



## Parabolic Trough Solar Concentrators (PSTC) Technology as an alternative Method of generating electricity in Nigeria

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### ABSTRACT

*The demand of energy and global warming as well as the greenhouse gas emission has mandated the world to shift towards alternative sources of energy. Nigeria had unfortunately fallen among the least electricity generating countries in the world due to the highly dependent on the fossil fuel in electricity generation. Solar thermal power plants are the most promising technologies that can supplement/replace the use of fossil fuels sources of energy. This paper focuses on the review of the development of the parabolic trough solar concentrators (PSTC) in Nigeria and looking forward the feasibility of using the technology to be an alternative method of generating electricity thereby pointing out some challenges with the regard to the installation of parabolic trough solar power technology in Nigeria.*

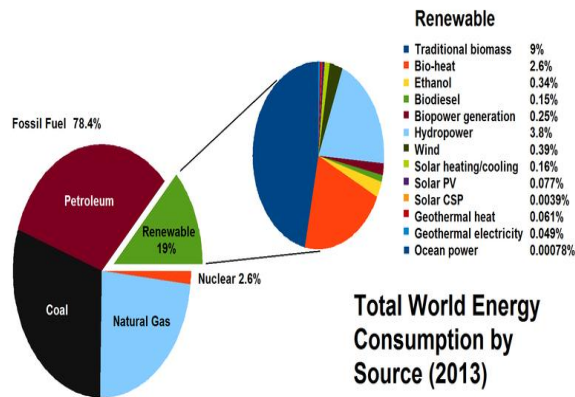
**.Keywords:** Parabolic, Concentrators, Electricity, Photovoltaic and Environment.

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### 1. INTRODUCTION

Due to the increase in electricity demand, issue in global warming and greenhouse effect as well as depletion in source of fossil fuels has forced the scientist around the world to look for alternative clean sources of energy (Thomas., 1996). Nigeria as a country is bless with abundance of renewable and non-renewable energy resources but unfortunately its energy supply is highly reliant onon fossil fuels and woody biomass for both domestic and non-domestic use (Ijeoma Vincent-Akpu, 2012). However, the country is among the most populous countries in the world with over 170 million people in the last National Population Census conducted 2006 but unfortunately fall among the lowest electricity producing countries in the world with only 6,050MW available.Capacity. This resulted toan oscillatory power supply throughout the country.

Solar thermal plants are regarded as an alternative source of energy that can supplement/replace fossil fuels in electricity generation. Among the solar thermal technologies, parabolic solar trough technology is the most matured, low-cost and efficient source of energy from the concentrated solar power (CSP) technology that can be used in providing clean electricity generation. Figure 1 Shows that 78.4% of the world energy consumptions is supplied from the fossil fuels and only 19% of the supplied energy is from renewable energy while nuclear energy carries 2.6%.



**Fig: 1** World energy consumption charts (Ahmad, 2012).

The forgoing studies is the simple reviews of parabolic trough solar collectors for steam and electricity generation and consequently points out the feasibility of implementing parabolic trough solar concentrators (PTC's) as an alternative method of generating electricity in Nigeria and also some challenges with the regard to the installation of parabolic trough solar power technology in Nigeria.

## 2.0 REVIEW OF PARABOLIC THROUGH SOLAR COLLECTORS (PSTC).

The first experience with the PTC<sup>s</sup> goes back to 1870 (30), when a Swedish engineer, John Ericsson, design and construct a 3.5m<sup>2</sup> aperture collector that operates the small engine of 373-W called direct steam generation (DSG). Steam produces directly from the solar collector. The world attention on concentrating solar thermal technology was negligible for almost 60 years (Fernandez et al., 2010). But, in reaction to the oil crisis, global warming and greenhouse gas emission, international interest were drawn towards alternative energy sources to supplement fossil fuels (Thomas and Guven, 1993). PTC is an alternative means from CSP technology that can generate electricity and steam production. Many parabolic trough

solar thermal concentrators have been designed, manufactured, developed, constructed, installed and evaluated for research purpose, steam generation or for the electricity generation throughout the world, but a few will be discussed in this paper.

The most common and recent application of PTC for power generation is the nine commercial solar energy generating systems (SEGS) that has aperture of a black silvered mirror area of 2.32x10<sup>6</sup>m<sup>2</sup> and a receiver of 70mm diameter steel tube which have been developed, installed and in operation in Mojave desert Area of southern California that has a total installed capacity of 354MWe (Kalagirou, 2014).

Another important application of this type of collector for power generation was installed at Plataforma Solar de Almeria (PSA) in Southern Spain mainly for experimental purposes. The total installed capacity of the PTCs is equal to 1.2 MW (Almanza & Lentz, 1998). The receiver of a parabolic trough is linear. Usually, a tube is placed along the focal line to form an external surface receiver.

Kawira et al., (2012) reported the study of the potential of solar thermal concentrators for the steam produced from three parabolic trough solar concentrators (PTSC). The collector dimensions are: aperture width 1.2m, collector length 508m, and aperture area of 6.95m<sup>2</sup>, the receiver was made from a copper tube which carried water as the heat transfer fluid. Testing was carryout for each of the concentrators and the maximum temperature of the steam obtained was 248.3<sup>0</sup>C while the average temperature of the steam produced was 150<sup>0</sup>C. The result indicates that the concentrators can be used in providing electricity to the rural areas which are far away from the electricity transmission grid.

*Umar, et. al.* (2013) Conducted experiments for the performance evaluation of PTC under climatic condition of the Dundaye Area of the Usmanu Danfodiyo University Energy Research Centre Sokoto, Nigeria. The experimental performance evaluation was carryout using PTC constructed with an aperture area of 2.85m<sup>2</sup>, focal distance 1.82 and collector's lengths of 1.82m using locally available materials. Copper pipe of 28.5mm diameter was used as a receiver. Result obtained from this experimental study indicates that the maximum outlet temperature of 110<sup>0</sup> attained can fairly be acceptable. Similarly, the development of small scale concentrating PTC for drying purpose was reported in (Aamir et al., 2013). In this study, a concentrating PTC was developed using steel sheet reflector of aperture area of 2.9m<sup>2</sup> and a steel pipe receiver of 0.05m diameter connected to steel drying box with the aim to determine the performance of the PTC for drying fruits and consequently to study the thermal efficiency of the concentrating collector.

### **2.1 Method of Converting Solar Thermal Energy.**

The conversion of solar radiation into electric energy divided into two types: Thermodynamic cycle and photovoltaic system. The first type of converting solar energy is the thermal. This type of conversion also subdivided into two groups: the first group is the one operating at medium of about 500<sup>0</sup>C and that of higher temperatures of about 1000<sup>0</sup>C which is regarded as the most promising in the field of solar thermal technology for the generation of electricity. The other group is the one operating at medium of about 100<sup>0</sup>C and higher temperatures about 250<sup>0</sup>C and is very suitable for steam generation such as heating of water, cooking, drying, refrigeration etc. Concentrating solar power

(CSP) systems can be used to generate electricity from solar energy (Odeh& Abu-Muwalah).

The CSP systems, namely, power tower, linear Fresnel reflector, parabolic dish and parabolic trough solar concentrators are capable of producing power (Lertsatitthanakorn et al., 2014).

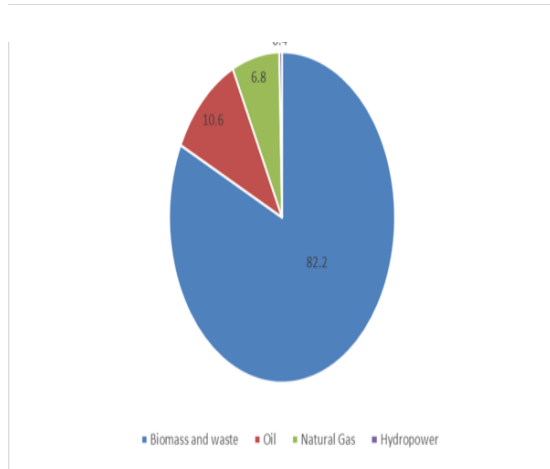
### **3.0 SOLAR ENERGY IN NIGERIA.**

Nigeria is located between longitude 8°E and latitude 10°N with two major seasons, wet and dry. The daily solar irradiation in Nigeria is around 15.4 to 22.6 MJ/m<sup>2</sup>/day (AbdulrahimAbdulbaqiToyin, 2014) while the total annual value of the solar radiation falls on the entire land area of Nigeria according to The National Energy Policy Document is an average of 6,372,613 PJ/year (≈1, 770 thousand TWh/year). This is about 120 thousand times the total electrical energy generated by the National Electric Power Authority for the whole country for the year 2002.

Nigeria is averagely blessed with almost 5-7.0hourssunshine per day and the annual, varying temperature of 28to 30<sup>0</sup>C.However, this value of solar irradiation is high on the average for the whole country throughout the year, but relatively bit higher in the northern Nigerian states and some few places in the eastern part of the country. However, Nigeria is considered as one of the wet climate countries where the annual rainfall is about 2250mm/year and the cloud cover is normally high throughout the rainy season. The rate of humidity in Nigeria varies from 80% to 90%. Therefore, by evaluating the solar radiation data in Nigeria, northern states and some places in the eastern part of the country can be considered as suitable places for CSP technology when compared to other places in Nigeria.

### 3.1 The Current Situation of Energy in Nigeria.

According to the International Energy Agency (IEA) statistics, the total Nigerian primary energy supply was 118,325 Kilotonne of Oil Equivalent (ktoe) - excluding electricity trade - in 2011. Figure 2 below shows that the biomass and waste highly dominated with 82.2%, while



**Figure: 2** Energy supply by source in 2011. (Adebayo, 2014).

Renewable energy sources which consist of hydropower, wind, solar etc. accounted for a small share of the energy supply. From Figure 2, hydropower carries only 0.4%, while the use of solar and wind and from the figure is at a minor level at present (Adebayo, 2014).

Electricity generation in Nigeria began in 1896, and the first thermal power station was built in 1920. The first hydro power station Kainji was built in 1968 which is a large centrally located power plant with grid extension (132KV line) to other locations. Thermal power electricity generation accounts almost 79% of the electricity generation in Nigeria, with about two-thirds of thermal power being derived from natural gas and the rest from oil leaving the hydroelectric power generation in Nigeria with only 21% (Ijeoma Vincent-Akpu, 2012).

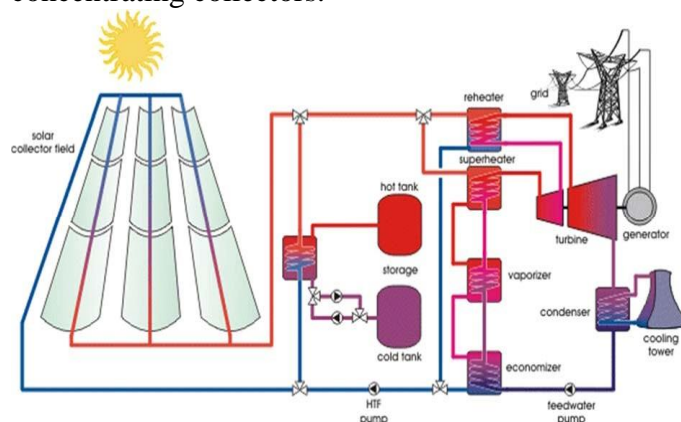
The energy consumption mix in Nigeria is highly dominated by fire wood (50.45 %) with fossil fuels (41.28%) and hydroelectricity (8 %) while coal, nuclear, geothermal, tidal, wind and solar energy are currently not part of Nigeria's energy mix, as they have either been neglected, not discovered or are currently at their early stage of development (Omokaro, 2008). The energy utilization pattern in Nigeria can be grouped into industry, transport, commercial, household and agricultural sectors. Fuel wood is used by over 60% of people living in the rural areas and 80% of Nigerians as an energy source. Renewable energy sources such solar thermal power, particularly parabolic trough solar concentrators (PSTC) need to be given serious attention if the country need to meet up with the emergent energy requirement.

### 3.2 Parabolic Trough Solar Concentrators for Electricity Generation.

The conversion of solar energy to mechanical down to electrical has experimentally conducted for many years, starting from 1872 when Mouchot presented concentrating collectors that can produce steam to heat engines and supply electricity known as steam powered printing press at the Paris exposition (Kalogirou, 2014). Historically, many types of these systems have been used for small scale applications such as water pumping, cooking, water heating etc. However, since 1975 there have been several large-scale power systems constructed and operated. Commercial plants of 30 and 80 MW electric (peak) generating capacity are currently in operation for more than a decade. This paper is concerned with generation of electricity from solar thermal energy based on the processes of solar concentrating collectors. The basic procedure for conversion of solar to

mechanical energy down to electrical is given schematically in Figure 3.

The main modules in the systems are the concentrating collectors, the heat working fluid, the power generation system, the natural gas auxiliary subsystem, and the controls. The process is that the solar energy is collected by concentrating collectors and then reflected back at the focal point of the collector which will be absorbed by the tube receiver to heat the thermal working fluid in the receiver system and then piped to the solar steam generator and superheated where it generates the steam then drives the turbine and generate electricity (Fernandez et al., 2010). The power generation system consists of a conventional Rankine cycle, reheat steam turbine with feedwater heaters deaerators, etc. The concentrators used are usually made of black-silvered, low-iron glass collectors which are shaped over parabolic forms, mirrors etc. Protective coatings are applied to the back of the silvered surface. The receivers can be conductive steel tubes, copper tubes, dawer tubes, aluminum tubes etc. The receiver's usually painted with certain selective coating sand then covered by a vacuum glass jacket in order to minimize heat losses. The tracking system that will rotate the concentrating collectors about horizontal north-south axes should be provided to the concentrating collectors.



**Fig: 3** Schematic of a concentrated trough solar power (<http://www.volker->

#### 4.0 CHALLENGES AND WAY FORWARD.

Some challenges and way forward towards installation of solar thermal power plant in Nigeria are as follows:

- The solar thermal power systems of generating electricity in Nigeria are not given much concern by the Nigerian government, despite the fact that there is an enormous amount of UN utilized solar energy radiation received every year. This challenge can be overcome within a short period of time if the Nigerian government is to give proper attention to research, development, commercialization and installation of solar equipment through good policy evolution.
- The installation of solar thermal power system is expensive when compared with other sources of energy. Therefore, it's very difficult for Nigerians to acquire this system of power generation. This is because the majority of the Nigerian population is living below poverty level. Though, there are many researches currently carrying out by scientist and engineers on how to reduce the cost of installation and maintenance of solar thermal power system
- Lack of awareness of how to make use of solar technology is another challenge facing the installation/use of solar power systems in Nigeria. More so, lack of solar thermal collectors in the local market for industrial and domestic applications such as, cooking, refrigeration, cooling, drying, hot-water generation, electricity generation, etc. Is also a great challenge to solar thermal systems in Nigeria, which parabolic trough solar concentrators

(PTC) included. For this challenge to be addressed, public enlightenment/awareness on how to use solar thermal technology in real life applications such as in industrial and domestic houses has to be created by the media.

- Lack of technical expertise locally for the installation and developing solar thermal power technology is also a challenge facing solar thermal technology which PTC included. Technical expertise that will repair the Equipment and component failure is very necessary, since the process of solar energy is very new in this part of the world, users get turned off if it does not perform up to the years of guarantee which the equipment is rated.

## 5.0 CONCLUSION.

Nigeria is located at the equatorial region with a higher solar energy potential that would enable the country to build large scale solar thermal power. Solar energy can be regarded as the best choice for future energy power generation, this is due to its low maintenance cost, independent of fuel source, environmentally friendly, and its contributions to lower carbon emissions. Solar thermal power method of generating electricity which parabolic trough solar concentrators (PSTC) included is considered as the matured in terms of electricity and steam generation. Therefore, the establishment/installation of solar thermal power technology particularly parabolic trough solar concentrators for power generation has to be given priority by the Nigerian government in order to supplement the thermal gas method of generating electricity in Nigeria which causes high emission of CO<sub>2</sub> to the environment.

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