small variations for locations within the same region. It also shows wider variations for locations within different regions.

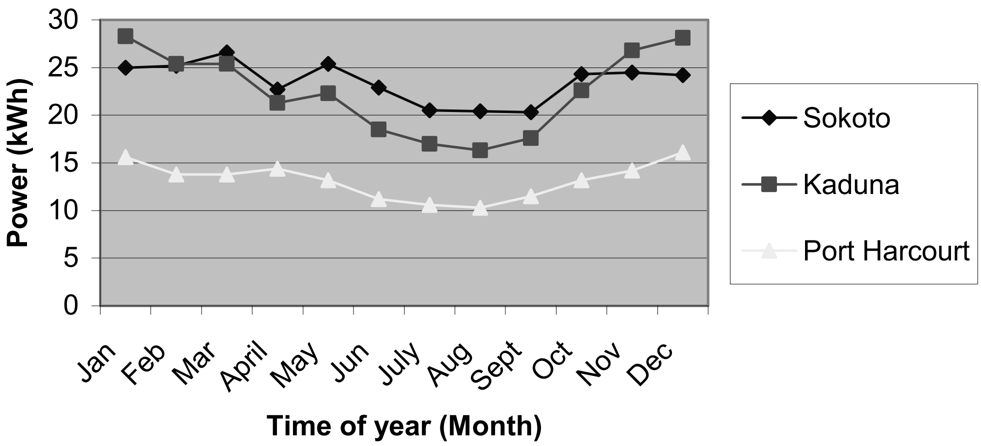

Figure 5 Regional PV power output for three locations SOKOTO (North), Kaduna (Middle) Port Harcourt (South)

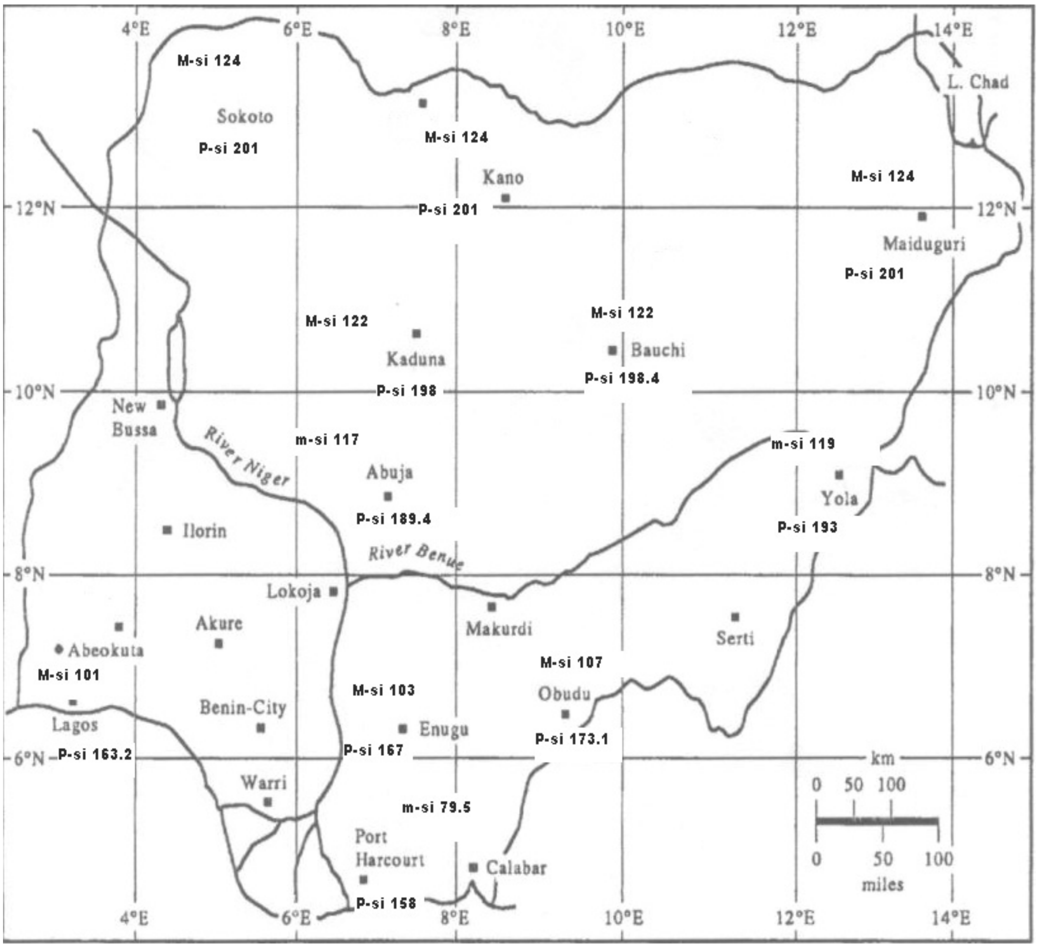

Figure6: shows energy output (Kwh/m2/annum) for various locations and types of PV cells Mono crystalline silicon (M-si) and Polycrystalline silicon (P-si).

CONCLUSIONS

The energy output and the potential of PV systems have been simulated using TRNSYS and RETSREEN simulation tools to establish the PV power output for various locations in Nigeria. Because the energy generation and distribution infrastructure in the country is stretched, renewable energy sources such as solar PV provides a sustainable source of energy for the country and especially as a means of reducing grid energy consumption in buildings. Application of such technologies can serve as medium to long term strategy for the power provision for buildings and facilities in rural and remote areas of the country. The energy supply and distribution problems have been reviewed and the performance of PV system has been established.

It has been established that solar PV technology may be used for various applications and in all locations in Nigeria to support grid electricity or as an alternative for grid power in remote locations. The data generated in this work can provide an initial guidance on the output of PV systems in all the regions of Nigeria. Various factors affect the performance of PV power output have been identified as intensity of solar radiation, positioning, solar tracking and PV module efficiency. Analysis shows that the performance of PV system increases from Southern to Northern parts of the country, this is primarily due to the difference in cloud during over the year.

There is every indication that application of Renewable Energy technologies in buildings will provides a viable option for energy provision in developing countries especially those with disperse nature of settlements in rural areas. This can have the potential to improve socio-economic development which is one option for alleviating poverty in some of these areas and remain one of the key issues in Agenda 21 for Sustainable Construction in Developing Countries.

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