GLOBAL JOURNAL OF ENGINEERING, DESIGN & TECHNOLOGY
(Published By: Global Institute for Research & Education)
www.gifre.org

A COMPARISON OF PHOTOVOLTAIC AND HYDROPOWER TECHNOLOGIES IN NIGERIA

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Abstract
Nigeria depends heavily on conventional methods of power generation through fossil fuels with the attendant global warming effects. In order to expose the adverse effects of global warming, this paper presents a comparison of economic and environmental characteristics of photovoltaic and hydropower technologies in Nigeria. A recommendation is made based on power demand and global warming reduction potentials of photovoltaic technologies.

Keywords: *Photovoltaic; Hydropower; Technologies; Conventional Power Generation*.

I. Introduction
The issue of global warming has drawn national and international attention. Targets have been set by different countries and regional blocks on reduction of greenhouse gas (GHG) effects. Martinot (2006) reported that the two largest global sources of GHG of which carbon dioxide (CO_2) is the most common is electricity heat and transportation of which both contributes 32percent and 17percent respectively. He also revealed that the use of electricity, heaters, air conditioners and motor vehicles contribute to these sources. Furthermore, the land uses, forestation, manufacturing and construction activities contribute 24percent and 13percent respectively.

In a recent research, Solangi et al. (2011) discussed CO_2 emission by Africa region as shown in the world CO_2 emission in Table 7 and projected that by 2025, Africa will emit 1524 million tonnes of CO_2. Bilen et al. (2008) opined that CO_2 screens sunlight and allows the penetration of sun rays but prevents heat radiation re-emergence. Nigeria generates her electricity mainly from fossil fuels. In order to achieve the global challenges of CO_2 emission reduction, there is urgent need to integrate renewable energy technologies into the nation's energy portfolio.

For this to be achieved, proper comparison and adequate choice of a renewable energy technology with considerable cost and little or no negative environmental impacts have to be made.
This work presents an unbiased assessment of photovoltaic and hydropower technologies with special interest in global warming reduction potentials.

II. Renewable Energy Policy in Nigeria
The overview of renewable energy policy as approved by the Nigerian government in 2003 (http: //www.reegle.info/policy-and-regulatory-overview/NG, 2012) is outlined as follows:

- Exhaustive harnessing of hydropower potentials in the nation.
- Vigorous pursuit of photovoltaic technology integration into the nation's total energy portfolio.
- Promotion of biomass and wind conversion technologies in the nation.

The policy envisages active private sector participation in the nation's energy resources with the view of making reliable energy accessible to 75percent of the population by the year 2020.

Potentials of Photovoltaic Technology in Nigeria
The Nigerian federation has verifiable unharnessed solar energy potentials as shown in Figure 1 and Table 1. These unharnessed potentials could increase the total energy portfolio of the nation with electricity extended to the remote villages. Recent educational research (Stephen et al., 2012) reveals that Nigeria has solar irradiation of about 5.5KWh/m^2/day with most of its solar energy resources underutilized.

The Nigerian policy and regulatory overview (http: //www.reegle.info/policy-and-regulatory-overview/NG, 2012) further reveals the average solar insolation to be about 5.25KWh/m^2/day and 7KWh/m^2/day at the northern region with 500PV installations currently in use in the Nigerian federation. This policy supports the views of Iloeje(1997, cited in Ilenikhena, 2007, p.104) on the average solar radiation per day in the northern region of the country. However Iloeje added that the average solar radiation in the coastal areas is 3.5KWh/m^2/day.

Potentials of Hydropower Technology in Nigeria
Nigeria depends largely on hydropower for her electricity generation as shown in Tables 1 and 2. The hydro potentials as shown in Figure 2 are underutilized as of today.The overview of the Nigerian Policy and Regulation (http: //www.reegle.info/policy-and-regulatory-overview/NG, 2012) has shown that 22percent of the nation's electricity is from hydropower potentials. This assertion was confirmed by Okoro and Madueme (2004) as mirrored in Table 2. It further estimated the total hydropower potentials at 14750MW with 1900MW large hydropower potentials being currently

harnessed at different locations in the country. 734MW of small hydropower (SHP) potentials are yet unharnessed while total SHP potentials are currently estimated at 3500MW.

III. Economic Characteristics of Photovoltaic Technologies

Nigeria depends heavily on fossil for electricity generation due to the vast deposits of crude oil and natural gas in the country. Notwithstanding the vast deposit of crude oil, Nigeria generates less than 4000MW of electricity with per capita consumption of 0.03kw (Table 8).This is the present situation despite the fact that the installed total capacity as far back as 1999 was put at 11,756MW (Oparaku, 2007). Photovoltaic technologies which are renewable and free for all unlike most conventional energy sources have the potentials to increase the total energy mix, improve the per capita consumption and extend electricity to rural and remote areas, considering the unharnessed potentials as shown in Table 1 and Figure 1 and confirmed by (http: //www.reegle.info/policy-and-regulatory-overview/NG, 2012;Stephen et al., 2012; Iloeje, 1997, cited in Ilenikhena, 2007, p.104; Okoro and Madueme, 2004).

Okoro and Madueme (2004) suggested introducing solar energy in Nigeria to improve the energy mix and to avoid energy crisis as a result of heavy dependence on fossil fuels,but warned that the cost of power generation through solar energy is enormous due to cost of photovoltaic (PV) modules. However, it is worthy of note that photovoltaic equipment has low maintenance cost and continuing research in photovoltaics will force the prices of modules down. This assertion on the enormous initial cost of PV modules is shown in Table 3 and confirmed by (Khan, 2010; Bilen et al., 2008; Sambo, 2007).

It is also worthy of note that solar electric power does not require construction of kilometre roads and buildings for its initial take off unlike hydropower and the rest and on completion does not require the building of flood control measures.

Furthermore solar technologies like the building integrated photovoltaic (BIPV) has the capability of offsetting partially the cost of the modules by replacing part of the building material as well as generating the required electricity (Pearsall, 2013). This is not realisable in hydropower technologies. This view is confirmed by Jones et al (2000) who opined that integration of PV arrays with the building fabric offers opportunity to replace other building components and as such offsetting cost of PV installation.

BIPV, a photovoltaic technology does not waste land, as no additional land area is required for the installation (Pearsall, 2013). The ground mounted PV systems have the potentials of reclaiming land area. The desert regions of Nigeria can be highly advantageous for this project hence reclamation of the desert areas as confirmed in Solangi et al (2011) and prevent further desert encroachment. This potential of land reclamation is not found in hydropower technologies.

Photovoltaic technologies create recycling opportunities of solar modules at the end of their life cycle and hence employment opportunities for millions of unemployed Nigerian youths and savings of land fill space among other benefits unlike hydropower and other conventional methods of electricity generation.

In agricultural sector, Nigeria has the opportunity of enjoying the efforts made by researchers worldwide in areas of solar water heating for dairy processing and irrigation projects, also there will be local solar support refrigeration for storage of agricultural produce and vaccines for livestock and solar dryers for drying crops thereby increasing its agricultural productivity, ameliorating food shortage and creating employment opportunities. This is not applicable to hydropower technologies and even where hydropower is used for irrigation, there is the challenge of flooding. Okoro and Madueme (2004) also confirmed that considerable efforts have been made in the agricultural sector in areas of solar water heater, micro irrigation and solar crops dryers. Furthermore they assert that PV cells now replace power sources in our domestic appliances, like battery re-chargers, portable radios, emergency roadside telephones, buoys and even homes.

One interesting feature of Photovoltaic technology is that it can be privately owned by individuals or communities as the systems are smaller in capacity unlike hydro technologies. It can also be owned by the government and big private investors in the case of very large systems as it is applied to hydro technologies (Pearsall, 2013).

IV. Economic Characteristics of Large Hydropower Technologies

Nigeria is heavily endowed with hydropower fuel. Hence siting hydropower generation stations are economical to the nation. In a research study (Bilen et al., 2008) it was opined that the attractiveness of hydropower technology lies on its low cost of power generation and uninterrupted power supply provided the water level sustains constant inflow of water to the reservoir.This condition of sustained inflow of water to the reservoir in Bilen et al are not often met in the dry seasons and over-flooding of the dam, farm lands and surrounding villages are the challenges faced in the rainy seasons unlike photovoltaic energy technologies. In Igweonu and Robert (2012) the costs associated with developing hydropower are very site-specific. Meeting environmental issues and the need to design the power plant to maximize its output vary from area to area. However, hydropower is among the least expensive of all the energy resources. Although the capital cost of these facilities are very high, they have lower maintenance and operation costs. This assertion made by Bilen et al. was confirmed in Sambo (2007) as shown in Table 3. And Igweonu & Robert, 2012). However Igweonu and Robert emphasised that cost varies from site to site.

V. Environmental Characteristics of Photovoltaic Electrical Power Generation

Solar energy is a clean energy source. Electric power generation through this energy source imposes little or no environmental hazards. Unlike most conventional source of power generation and even some renewables like wind energy technologies, PV technologies generate no noise though the inverter systems could produce a system humming noise which is normally absorbed by the domestic noise background.In a research by Various (1996, cited in Tsoutsos et al., 2005, p.292) it was emphasised that though PV systems are devoid of liquid, radioactive or CO_2 emission, CIS and

CdTe modules are prone to emit toxic substances to the environment especially when fire accident occurs in any of the array.Fthenakis and Zweibel (2003) however showed that the Cd emission in relation to CdTe used is 0.001percent (equivalent to 0.1g/GWh). This is insignificant and as such has no health implication.

The aesthetics of building integrated photovoltaics (BIPV) cannot be over emphasised as BIPV if properly installed always add to the beauty of the environment. This assertion is in agreement with Tsoutsos et al. (2005) who see the PV technologies worthy of usage in urban areas to replace existing building cladding materials and recommended for use in scenic areas and National Parks.

In solar technology the issue of land use has been controversial. Tsoutsos et al., (2005) opined that impact is dependent on topography of the landscape, PV system installed areas, the type of land and proximity to areas of natural beauty or sensitive ecosystems, and the biodiversity. This is expected to occur during modification of landscape, construction and transportation of materials. However in a recent research Solangi et al. (2011) outlined the merits of solar energy technology as follows:

- No emissions of CO_2,NO_X , SO_2or particulates;
- Degraded land reclamation;
- Transmission lines from the grid are reduced;
- The quality of water resources are improved;
- Increase in the national energy portfolio

VI. Environmental Characteristics of Large Hydropower Electric Generation

Hydropower as of today contributes significantly in the Nigerian total energy mix as shown in Tables 1 and 2. It is predominated by large hydropower which is characterised by aquatic disturbances, deforestation, loss of species, rehabilitation, submergence especially during rain seasons and water pollution, air pollution and so on. Fish farmer are subjected to abject poverty as their source of income is affected. In a research study(United Nations Development Program [UNDP], 2000) large dams were shown to strongly threaten the existence of the ecosystem and social stability with little or no compensation to settlers. In a similar research Okoro and Madueme (2004) confirmed that in-flow of water into the hydro plants' storage affects the upstream pressure with consequent drought. This is a situation that sets farmers and merchants in perpetual poverty as the waterways are obstructed. This assertion is upheld in the UNDP report (UNDP, 2000).

Rule et al. (2009) proclaimed that the life cycle of CO_2 emission in hydroelectric and geothermal electricity generation is higher than those of wind and tidal electricity generation. This CO_2 emission causes global warming and natural balance instability, a situation that has attracted global concern. Igweonu and Robert (2011) emphasisedthat CO_2 has a strong affinity for hemoglobin forming carboxyhaemoglobin (COHb) in the human body. The effect is to reduce the oxygen carrying capacity of the blood, which has adverse effects all over the body, the most critical being the effect on the nervous system (CNS) and the heart. Carbon-monoxide emissions also cause the build-up of greenhouse gases in the atmosphere and depletion of the ozone layer with the attendant adverse effects such as global warming and rise in the sea level which may lead to flooding. WHO Commission on Health and the Environment 1992, reports that during the 1980's, carbon-monoxide emissions mostly from fossil-fuel burning were responsible for half of the total global warming effect.

VII. Summary of Comparison of Environmental Characteristics of Solar and Hydropower Technologies

In order to come up with an unbiased recommendation, a comparison is made between solar power and hydropower technologies in terms of their environmental impacts. From Table 6, it is obvious that the solar technology has more positive, less negative and more impact notations.

Table 6: Summary of Solar and Hydropower Comparison

Criteria	**Solar Technologies**	**Hydropower Technologies**
Atmospheric pollution	*	-
Water pollution	*	-
Ecosystems impacts	*	-
Land use	+/-	-
Visual intrusion	+/-	-
Resource depletion	*	-
Noise	*	-
Public health impacts	*	-
Global warming	*	-
Acidification	*	-

+: positive impact; - : negative impact; *: no significant impact

VIII. Conclusion And Recommendations

Comparison of economic and environmental characteristics of photovoltaic and hydropower technologies in Nigeria is very imperative to avoid global warming arising from total dependence on conventional methods of power generation. This is necessary as CO_2 generated by most conventional energy sources prevent heat radiation re-emergence. Nigeria blessed with solar and hydropower potentials have the manpower to invest in any or both technologies. However this research suggests more emphasis to be placed on photovoltaic systems for Nigerian power system considering the

economic, social and environmental benefits. It also has a good, simple, and cheap maintenance technology though its initial investment cost may be considered to be high but with continuous research, cost will eventually become minimal.

Therefore it is the authors' considered view is that:

- Government should give tax waver incentives to PV module manufacturers who are ready to setup factories in the country.
- Individuals should be encouraged to embrace photovoltaic technology for off-grid power supply in the rural areas.
- Photovoltaic research centres should be established and adequately funded by the government in each of the six geo-political zones of the country through tertiary education trust fund (TETFUND).
- More stringent measures should be employed on the reduction of CO_2emission.
- Photovoltaic system technology should be introduced as a course in all secondary and tertiary institutions in the nation to enhance its growth.
- Solar Energy Society of Nigeria (SESN) in conjunction with Council for Regulation of Engineering in Nigeria (COREN) should champion the reduction of CO_2 emission through the environmentally friendly solar technologies.
- Government should pursue a vibrant solar technology policy to make solar energy form at least 10percent of the national energy mix on or before year 2020.

Table 1: Renewable Energy Resources

Renewable Energy Type	**Production**	**Domestic Utilization (Natural Unit)**
Large Hydropower	1938MW	1938MW
Small Hydropower	30MW	30MW
Solar Radiation	~=6MWh/day Solar PV	~=6MWh/day Solar PV
Wind		

Source: (Sambo, 2009)

Table 2: Generating plants-grid stations

Site	**Type**	**Installed capacity(MW)**	**Available capacity(MW)**	**Number of Units**
Afam	Thermal	700	488	18
Delta	Thermal	812	540	20
Egbin	Thermal	1320	1100	6
Ijora	Thermal	66.7	40	3
Sapele	Thermal	1020	790	10
Jebba	Hydro	540	450	6
Kainji	Hydro	760	560	12
Shiroro	Hydro	600	600	6
Orji River*	Thermal	60	-	4
Others	Diesel	46	18	-

*Operational inactive.

Source: (Okoro and Madueme, 2004)

Table 3: Relative High Investment Cost on Renewable Energy Systems

Technology	**Investment Cost ($/KW)**	**Lifespan**
Large Hydro	1000-2000	50
Small Hydro	1-5000	20-30
Solar PV	4500-7000	20-30
Solar Thermal	3000-6000	20-30
Bioelectricity	500-4000	20-25
Wind Electricity	850-1700	20-25
Diesel Engine	500	8-10

Source :(Sambo, 2007)

Table 4: Solar Technologies' Negative Impacts

Impacts-burdens	Alleviation technologies/techniques
Solar thermal heating	
Visual impact on buildings' aesthetics	Adoption of standards and regulations for environmentally friendly design; Good installation practices; Improved integration of solar systems in buildings; Avoid siting of solar panels on buildings of historic interest or in conservation areas.
Routine & accidental releases of chemicals	Recycling of the used chemicals; Good practices-appropriate disposal.
Land use	Proper siting and design.
Photovoltaic power generation	
Land use: large areas are required for central systems. Reduction of cultivable land	Use in isolated and deserted areas; Avoidance of ecologically and archeologically sensitive areas; Integration in large commercial buildings (facades, roofs); Use as sound insolation in highways or near hospitals.
Visual intrusion-aesthetics	Careful design of systems; Integration in buildings as architectural elements; Use of panels in modern architecture instead of mirrors onto the façade of buildings.
Impact on ecosystems (applicable to large PV schemes).	Avoidance of sensitive ecosystems and areas of natural beauty, archaeological [sic] sites.
Use of toxic and flammable materials (during construction of modules).	Avoidance of release of potentially toxic and hazardous materials with the adoption of existing safety regulations and good practice.
Slight health risks from manufacture, use, & disposal.	Good working practices(use of protecting gloves, sunglasses, clothing during construction).
Solar thermal electricity	
Construction activities	Good working practices; Site restoration; Avoidance of sensitive ecosystems and areas of natural beauty.
Visual impact-aesthetics	Proper siting(avoidance of sensitive ecosystems and areas of natural beauty, densely populated areas).
Land use	Proper siting.
Effect on the ecosystem, flora and fauna (especially birds). Impact on water resources, water use (for cooling of steam plant) and possibly, water pollution due to thermal discharges or accidental discharges of chemicals used by the system.	Proper siting (avoidance of sensitive ecosystems). Appropriate constraints (not the excessive use of existing resources); Improved technology (use of air as heat-transfer medium); Exploitation of the warm water in the nearest industry in the production stream. Good operating practices and compliance with existing safety regulations; Employees should be educated and familiarized with the systems.
Safety issues(occupational hazards)	

Source: (Tsoutsos et al., 2005)

Table 5: Environmental Impact of Present Energy System

Energy source	Inherent		Avoidable	Local
	Global	Local	Global	
Coal	CO_2	Mining	Acid rain	Air pollution
Oil	CO_2		Ocean pollution	Air pollution, local water resources
Gas	CO_2		Greenhouse gas due to leakage pipelines	
Hydropower		Aquatic ecosystem/ competition with other water usage		Aquatic ecosystem/ competition with other water usage
Nuclear	Non-proliferation	Accidents / political stability		Radioactive waste

Source: (Solangi et al., 2011)

Table 7: world carbon dioxide emissions by region, 1990-2025

Region	1990	2002	2010	2015	2020	2025
Mature Market Economics	10,465	11,877	13,080	13,745	14,392	15,183
North America	5769	6701	7674	8204	8759	9379
Western Europe	3413	3549	3674	3761	3812	3952
Mature Market Asia	1284	1627	1731	1780	1822	1852
Transitional Economics	4894	3124	3643	3937	4151	4386
Emerging Economics	6101	9408	13,478	15,602	17,480	19,222
Asia	3890	6205	9306	10,863	12,263	13,540
Middle East	845	1361	1761	1975	2163	2352
Africa	655	854	1122	1283	1415	1524
Central And South America	711	988	1289	1280	1639	1806
Total world	21,460	24,209	30,201	33,284	36,023	38,790

Source: (Solangi et al, 2011)

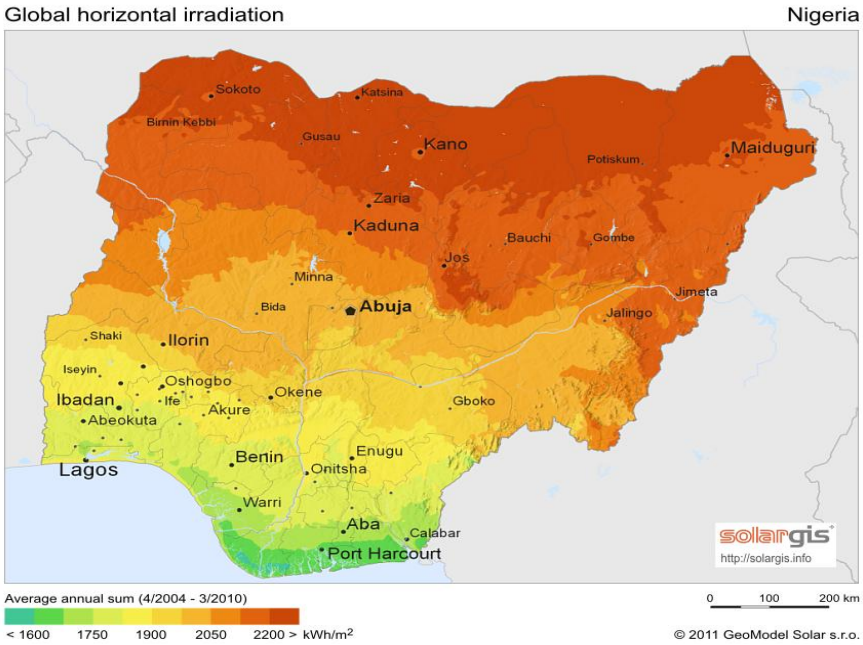

Figure 1: Map of Nigeria showing Solar Potentials

Source: http://solargis.info/doc/_pics/freemaps/1000px/ghi/solarGIS-solar-map-Nigeria-en.png

Figure 2: Map of Nigeria Showing Hydropower Potentials

Source: http://cloudfront.bernews.com/wp-content/uploads/2011/05/mnigeria.gif

Table 8: Country Statistics of Electricity Generation and per capita consumption

Continent	Country	Population (million)	Generating capacity(MW)	Per capita consumption (kw)
Africa	Nigeria	140	>4000	0.03
	Egypt	67.9	18,000	0.27
	South Africa	44.3	45,000	1.02

Source: National Centre for Energy Research and Development (NCERD).

References

Bilen, K., Ozyurt, O., Bakirci, K., Karsli, S., Erdogan, S., Yilmaz, M., and Comakli, O. (2008) 'Energy production, consumption and environmental pollution for sustainable development: A case study in Turkey', *Renewable and Sustainable Energy Reviews* 12 (6), p.1529-1561, NORA [Online]. Available at: http://www.sciencedirect.com/science/article/pii/S136403210700041X(Accessed: 23-02-2013)

Fthenakis, V. and Zweibel, K. (2003) 'CdTephotovoltaics: Real and Perceived EHS Risks', NCPV Program Review Meeting, Google Co.UK [Online].Available at: http://www.nrel.gov/docs/fy03osti/33561.pdf (Accessed: 23-02-2013)

Igweonu, E. I., and Robert, B. J. (2011) 'Environmental Health Hazards of Electric Power Generation from Fossil-Fuels: The Nigerian Case', *International Journal of Engineering Science* 3(3), p.1-7

Igweonu, E. I., and Robert, B. J. (2012) 'Small Hydro Power (SHP) Development in Nigeria: Issues, Challenges and Prospects', *Global Journal of Pure and Applied Sciences* Vol.18, No. 1&2, p.53-58 GoogleCo.UK [Online]. Available at: http://www.globaljournalseries.com/index/index.php/gjpas/article/viewArticle/661(Accessed: 23-02-2013)

Martinet E. (2006) 'Renewable energy gains momentum: Global markets and policies in spotlight'. *Issue Environ*, 48(6), p.26-43. NORA[Online]. Available at: http://search.proquest.com/docview/224015516 (Accessed: 23-02-2013)

Nigeria 2012 policy and regulatory overviews: clean energy

Google Co.UK [Online]. Available at: www.reegle.info/policy-and-regulatory-overview/NG

(Accessed: 23-02-2013)

Okoro, O.I., and Madueme, T.C. (2004) 'Solar energy investments in a developing economy', *Renewable Energy 29*(9), p.1599-1610, NORA [Online]. Available at: http://www.sciencedirect.com/science/article/pii/S0960148103003999 (Accessed: 23-02-2013)

Oparaku, O.U (2007)'Decentralized Electric Power Generation in Nigeria: The role of renewable energy resources', Proceedings of the international workshop on renewable energy for sustainable development in Africa (IWRESDA), p.28-36, 30th July-1st Aug. GoogleCo.UK [Online]. Available at: http://iwresda.ncerd.com/files/IWRESDA%20PROCEEDINGS1.pdf(Accessed: 23-02-2013)

Pearsall, N (2013) Photovoltaic Lecture note.

Rule, B.M., Worth, Z. J., and Boyle, C.A. (2009) 'Comparison of life cycle carbon dioxide emissions and embodied energy in four renewable electricity generation technologies in New Zealand', *Environmental Science and Technology* 43(16), p.6406-6413, NORA [Online]. Available at: http://jr3tv3gd5w.search.serialssolutions.com/?ctx_ver=Z39.88-2004&ctx_enc=info%3Aofi%2Fenc%3AUTF-8&rfr_id=info:sid/summon.serialssolutions.com&rft_val_fmt=info:ofi/fmt:kev:mtx:journal&rft.genre=article&rft.atitle=Comparison+of+Life+Cycle+Carbon+Dioxide+Emissions+and+Embodied+Energy+in+Four+Renewable+Electricity+Generation+Technologies+in+New+Zealand&rft.jtitle=Environmental+Science+%26+Technology&rft.au=Rule%2C+Bridget+M&rft.au=Worth%2C+Zeb+J&rft.au=Boyle%2C+Carol+A&rft.date=2009-07-16&rft.issn=0013-936X&rft.eissn=1520-5851&rft.volume=43&rft.issue=16&rft.spage=6406&rft.epage=6413&rft_id=info:doi/10.1021%2Fes900125e (Accessed: 23-02-2013)

Sambo, A.S. (2007) 'Renewable energy development in Nigeria: A situation Report',

Proceedings of the international workshop on renewable energy for sustainable development in Africa (IWRESDA), p.1-12, 30th July-1st Aug. GoogleCo.UK [Online]. Available at: http://iwresda.ncerd.com/files/IWRESDA%20PROCEEDINGS1.pdf(Accessed: 23-02-2013)

Sambo, A.S. (2009) 'The place of renewable energy in the Nigerian energy sector'.Presented at the world future council workshop on renewable energy policies, p.1-18 10th Oct. 2009, Addis Ababa, Ethiopia.Google Co.UK [Online]. Available at: http://www.area-net.org/fileadmin/user_upload/AREA/AREA_downloads/AREA_Conference_09/Presentations/Nigeria_RENEWABLE_ENERGY MASTERPLAN.pdf (Accessed: 23-02-2013)

Solangi, K.H., Islam, M.R., Saidur, R., Rahim, N.A., and Fayaz, H. (2011) 'A review on global solar energy policy', *Renewable and Sustainable Energy Reviews* 15(4), p.2149-2163, NORA [Online]. Available at: http://www.sciencedirect.com/science/article/pii/S1364032111000220 (Accessed: 23-02-2013)

Stephen, O.O., Liu, Y., Zhou, W., and Sun, H. (2012) 'Impact of PV generation for small autonomous electricity generation in Nigeria',

*Transnational Journal of Science and Technology*2(7), p.81-90.Google Co.UK [Online]. Available at: http://www.tjournal.org/tjst august 2012/6.pdf(Accessed: 23-02-2013)

Tsoutsos, T., Frantzeskaki, N., and Gekas, V. (2005) 'Environmental impacts from the solar energy technologies'

Energy Policy 33 (3), p.289-296,NORA [Online]. Available at: http://www.sciencedirect.com/science/article/pii/S0301421503002416 (Accessed: 23-02-2013)

United Nations Development Program (UNDP). 'World energy assessment', New York, NY: UNDP; 2000.http://www.undp.org/content/dam/aplaws/publication/en/publications/environment-energy/www-ee-library/sustainable-energy/world-energy-assessment-energy-and-the-challenge-of-sustainability/World%20Energy%20Assessment-2000.pdf (Accessed:23-02-2013)