# SOLAR ENERGY, A PANACEA TO RURAL ELECTRIFICATION UTILISATION: A CASE STUDY OF NIGERIA

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# ABSTRACT

Solar energy has always been one of the abundant renewable energies in Nigeria, and today there is a gap between its availability and utilization. This is underlined by the fact that the average sunshine hour per day is 6hrs and the reserve estimate is 3.5-7.0KWh/$m^{2\text{-day}}$. At present in Nigeria, electricity installed capacity sourced from coal, oil, water, gas and fossil nuclear materials is about 3500MW compared with projected electricity demand of 15,730MW by 2015. The continued usage of coal, oil, water, gas and fossil nuclear is faced with a lot of challenges ranging from the release of greenhouse gases, un-replenished and restricted installation among others. This paper examines solar energy utilization in Nigeria, vis-à-vis rural energy consumption and makes recommendations on how to fully harness solar energy to augment electricity generation into the national grid for increased power supply to rural communities.

Keywords: Solar, Energy, Nigeria, greenhouse gases, National grid, Power.

## 1.0 INTRODUCTION

The use of solar power in the generation of electricity (both for household use and for commercial purpose) is gaining much ground in the developed countries (such as America and the United Kingdom) and some other developing countries like India. It is the cleanest means of generating electric power when compared to other means such as the use of fossil fuel and biogas which the developed countries are trying to do away with.

Although solar system's efficiency is quite low when compared to other fuel sources, its advantages far supersede others. Presently, its efficiency varies from 6-40%. Nigeria is blessed with a lot of sunshine with sunshine hours averaging 6 hours per day and a reserve estimate of 3.5-7.0kwh/$m^2$day. If judiciously harnessed, most towns in the urban and rural areas in Nigeria will phase-out the blackout syndrome currently being experienced

nationwide. A nation like India contributes some quantity of electric power to their national grid from their solar farms, nothing therefore in Nigeria should stop us from doing likewise.

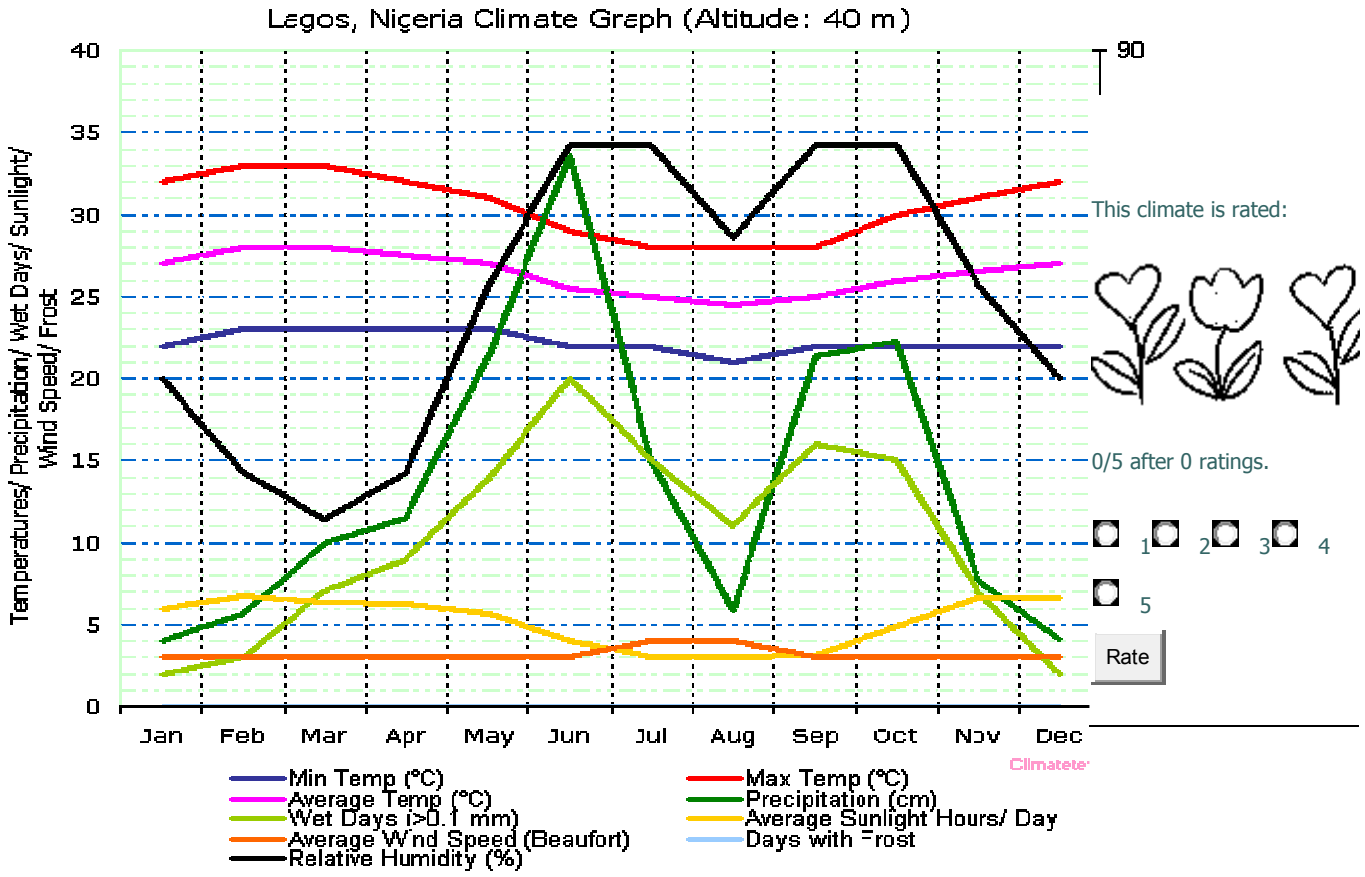


Fig. 1: Lagos, Nigeria climate graph. –

Source: http://www.nigeria.climatemps.com/ retrieved 02/07/2012 time 12:17am

From the graph of fig.1 above, the forth line from the bottom depicts the average sunlight Hours/day for Lagos metropolis. The lowest average sunlight Hour/day is 3H/day which was experienced between mid June to mid August, while the highest of 6.7H/day was experienced between November and mid January.

## Yearly Minimum Peak Sun Hours

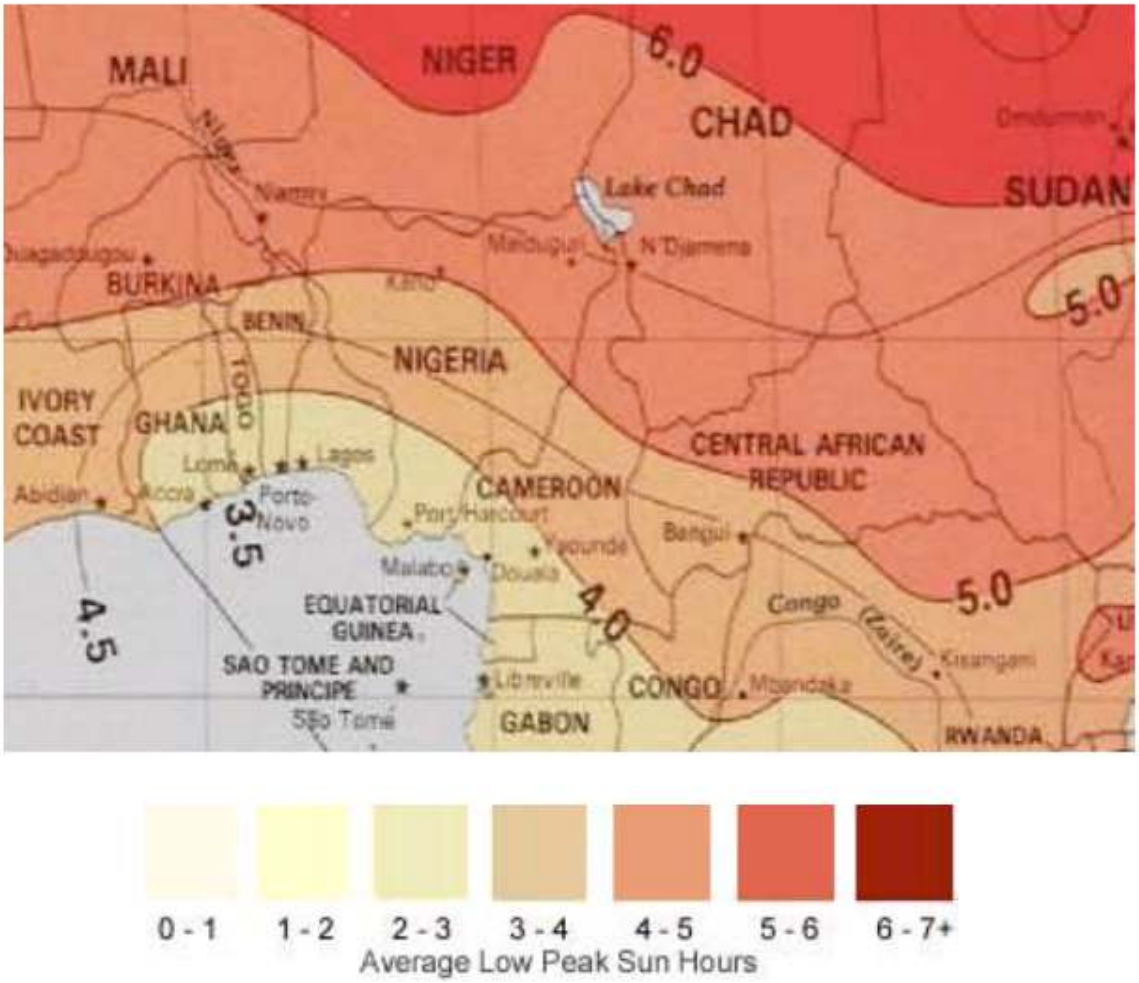


Fig 2: Yearly minimum peak sun hours

Source: "Global Solar Power Map #9: North Africa." Solar4Power < http://www.solar4power.com/map9-global-solar-power.html>.

In fig.2, we find that the southern part of Nigeria has an average low peak sun hour of 2-3H/day, while the middle belt through to Sudan savannah is having 3-4H/day. The topmost Sahel savannah has 4-5H/day.

Although the price of an efficient solar panel together with its installation would be on the high side for the less privileged to cope with, governments intervention can bring

succor to this class of people there if there is actually the will to tackle the present epileptic power problem. Government has to be involved in providing electrification for the rural communities as connecting them to the national grid is usually much expensive to the communities to bear and extending an electric grid to a few households in a rural setting can result in reduced energy costs per kilowatt-hour. This picture is better appreciated if we note that the cost of providing electricity in a rural setting is seven times the cost of providing electricity in an urban area.(Goldemberg, 2000).

The lack of adequate energy service in rural areas most especially, in Nigeria and other non developed and developing countries have made the rural dwellers more prone to hard labour (which involves the felling and sawing of wood) and high cost of living just for the quest of having adequate energy. Actually if sufficient energy is available for rural dwellers, they are ready to foot the bill if the service is there.

Likewise, the close relationship between the proximity of energy resources to the potential users coupled with the high cost of conventional energy sources have led to a considerable interest in the development and application of renewable energy resources. And here in Nigeria as shown from the sample graph of the average amount of sunlight hours/day in Lagos (Nigeria), one will see that we are blessed with enough solar energy that if properly harnessed the rural electrification problem will be a thing of the past.(Sambo, 1991).

## 2.0 Barriers to Solar Rural Electrification in Nigeria

Barriers to solar Rural Electrification in Nigeria are:

- **High investment cost:** Photo Voltaic cells used in generating electricity are very expensive both in cost of purchase and maintenance. Usually, initial investment is high, but the profit derived from it is usually enormous.
- **Absence of good network:** the network structure of the National grid in the country needs to be worked upon to facilitate better performance.

- **Capacity to maintain solar system:** in this part of the globe, we lack the man power and technology to maintain solar infrastructure. The solution to this is to train personnel and imbibe good maintenance culture.
- **Quality assurance of Solar P.V:** the market today is flooded with all sorts of solar panel ranging from fake to high quality ones. Knowing the right one to get usually poses challenges as there are different types of P.V panels meant for different application. (See appendix for the types available.)
- **Low awareness of the technology among end-users:** the awareness as to the use of solar energy, its use and advantages is inadequate in Nigeria. And where there is awareness of this energy source, corruption and the choice of problematic alternatives lead to the neglect of solar energy.
- **Slow decision-making process:** In 2007 the Nigerian government launched its Renewable Energy Master Plan (REMP) which provides a road map for the gradual move away from fossil fuels. But still in 2012, we are still busy building more fossil plants instead of concentrating on how the goal of phasing out fossil fuel plants can be achieved.

# 3.0 Energy Crisis of Nigeria and to improve Rural Electrification using solar

The energy sector in Nigeria is characterized by missed opportunities and wastage, due to poor regulation, entrenched corruption, lack of maintenance, limited access to the National grid, inadequate power generation and transmission and high generation fuel costs. These are persistent problems facing most Nigerians.

The National grid of Nigeria is powered by hydro and thermal power, which in themselves is composed of fossil fuels, and within each of these sources there are structural problems that detract from overall efficiency of the energy producing capacity of each type of infrastructure.

Some of the grids structure is unstable and vulnerable to sabotage. Below are the outlines of some of the problems associated with the grid structure in Nigeria.

- People are able to connect their residences or industries to the grid most often without a meter.
- There are zoning issues which often wreck havoc on the system.

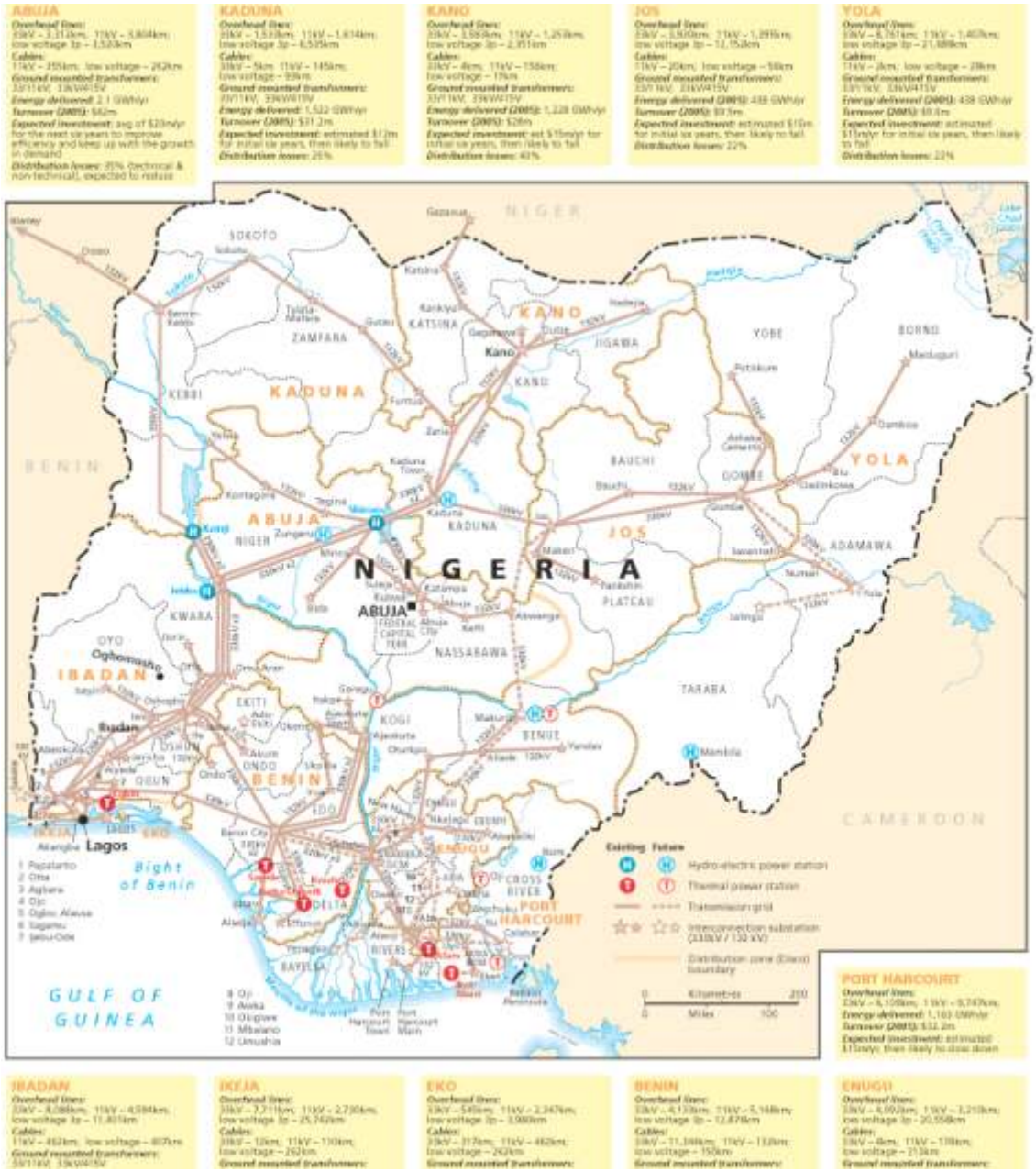


Fig 3.

Source: "Nigeria National Electricity Grid." Global Energy Network institute

http://www.geni.org/globalenergy/library/national_energy_grid/nigeria/nigeriannationalelectricitygrid.shtml.

The national grid as shown in fig.3 spreads through where the thermal power station (shown with red circles) and the hydro electric power station in the middle belt (shown with blue circles) are located. The mangrove region covering Bayelsa state and some parts of River state are outside where the national grid reached. Also parts of Borno, Yola, Taraba e.t.c are likewise outside the national grid coverage.

The government has great difficulty funding and organizing its endeavor as to their recognition for the need for more electricity. With a population of over 150 million, it was found that over 60% is not connected to the national grid, while less than 40% of the population is connected to the national grid.

**Table 1: Electricity Supply-Demand Balance Sheet (March 1991)**

| | Plants Capacities (mw) | | Demand Situation (mw) | | | |
|---|---|---|---|---|---|---|
| | Installed | Effective | Morning Peak | Evening Peak | Highest Demand | Average Demand |
| Demand | 4,633 | 1,712 | 1,500 | 1,800 | 1,902 | 1,855 |
| Excesses | | - | 212 | - | - | - |
| Shortages | | 2,921 | - | 88 | 190 | 143 |
| Remarks | | Unsatisfactory | Unsatisfactory | Unsatisfactory | Unsatisfactory | Unsatisfactory |

**Source:** Adegbulugbe & Seriki **Ed**. Energy Issues in Nigeria, 1991.

From table1 the remarks obtained due to the electricity demand balance sheet for March 1991 were all unsatisfactory. Relative demand with installed plant capacity rose to 4,633. The country's population has almost doubled, yet our plant installed capacity has not appreciated. The plants are delivering below its installed capacity due to ageing factors.

Another problem rocking Nigeria's Energy is the populace's attitude towards the government's panacea to the energy sector by trying to privatize the two electricity sectors of the country (Generation and Distribution). The paradox presently experienced in the privatization

syndrome includes the fear of the members of the present sector losing their job hence they are making matters worse and negating the efforts of the government.

Reports have it that the collection rate from consumers on the power grid is roughly 75-80% compared to 100% in developed countries. (Ikeme, J., Obas John Ebohon 2005). This shows that 20%-25% of consumers on the power grid are free riders.

In Nigeria, severe technological deficiencies are prevalent throughout the power system, both the upstream and downstream. With modern technology about 40% of the energy consumed in the thermal plants can be converted to electrical energy. In the absence of this technology, which currently is the case in Nigeria, this figure can be as low as 12%. Note that there is further loss of energy generated through transmission. Between 30 and 35% of the power generally generated in Nigeria's power station is lost in this way (Sambo A.S. 2005; Ikeme J, Obas John Ebohon, 2005).

Nigeria's electricity capacity presently is about 4000MW with about 2000MW being generated from Hydro stations. Below are some of the problems associated with hydro power in Nigeria.

- The current infrastructure of Nigeria's hydro plants (Kainji hydro power station, Jebba hydro power station and Shiroro hydro power station,) is in dire need of rehabilitation and the actual energy output of the plants is far below their projected capacity.
- The output of hydro plants is highly oscillating according to seasonal drought experienced in the North where these stations are located.

# 4.0 Promoting Access to Rural Electrification in Nigeria.

Rural Electrification programmes rarely support themselves financially (World Bank). The key synergies facilitated by the introduction of electricity (which accrues benefits) includes improved access to communication, education, extended and more reliable health services and improved security. In promoting access to Rural Electrification, grid extension is sometimes not the most-effective solution as we have seen earlier. Decentralized delivery options, such as the use of solar photo-voltaic (P.V.) and other alternative energy sources should be considered.

Considerable lowering of the unit network costs of new connections by introducing equipment standards, reticulation design, operations and maintenance practices that better suits rural area conditions should be employed. Rural Electrification should ideally be introduced in areas where there is already demand for electricity. These would be places where there is agricultural growth, rural businesses and rural incomes.

Introducing the private sector in participating in Rural Electrification schemes in a country like ours (Nigeria) should be a welcome idea especially if an appropriate legal framework and risk management options are put in place, including the assurance of a level playing field in terms of competition and the ability to charge full cost-recovery tariffs.

It is obvious that Rural Electrification will reduce rural poverty mainly through a general rise in income obtained by productive uses. Survey reveals that, in regions with high overall adoption rates, the poor benefit significantly from Rural Electrification programs. They will adopt, if the connection policies are appropriate.

The defunct N.E.P.A's (National Electric Power Authority) policy guidelines on rural electrification in Nigeria have the following main objectives for Rural Electrification. And these are:

- To increase agricultural productivity by means of adequate irrigation and easy mechanization through the supply of electricity for rural areas that are versed in agricultural practice.
- To make the processing of agricultural products and preservation of primary crops easy.
- To promote rural industries which will generally assist in raising the standard of living of the rural communities and
- To reduce migration from rural to urban areas by making it possible to bring to the rural population, entertainment, enlightment and communication facilities which constitute the main attractions to urban areas.

The above stated objectives are worth pursuing as they will see to the development of rural areas and the migration from rural to urban cities will be at its barest minimum. Following the unbundling of the authority, the Rural Electrification sub sector in Nigeria was decentralized. The headquarters of this sub-sector are as follow.

1. South-West zone 1 (Lagos N.E.P.A. zonal office)
2. South-East zone 2 (Enugu N.E.P.A. zonal office)
3. North-East zone 3 (Kaduna N.E.P.A. zonal office)
4. North-Central zone 4 (Abuja N.E.P.A. zonal office)
5. North-West zone 5 (Yola N.E.P.A. zonal office)
6. South-South zone 6 (PortHarcourt N.E.P.A office)

With all the outlined objectives drawn out with the unbundling and strategizing policies, N.E.P.A. still had challenges. The major constraints being experienced by its distribution sector are:

- **Distance to the National grid:** Several of the project's locations are so far that so many kilometers of 33KV Inter Township Connection (ITC) lines must be constructed before the targeted towns or villages are reached. This has often resulted in very low voltages at the receiving end.
- Wanton vandalization of installed materials by miscreants in the society.
- Lack of necessary off-shore materials. Especially in the localized river-rine rural areas.

Encountering these challenges, their effort at providing Rural Electrification has been hampered and most often jeopardized. Then we might want to ask ourselves what then is needed to be done to bring electricity to our rural areas? The answer is not far-fetched. Argentina, Benin, Togo, Cape Verde, Peru and Bolivia at one time or the other, tackled such problems with their governments by launching Rural Electrification Schemes with most

solutions evolving from Solar PV projects in partnership with the world bank. (see Appendix for a table on Argentin's solar home system project.)

## 5.0 Comparison of cost in electrifying a rural settlement by Solar and from the National grid

An estimated cost of electrifying a rural area which is 20km away from the national grid is heighted below.

Note: this estimated cost only covers the extension of the grid to a rural settlement. It excludes the distribution of electric power to each home.

**Table 2. cost for extending the national grid by 20Km to a rural settlement**

| Materials | Poles | Aluminum Cord | Pot insulators | Channel Iron | 500kva xformer For one | Sub station | Low Tension materials | Other materials |
|---|---|---|---|---|---|---|---|---|
| Cost in Naira | 9.6m | 13.64m | 2.7m | 2.1m | 2.9m | 1.5m | 5.0m | 10.0m |
| Total | 47.44m | | | | | | | |

M =Million Naira

Source: from a major contractor to the federal government of Nigeria.

In solar electrification the cost of extending the grid is eliminated. Table 3. Gives an estimate of cost for solar systems of various power rating when off-grid, grid-intertied and for on-grid with battery backup as found in the United State of America

**Table 3. cost for procuring solar equipment for a 2Kw, 5Kw and 10Kw power**

| System Type | 2 kW (small/average) | 5 kW (average/big) | 10 kW (gigantic) |
|---|---|---|---|
| Off-grid | $20,800 | $52,000 | $104,000 |
| Grid-intertied | $16,000 | $40,000 | $80,000 |
| On-grid with battery backup | $19,200 | $48,000 | $96,000 |

**Source:** http://www.motherearthnews.com/ask-our-experts/solar-electric-system-cost-z10b0blon.aspx retrieved 28/08/2012 time 11.08am

It is obvious that if the cost of distribution is added to the cost of extending power from the national grid we will probably be talking of a cost close to N100,000,000 to electrify a rural settlement which is 20Km away from the grid. In comparison to the solar alternative off grid 10Kw which cost is 104,000 dollars (equivalent to N16.64M), solar electrification of rural settlement should be embraced.

## 6.0 Benefits to Solar Rural Electrification in Nigeria

Although presently in Nigeria, we have six solar power sites located in each of the geopolitical zones which are at Owerri ($5^0$ 29'N, $7^0$ 1'E), Port-Harcourt ($4^0$ 47'N, $7^0$ 0'E), Lagos ($6^0$ 26'N, $3^0$ 17'E), Abuja ($9^0$ 3'N, $7^0$ 15'E), Maiduguri ($11^0$ 51'N, $13^0$ 9'E) and Sokoto ($13^0$ 3'N, $5^0$ 14'E) with its Solar potential been over 3000Wh/$m^2$/day, this initiative can be further channeled into the rural areas of Nigeria. With rapid population growth and increase in industrial activities, more energy is consumed, resulting in environmental pollution and economic difficulties. Therefore, there is the need for utilizing renewable energy resources.

Energy is the lifeblood of economies around the world and global economic growth depends on adequate, reliable and affordable supplies of energy. Key foreign policy objectives, including support for democracy, trade, sustainable economic development,

poverty reduction and environmental protection rely on the provision of safe, reliable and affordable energy supplies. (Eleri, 1993).

There are lots of benefits that accrue from the use of solar energy, ranging from climate protection, productive use, poverty reduction and economic growth and Agriculture. A highlight of these benefits will be discussed briefly.

## 6.1 Climate Protection

Nations that are party to the U.N climate convention drafted the Kyoto protocol in 1997. This protocol is all about how Green House Gas (GHG) emission could be lowered. Off-grid applications of renewable energy like solar in our country Nigeria can help in the displacement of GHG emissions while providing a valuable near-term market niche for emerging technologies, thereby significantly elevating the living condition of the rural populace.

## 6.2 Production Use.

In the year 2000, the Nigeria legislature passed a law which supports independent power production, permitting Nigerian states to build their own decentralized power plants. This is an avenue for making income by the big time investors, as Solar thermal plants can be built. These plants are far more stable than the hydro ones available.

The Nigerian government launched its Renewable Energy Master Plan (REMP) in January 2007, and solar energy is a key component of this policy (see appendix Box 2.5 for the master plan). This provides a roadmap for the gradual move away from fossil fuels, and an increase in the role of renewable energy in satisfying the country's energy needs. It is hoped that the policy as structured would facilitate greater access to energy for Nigerians in order to improve living standards, especially in Rural Areas.

Government-led projects are targeting rural communities but are having limited impact,

with particular challenges in the areas of maintenance and replication. There has been less commercial interest in supporting renewable energy. The current available technology is not yet cost effective, but this is expected to change between 2010 and 2015, if the market is supported and nurtured. More affordable solar technology components and services are beginning to emerge in local markets, with many of these being imported from China.

### 6.3 Poverty reduction and Economic Growth.

When Renewable Energy like Solar reaches our rural areas, it will definitely generate wealth for the rural youths as they can start small scale businesses which can depend on cheap electricity. As the youths are engaged, the poverty index of the country will be reduced and the economic outlook of the country (particularly the per capital income) will improve. There will be good health care, safe drinking water, schools, community and properly powered public buildings.

### 6.4 Agriculture.

Energy is an essential input for the enhancement of rural production and food security, through land preparation, fertilization, irrigation, agro-processing, conservation and transport.

In the Agricultural sector there are many areas where solar P.V can be applied. e.g for pumping in irrigating farms, for livestock watering, for aqua-culture and fishing, refrigeration of meat and dairy and other products. In a country like ours, which is blessed with lots of sunshine, applying solar energy in Agricultural use as stated above will bring many benefits which cannot be over emphasized.

## 7.0 Strategies for Rural Electrification.

Several options exist for enhancing the poor's access to Rural Electrifications:

- **Sequencing reforms** – The State needs to ensure that they establish structures and mechanism for increased rural electrification before embarking on large-scale privatization reforms. Evidence from Ghana, Zimbabwe, South Africa, Mauritius and other developing countries indicate that higher levels of

access to electricity among the poor, especially in rural areas, have been achieved when rural electrification initiatives precede major market oriented reforms such as privatization.

- Linking Electrification Targets to contract renewals REA (Rural Electrification Agencies) Board members – The newly formed rural electrification agencies should have specific targets for electrifying the poor. This should be enforced through making the targets as part of the agency's annual reporting as well as renewal of the contracts of the board members as well as the executive employees of the agencies. Kenya has a similar policy in place through the institution of performance contracts for public institutions.
- Linking electrification targets to licensing renewals and tariff increments.- the electricity regulatory agencies could also enforce the electrification of the poor through linking set targets to issuance of licenses and concession to electricity distribution utilities. Linking the number of connections to licenses and concession is critical to ensuring the electrification of the poor (ECA/UNEP 2005). Also to ensure that the poor's access to electricity is sustainable, the regulatory agencies should ensure that tariff increments do not adversely affect the poor by providing for subsidies as well as encouraging utilities to utilize low cost electrification options.

# 8.0 Recommendation.

The following recommendations are hereby pro-posed:

- The LGA, Councils, State and Federal Government should formulate a workable agreement on how the rural areas in Nigeria will be provided with the basic amenities and infrastructure.
- The present deregulation in the power industry and energy sector should be pursued with all vigor by the Federal, State and Local Government Authorities (LGA's).
- The Federal Government should encourage the idea of new technology to harness energy, such as Flexible Alternating Current Transmission Systems (FACTS), Wide Area Monitoring and Control and Wind Power. These new technologies will not only

help in providing alternative means of energy, but will also reduce carbon emission that has become a problem globally.

## 9.0 Conclusion.

The reasons for failure of rural energy projects include poor quality products, poor installation and maintenance, and systems being "oversold" (marketing claims that raise expectations higher than the technology can deliver). Codes, standards and certification are important elements to address these issues, as well as reduce commercial risks. The uses of Solar Energy will definitely bring succor to the lives of the Rural populace and reduce to the minimum, the failing efforts of the government (Federal State and Local). Although the initial costs of embarking on solar projects are high, the government can partner with the World Bank in bringing solace to the rural areas of our country. Ordinarily the present power produced in the country is not enough for the urban cities so new and renewable energy sources should be focused on with particular attention given to SOLAR energy.

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http://www.motherearthnews.com/ask-our-experts/solar-electric-system-cost-z10b0blon.aspx retrieved 28/08/2012 time 11.08am

# Appendix

## TYPES OF SOLAR PANEL

There are presently about five different types of solar panels and these

- Monocrystalline silicon (mono-silicon or single silicon).
- Polycrystalline silicon (multycrystalline, multisilicon, ribbon).
- Thin film (amorphous silicon, cadmium teuride, copper indium gallium (di) setemide).
- BIPV (building integrated photovoltaics) and
- Solar hot water (thermal) panels.

Source: **http://howsolarworks.1bog.org/different-types-of-solar-panels/ retrieved on 5/7/2012. And**

**http://www.solar-power-answers.co.uk/solar_cell_types.php retrieved on 05/07/2012**

Monocrystalline silicon.

Polycrystalline panel.

Amorphous panel.

**Table 2: Illustrative Full Economic Costs Per Installed Solar Home System (US$) for Argentina Project**

| SHS size | Installation cost | O&M (NPV) | Battery replace-ment (NPV) | Total | Monthly payment (full cost) |
|---|---|---|---|---|---|
| 50 Wp | 764 | 390 | 216 | 1370 | 16.8 |
| 70 Wp | 1074 | 390 | 299 | 1763 | 23.1 |
| 100 Wp | 1347 | 390 | 418 | 2155 | 26.7 |

**Box 2.5. Renewable Energy Master Plan**

1. **Policy guidelines to improve market development** including local manufacturing of renewable energy components, strategic agreements with technology providers (private sector/international governments) and skills development (e.g. maintenance, installation).
2. **A Donors' Consultative Forum** to mobilise resources from development partners for achieving the aims of the National Action Programme.
3. **Media and communications strategy** to enhance public awareness of renewable energy and energy conservation.
4. **Pilot projects** to support the implementation of solar and other rural electrification pilots.

**Table 3.1. Key actors involved in Nigerian energy issues**

| Category | Examples |
|---|---|
| Government | Federal, state and local government, Niger Delta Ministry, Energy Council of Nigeria |
| Parastatals | Nigeria National Petroleum Company (NNPC), Niger Delta Development Corporation (NDDC) |
| International oil companies[58] | BG Group, Chevron, Conoco Philips, ENI, ExxonMobil, Total, Shell, Statoil-Hydro |
| Development aid agencies | USAID, European Commission, UK Department for International Development (DFID), World Bank/ International Finance Corporation (IFC), UN agencies, Canadian International Development Agency (CIDA) |
| International NGOs | Oxfam, Save the Children, Christian Aid, Africare |
| National and local NGOs | Living Earth Foundation Nigeria, Social Action, Stakeholder Democracy Network, ERA/Friends of the Earth Nigeria, Niger Delta Wetlands Centre |
| Charitable foundations | Ford Foundation, MacArthur Foundation, Clinton Foundation |
| Communities | Mega cities (e.g. Lagos), urban, peri-urban, rural and isolated villages[59] |

# Nigerian Renewable Energy Resource Base

## Renewable Resource Potentials

| S/no | Resource | | Reserve | Utilization Level |
|---|---|---|---|---|
| 1 | Large hydro power | | 11,250MW | 1,972MW |
| 2 | Small Hydro power | | 3,500MW | 64.2MW |
| 3 | Solar Energy | | 4.0KW/$M^2$/day to 6.5KW/$M^2$/day | -10MW solar PV stand-alone<br>-No solar thermal electricity |
| 4 | Wind | | 2-4m/s at 10m height | -2x2.5KW electricity generator<br>-10MW wind farm contracted in 2009. |
| 5 | Biomass | Fuel wood | 11 million hectares of forest and woodlands | 43.4 million tonnes of fuel wood/yr |
| | | Municipal waste | - 18.3 million tonnes in 2005* | -Not yet exploited |
| | | Animal waste | - 243 million assorted animals in 2001 | -Not yet exploited |
| | | Energy Crops and agric waste | - 28.2 million hectares of Arable land | 8.5% cultivated |

Source: REMP (2005)


**7.2 kWp PV Village Electrification, Kwalkwalawa, Sokoto State by SERC**

**Figure. 14:1.87 kWp PV Village Electrification & TV-Viewing Plant Iheakpu-Awka, Enugu State by NCERI**

Solar PV lighting at Basic Health Centre, Ilaje, Ondo State