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Analysis Of Telecom Base Stations Powered By Solar Energy

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Abstract: Improved Quality of Service and cost reduction are important issues affecting the telecommunication industry. Companies such as Airtel, Glo etc believe that the solar powered cellular base stations are capable of transforming the Nigerian communication industry due to their low cost, reliability, and environmental friendliness. Currently, there are several research efforts directed on the use of solar power in the Nigerian telecommunication industry. In this paper, the importance of solar energy as a renewable energy source for cellular base stations is analyzed. Also, simulation software PVSYST6.0.7 is used to obtain an estimate of the cost of generation of solar power for cellular base stations. The simulations were carried out for the Grid-Connected and the Stand-Alone solar power systems by using Benin City, Nigeria as a case study. The PVSYST6.0.7 simulation results shows that the power generation costs for the grid connected solar powered system is less when compared to standalone solar powered system in Benin City, Nigeria.

Index Terms: Cellular Base station, Environmental Friendliness, Photo Voltaic Cell, , PVSYST6.0.7, Renewable Energy, Solar Power, Telecom.

1 Introduction

CELLULAR communications technologies such as handsets and base stations have become very common technologies throughout the developing and developed world. Roughly three billion users spend large portions of their income on these communication technologies [1]. However, the remaining half of the world currently has limited access, in large part due to lack of network coverage. Some areas do not have a high enough population density to support a traditional cellular deployment. Other areas are too far from established infrastructure to make a deployment economically possible. This is why there are many rural areas where there is no network coverage at all [2]. Mobile telecom networks require an enormous amount of power. In markets with unreliable grid power, this energy often comes from diesel fuel. By some estimates, Nigeria alone already uses well over 150 million litres of diesel fuel every year to power telecom base stations when the grid power is not present or not available. This does not include the fuel needed to transport fuel to the mobile sites. Adding several base-stations for rural users can only multiply this destructive environmental impact, unless these base-stations are supported by a sustainable alternative. Running mobile phone networks is getting more expensive and difficult, due to increasing energy costs in developing countries and as operators increase the number of base-stations in the infrastructure, so that they can offer third generation networks, wireless services at broadband data rates, power consumption is set to continue to rise.

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Operators are therefore looking for alternatives to help them improve base-station efficiency [3]. Before the actual deployment of the solar powered base stations it is very essential to get an estimate of not only the number of the photovoltaic (PV) cells [5], inverters, batteries and generators required but also the cost of production of energy per unit. In order to do so it is always suggested to design and simulate the deployable solar powered base stations using software such as PVSYST6.0.7. PVSYST6.0.7 software can be used to design and simulate solar powered base stations in African countries like Nigeria by considering geographical and other salient design parameters. Hence, the use of PVSYST software will allow for the design and simulation of cost efficient and reliable solar powered base stations.

2 RENEWABLE ENERGY

Renewable energy is energy that is derived from resources which are continously replenished such as wind, rain, sunlight, tides, waves and geothermal heat. There is a world wide growing concern on the negative effects of other conventional energy sources such as water, coal, oil, gas, uranium, and so on to the environment and also to the health of the general populace. Conventional energy sources are a huge source of atmospheric pollution. The renewable energy sources use natural resources and do not cause any pollution, hence they are termed green energy sources [4].

2.1 Solar Energy

Sunlight is an excellent renewable energy source. Thus, the use of solar energy for applications such as electricity generation, powering of automobiles, powering of cellular base stations is becoming very common. The generation of electricity using solar energy is done using photo-voltaic technology [5]. The solar photovoltaic cell operates based on the principle of conversion of sunlight into electricity. In order to generate electricity in large amounts, an array of solar PV cells are connected in parallel or series. Irradiance is a measure of the sun's power available at the surface of the earth and it averages about 1000 watts per square meter. With typical crystalline solar cell efficiencies of around 14-16%, we can expect to generate about 140-160W per square meter if solar cells are exposed to full sun. Insolation is a measure of the available energy from the sun and is expressed in terms of "full sun hours" (i.e. 4 full sun hours = 4 hours of sunlight at an irradiance level of 1000 watts per square meter). Obviously different parts of the world receive more sunlight and will have more "full sun hours" per day than others. The solar insolation zone map (below) will give you a general idea of the "full sun hours per day" for your location. This solar insolation map shows the amount of solar energy in hours (peak sun hours), received each day on an optimally tilted surface during the worst month of the year [6]. The solar insolation map is shown in fig.1. From the map it can be seen that tropical countries like Nigeria can benefit from the use of solar energy as a viable source of energy.

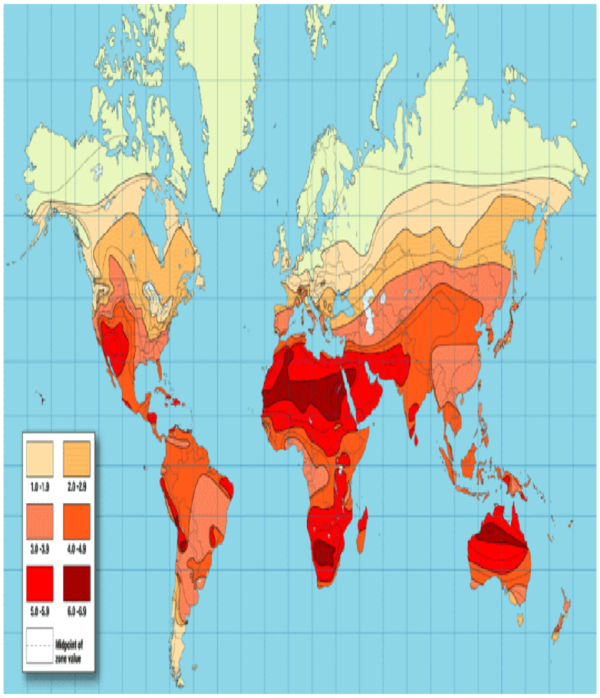


Fig.1. World Solar Insolation Map [6]

2.2 Solar Cell Technology

A solar cell (PV cell) is an electrical device that converts light energy into electricity by the photo-voltaic effect. It is a photo-electric cell which when exposed to light, generates an electric current without being attached to any external voltage source. The photo-voltaic cell works in three steps:

1. Photons in sunlight impact the solar panel and are absorbed by semi-conducting materials, such as silicon, gremanium, and so on.
2. Negatively charged electrons are knocked loose from their atoms, causing an electric potential difference. Current starts flowing through the material due to the potential difference, and due to the composition of solar cells, the electrons are only allowed to move in a single direction.
3. An array of solar cells converts solar energy into direct current electricity.
4. Assemblies of solar cells are used to build solar modules which generate electricity from sunlight. Multiple cells integrated together and oriented all in one plane make up a solar photo voltaic panel or solar photovoltaic module. A group of connected solar modules is called a photo voltaic array. Solar cells consists of two semi conductor layers. The two layers are oppositively charged. One layer is having a positive charge and the other is having a negative charge. When light falls on the solar cell, semi conductors absorb photon from light. When electrons travel from negative layer to poitive layer, electricity is generated. A simple circuit that shows a photo- voltaic cells PN junction is shown in fig. 2.

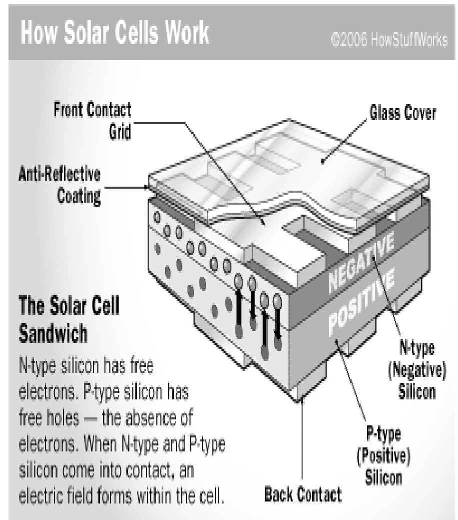


Fig. 2. Diagram of a Solar Cell [7]

Without an electric field, the cell would not work, the field forms when the N-type and P-type semi-conductor come into contact. Suddenly, the free electrons on the N-type see all the holes on the P-type and then there is a flow of electrons to fill the holes. However, right at the PN junction, electrons and holes mix and form something of a barrier, making it harder for electrons on the N-type to move to the P-type. Eventually an equilibrium condition is reached and we have an electric field seperating the two sides. The electric field functions like a diode, allowing electrons to flow from the P-type to the N-type, but not the other way round. When light in the form of photons hit the solar cell, the light energy breaks apart electron-hole pairs. Each photon will normally free one electron, resulting in a free hole as well. If this happens close enough to the electric field, the field will send electron to the N-type and hole to the P-type. This results to more change in electrical neutrality, and if an external circuit path is provided, electrons will flow through the path to the P-type to unite with holes that was sent there by the electric field, performing useful work along the way. The electron flow provides the current, the voltage is provided by the solar cell's electric field. The product of current and voltage gives the useful solar power. Silicon, being the most widely used semi-conductor used to build solar cells, is a very shiny material, which can reflect the photons away before they've done their job, so anti-reflective coating is applied to reduce those losses. The final step is to install a glass-cover plate that will protect the solar cell from the elements. Photo-voltaic modules are generally made by connecting several individual cells together to achieve useful levels of voltage and current, and putting them in a sturdy frame complete with positive and negative terminals.

2.3 Developments in Solar Technology

A lot of research is ongoing, aimed at developing new ways to make solar power increasingly competitive with traditional energy sources. The economic effectiveness of photo-voltaic electricity depends on the conversion efficiency and capital cost. Single crystalline silicon is not the only material used to make photo-voltaic cells. In an attempt to reduce manufacturing cost, plycrystalline silicon is used, though it has a lesser efficiency. Second generation solar cell technology are known as thin-film solar cells. They are simple and cheaper to produce, though still less efficient. The thin film solar cells can be made from a variety of materials, including gallium arsenide, cadmium telluride, copper indium diselenide and amorphous silicon. A strategy for increasing efficiency is to use two or more layers of diferent materials with different band gaps. Depending on the substance, photons of varying energies are absorbed. So by stacking higher band gap material on the surface to absorb high-energy photons (while allowing lower energy photons to be absorbed by the lower band gap material beneath), much higher efficiencies can result. Such cells, called multi-junction cells, can possess more than one electric field [8]. Another promising field of solar energy development is the use of concentrating photo-voltaic technology. Instead of simply collecting and converting a portion of sunlight to electricity, concentrating photo-voltaic systems use optical equipments like mirrors, lens, and so on, to focus higher amount of solar energy onto efficient solar cells. Research is currently ongoing on the use of organic material and nano-particles (Quantum Dots) as materials for solar cells.

2.4 Types of Solar Powered Systems

There are four general types of electrical designs for PV power systems that can be used for cellular base stations; Systems that are connected to the power utility grid and have no battery back up capability, systems that interact with the utility power grid and include battery back up, stand alone systems, and hybrid stand alone systems.

2.4.1 Grid-Connected (No-Battery Back-up) Systems

This type of system only operates when utility is available. However, in the event of an outage, the system is designed to shut down until when the utility power is restored.

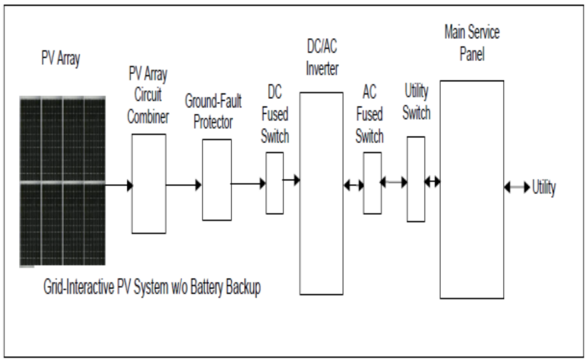


Fig. 3. Diagram of a Grid-Connected (No-Battery Back-up) System [9]

2.4.2 Grid-Connected Systems With Battery Back-Up

This type of system uses an energy storage battery to keep critical load circuits operating when there is a power outage. When an outage occurs, the unit disconnects from the utility and powers specific circuit. If the power outage occurs during the day, the PV array is able to assist the battery in supplying the critical loads. If the outage occurs at night, the battery supplies the load.

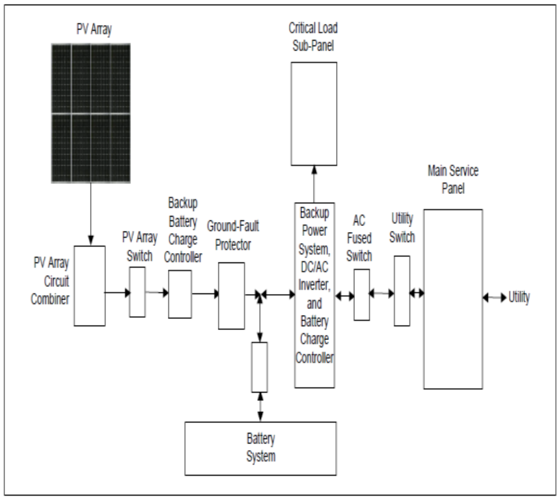


Fig. 4. Diagram of a Grid-Connected with Battery Back-up System [9]

2.4.3 Stand Alone Solar Power Systems

These are solar power systems that are not connected to the utility grid. They are made from the combination of batteries, inverter, switches, and solar array. The power from PV rays passes to batteries, from the batteries it passes to the inverter which converts the DC to AC. From the inverter the power passes to the base-station.

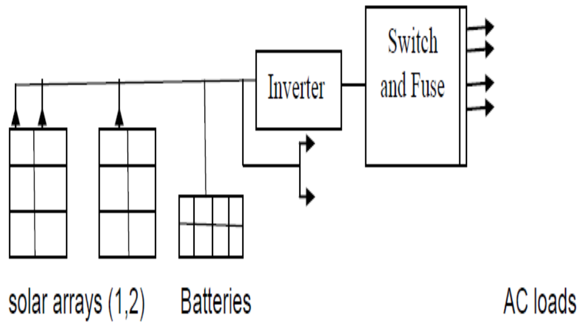


Fig. 5. Diagram of a Stand-Alone Solar Power System [5]

2.4.4 Stand Alone Hybrid Systems

This system does not depend on a single power source. Multiple power sources are used. There are two types of stand alone hybrid systems; stand alone hybrid system with diesel and stand alone hybrid system with fuel [5].

3 SOLAR-POWERED TELECOM BASE-STATION

In radio communication, a base-station is a wireless communication station installed at a fixed location and used to communicate as part of a wireless telephone system such as cellular CDMA or GSM cell site. These base-stations are made up of several antennas mounted on a metallic tower and a house of electronics at the base of the tower [10]. Many people in emerging markets like Nigeria live in rural areas with limited access to the electricity grid. This presents a significant barrier to expanding network coverage in these areas as mobile phone base stations rely on a secure supply of power. Even in areas connected to the grid, the power supply can be unstable and expensive. The use of diesel generators to power base-stations require regular maintenance, are expensive to run, and cause air pollution. By utilizing solar power to run the base-stations, operators will be able to reduce their operational cost and thus allows for deeper penetration of mobile networks [11]. In recent years, the telecoms sector has shown an increased interest in the adoption of solar technology to generate power for cellular base stations. Typically, solar power is being utilized in more remote cellular base stations, particularly in developing countries where base stations are often off-grid and reliant on their own power sources. According to a forecast from In-Stat, over 230,000 cellular base stations in developing countries will be solar-powered or wind-powered by 2014 [12]. Renewable energy from solar panels offers a viable alternative to diesel generators in these remote off-grid sites, and a new report from Pike Research forecasts that renewable energy will power 4.5% of the world's mobile base stations by 2014, up from just 0.11% in 2010. In developing countries, the percentage will be even higher - the clean-tech market intelligence firm forecasts that 8% of base stations in those regions will utilize renewable power by 2014[13]. There are about five million cell phone towers worldwide, 640,000 of which aren't connected to an electrical grid and largely run on diesel power. Renewable options also become much more viable as the amount of energy needed to power base stations is reduced. The average cellular base station, which comprises the tower and the radio equipment attached to it, can use anywhere from about one to five kilowatts (kW), depending on whether the radio equipment is housed in an air-conditioned building, how old the tower is and how many transceivers are in the base station. Most of the energy is used by the radio to transmit and receive cell-phone signals [14]. An Indian telecom company is deploying simple cell phone base stations that need as little as 50 watts of solar-provided power. It will soon announce plans to sell the equipment in Africa, expanding cell phone access to new ranks of rural villagers who live far from electricity supplies. Over the past year, VNL, based in Haryana, India, has re-engineered the traditional technology of the dominant cellular standard, GSM, in order to create base stations that only require between 50 and 150 watts of power, supplied by a solar-charged battery. The components can be assembled and booted up by two people and mounted on a rooftop in six hours. One such station–dubbed a "village station"–can handle hundreds of users. Groups of such village stations feed signals to a required larger VNL base station within five kilometers. In turn that larger station, which is also solar-powered, relays signals to the main network [15]. A low-powered cell phone solar powered base station is shown in fig. 6. Fig. 7 shows a typical solar power connection to a radio base station.

Fig. 6. A Low Powered Cell Phone Solar Powered Base Station [15]

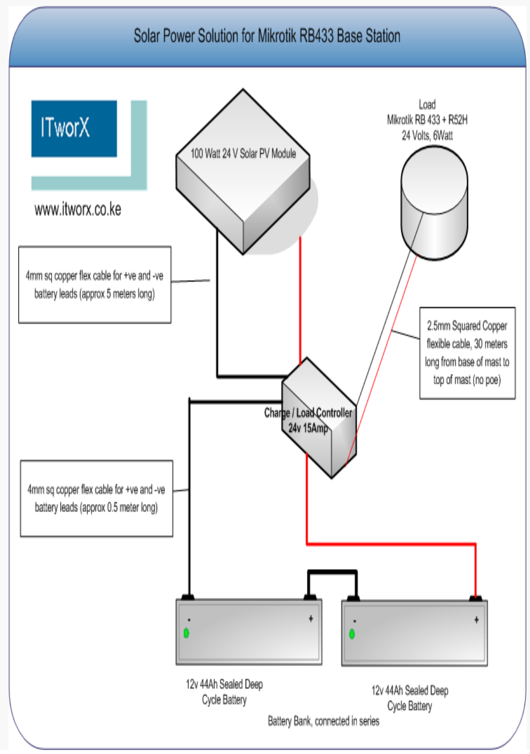
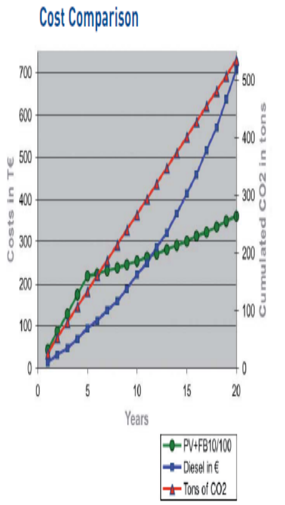


Fig. 7. Solar Power Solution for Mikrotik RB433 Base Station [16]

According to [17], one 15KWp Photo-voltaic installation can replace 12 diesel generator installations and save 203,000 litres of diesel in 20 years. Fig. 8 shows a cost comparison between solar powered and diesel powered telecom base station.



20 Years	Diesel in €	PV+FB10/100 in €
Cap. Invest. 60 month Lease	9,368	188,690
Replacements	12	0
Repl. Costs val. 5%	78,861	99,198
O+M val. 5%	34,719	66,132
Fuel val. 10%	582,200	0
Insurance val. 5%	1,984	6,613
TOTAL	707,133	360,633

Fig. 8. Cost Comparison Between Solar and Diesel Powered Telecom Base Station [17]

4 SIMULATION AND RESULTS

In order to perform an economic evaluation of grid-connected and stand-alone solar systems for use in cellular base stations, we use PVSYST 6.0.7 software. The area of interest for our analysis is Benin City, in Edo State, Nigeria. The specification of solar module used in the experiment is as follows:

- **I.** Mono-crystalline PV cells
- **II.** Standard Module Design
- **III.** Flat Roof Mounting
- **IV.** Ventilated Enclosure

The solar path horizon at Benin City is shown in fig. 9. Fig. 10 and 11 gives the results of the simulations for grid-connected and stand-alone solar power systems for use in base-stations.

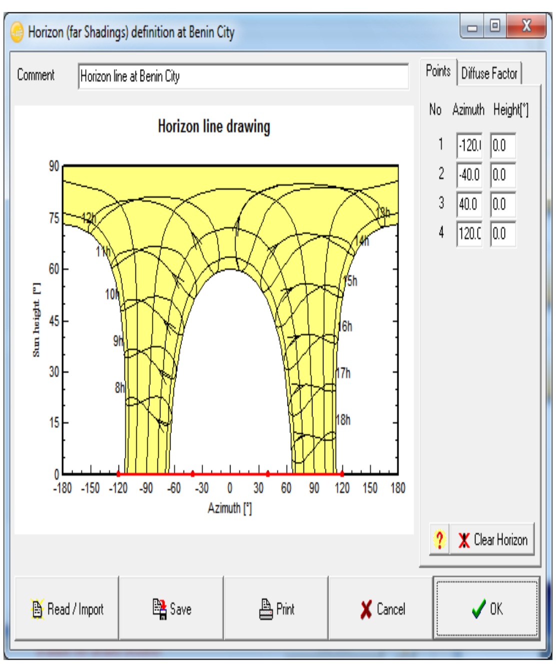


Fig. 9. Solar Horizon Profile for Benin City

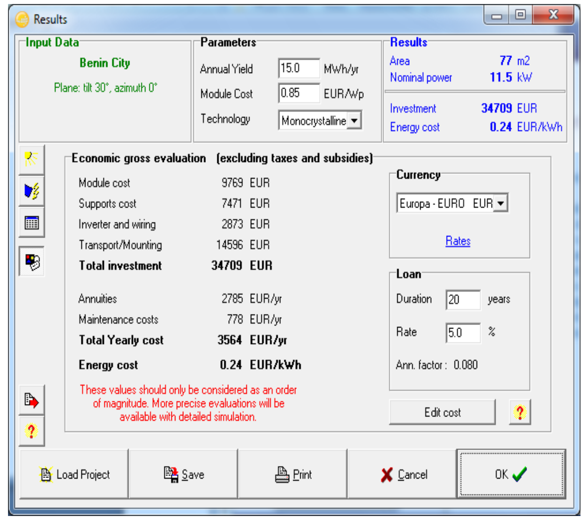


Fig. 10. Simulation Result for Grid-Connected Solar Base Station

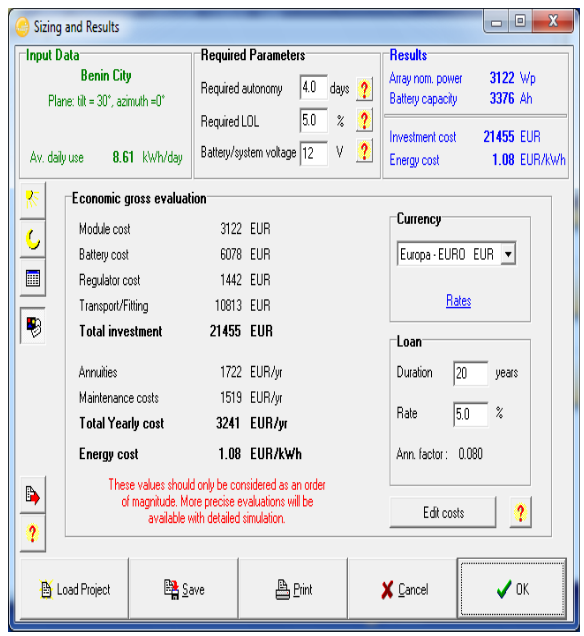


Fig. 9. Simulation Result for Stand-alone Solar Base Station

5 CONCLUSION

The simulation results of the solar powered cellular base station suggests that it is more cost efficient to deploy grid connected system than to deploy standalone system in Benin City, and even Nigeria as a whole.. Simulation results show that estimate of the cost of production was found to be 0.24 euro/kwh for grid connected system compared to 1.08euro/kwh for standalone system in Benin City, Nigeria. Also, the system design for standalone systems is more complex when compared to grid connected due to the presence of batteries and generators in addition to inverters and PV modules. This adds extra complexity to the design. Grid connected systems are suitable if the supply of solar energy is reliable. In other words it is suggested to use grid connected system in areas with adequate power supply. If the supply of electrical energy from the grid is not reliable then it is suggested to use standalone system though it is more costly when compared to grid connected system.

REFERENCES

[1]. GSM Association, "3 Billion GSM Connections on the Mobile Planet, http://www.gsmworld.com/newsroom/press-releases/2008/1108.htm.

[2]. Kurtis Heimerl, Eric Brewer, "The Village Base Station".

[3]. Infinite Focus Group, White paper on "Alternative and Sustainable Power for Nigerian GSM/Mobile Base Stations".

[4]. Renewable Energy Power for a Sustainable Future edited by Godfrey Boyle.

[5]. Wind and Solar Power Systems Design, Analysis, and Operation, Mukund R.Patel.

[6]. Red, "Will Solar Panel Work at My Location", retrieved from http://www.applied-solar.info/solar-energy/will-solar-panels-work-at-my-location/

[7]. Marshall Brain, "How solar yard light works", retrieved from http://home.howstuffworks.com/solar-light2.htm.

[8]. Jessika Toothman and Scott Aldous, "Developments in Solar Cell Technology", retrieved from http://science.howstuffworks.com/environmental/energy/solar-cell8.htm.

[9]. "A Guide to Photovoltaic (PV) System Design and Installation, prepared by Endecon Engineering, 247 Norris Court, California. 2001.

[10]. Geetha Pande, "A Case Study of Solar Powered Cellular Base Stations", unpublished Masters Thesis, Department of Technology, University of Gavle.

[11]. Solar Connect, "A Solar Powered Cellular Base Station", technical white paper.

[12]. "Solar Power in Cellular Base stations", retrieved from http://www.capacitymagazine.com/Article/2788162/Solar-power-in-cellular-base-stations.html.

[13]. "Renewable Energy to Power 4.5% of Mobile Base Stations by 2014" retrieved from http://www.cellular-news.com.

[14]. Katherine Tweed, "Why Cellular Towers in Developing Nations Are Making the Move to Solar Power", retrieved from http://www.scientificamerican.com/article.cfm?id=cellular-towers-moving-to-solar-power.

[15]. David Talbot, "Solar-Powered Base Stations can link up remote areas", retrieved from http://www.technologyreview.com/news/417442/a-50-watt-cellular-network/ on July 5, 2013.

[16]. wiki.mikrotik.com

[17]. "Solar Powered Telecom Base Station" retrieved from www.tngltd.com.au