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Carbondioxide Electricity generation Prospect in Nigeria

Samson A. Aasa... (Corresponding Author)
Department of Mechanical Engineering, Covenant University, Ota P.M.B 1023 Nigeria
Tel: 07039697998; E-mail. samson.aasa@covenantuniversity.edu.ng
Oluseyi O. Ajayi
Department of Mechanical Engineering, Covenant University, Ota P.M.B 1023
A. Stephen Adavbiele
Department of Mechanical Engineering, Ambrose Ali University Ekpoma, NigeriaCovenant University, Ota P.M.B 1023
Folorunso O. Akinbode
Department of Mechanical Engineering, Bells University of Technology Ota, Nigeria

Abstracts

The need to meet up with the present energy demand in Nigeria calls for urgent mediation. Using the carbon dioxide data obtained from IEA through the ministry of Environment in Nigeria and the knowledge of bottoming power generation; the ability of Carbon dioxides exhaust gas from the power plant is exploited. Qualitative amount of power is estimated from the nation industrial Carbon dioxide potential generation. The result shows that an optimum amount of 564.7MW of electricity per year could be estimated from this power source; this is equivalent to 10.8% of projected power required for year 2030. Therefore, using Carbon dioxide hybrid turbine a total amount of 1265MW of electricity could be spawned by year 2030. With these results it is concluded that Carbon dioxides powered turbine has better prospects in Nigeria energy needs.

1.0 Introduction

The electricity demand in Nigeria is far outstrips its supply, this has been attributed to a number of causes **Sambo, (2008)**. The little power available is epileptic in nature for few locations that is distributed. Its enormous needs in technological and socio-economic developments called for urgent attention; no substantial development could occur without it copiousness. Despites our huge resources and potential for power generation, this defect has made the development in the country to be so retrogressive.

The fact that the first electricity installed in Nigeria is over a century, coupled with our potentials of having a stable power supply is enough to possess a developed steady economics. More so, literature had it that the electricity came to Nigeria just after fifteen years it was introduced in England.

According to Sambo, (2008) various bodies were established in the process of regimenting this sector such blocs are; The Electricity Corporation of Nigeria (ECN) in 1950, Native Authorities and Nigeria Electricity Supply Company (NESCO), Niger Dams Authority (NDA), National Electric Power Authority (NEPA) and now Power Holding Company of Nigeria (PHCN), Energy Commission of Nigeria (ECN), with all the policies of these established bodies the power generation in the country is yet to be upright. In fact, **Osueke and Ezeh, (2011)** emphasized that instead for positive income elasticity demand Nigeria is having negative which show an in balance energy

Furthermore, a capacity of about 5,600MW power generating station was installed in Nigeria but less than 2000MW is generated as at 2001 and even now less than 2,600MW is available as compared to a load demands of 6,000MW and 120000MW in 2005 and 2030 respectively IAEA/ECN, **Osueke and Ezeh, (2011), IAEA/ECN, (2007)**. The mandate given by act 19 in 1989 gave strategic planning and co-ordination of national policies in the field of energy in all its ramifications. In all these power sources 31.3% and 68.3% Sambo, (2008) were for hydro and natural gas stations respectively and other occupied the remaining percentages. In spite of all these efforts the available power in the country now is less than 3000MW of electricity and the most of this power stations and other heavy duties industries give out huge emission of CO_2, a green house gas, GHG, which has great effects on the environmental conduciveness. **Sims et al (2007)** studied the various sources of green houses gases and found out that over 70% of energy generation emit CO_2 virtually in all parts of the world. Though most developed nations adopt different methods to control these like capturing methods but scientist still envisaged that greater measure is required to combat the release of this harmful gases. This means that all cost-effective means of reducing carbon emissions would need to be deployed in order to slow down the rate of increase of atmospheric concentrations **Stern,(2006)**.

Futher to this, Sambo, (2008) revealed that for Nigeria to reach this predicted power requirement we need to have an additional power of 11,686MW this is amounted to US$ 484.62 billion, which means investing US$ 80.77billion every five years within the period. One positive utilisation of this harmful gas is by optimum harnessing of all its potentials, that is, using it as working fluid for power generating plant, optima capture for enhancement of our crude oil and other fossil fuel sources and it utilisation for domestic and industrial purposes, such as equipment sterilization and product preservations. This study is therefore used to analyse the prospect of carbon-dioxide turbine and its energy contribution to our national grid using the available CO_2 emission potentials.

2.0 Materials and Methods

Using the available CO_2 data obtain from IEA and the knowledge of the considerable work done on supercritical carbon dioxide closed-cycle gas turbine that operates at supercritical temperatures of 550°C by **Yantovski, (1992)** , De Ruych, (1992), and Mathieu (1995). This could have large implications for bulk thermal generation of electricity, because the supercritical properties of carbon dioxide at above 500 °C and 20 MPa enable very high thermal efficiencies, approaching 45-47 percent. This thereby increase the electrical power produced per unit of fuel required by 40 percent or more. Given the volume of polluting fuels used in producing electricity, the environmental impact of cycle efficiency increases would be significant.

2.1 CO_2 Turbine

The CO_2 turbine is designed to be a bottoming Rankine cycle. That is the process by which the flue gases is captured, and the available clean carbon dioxides is then stored and compressed in reservior built with steam generator before it is used as working fluid. CO_2 turbine operates on a supercritical temperature of 500-550^{o}C and 20MPa the supercritical pressure.

Therefore its performance could be expressed as thermal efficiency, η_{th}, of rankine cycle (practical carnot cycle) which is given as

$$\eta_{th} = \frac{h_1 - h_2 + h_3 - h_4}{h_1 - h_4} \qquad (1)$$

Using the relationship between inlet and outlet heat absorption or rejection and the efficiency of the system,

the thermal efficiency is expessed as

$$\eta_{th} = 1 - \frac{T_1}{T_2} \qquad (2)$$

Each of the parameters are calculated using the usual diagram and or T-S diagram.

Working fluid consumption-Effeciency relation

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In estimating the amount of working fluid required for a desire power out put, the total power out of turbine obtained using different between turbine power and pumping power in the system is calculated using the assertion of first law of thermodynsmics.

Therefore,

Turbine power, P_t, = Product of turbine work,w_t , done and m_x mass flow rates

$$= m_x\, w_t = m_x\,(h_1\text{-}h_2) \qquad (3)$$

Where: m_x = mass flow rate

w_t = turbine work

the mass flow rate of the system, A, and the over all heat loss coefficient, U, with the temprature different, ΔT.

$$m_x = UA(T_3 - T_m) \qquad (4)$$

Where;

$$T_m = T_{out} + T_{in} \qquad (5)$$

Also, the pumping power,P_p is expressed as;

$$P_p = m_x w_p = m_x(h_3 - h_4) \qquad (6)$$

Where;

w_p = turbine work

Thus:

The total power out of turbinesP_T is expressed as

$$P_T = P_t - P_p \qquad (7)$$

But P_p that the pumping power is usually negligible therefore the total power out of turbine is expressed as

$$P_T = P_t \qquad (7a)$$

Hence, the quantity of working fluid consumption ratioWq that will be required is expressed as power out of turbine divided by effeciency of turbine given as **Zheng et al. (2002)**.

$$W_q = \frac{m_x}{P_T} \text{ x } 1000 \qquad (8)$$

Combine Eqs. (1) and (5), we can get

$$W_q \eta_{th} = 1 = \text{Constant} \qquad (9)$$

From the (9) we could deduce that the product of working fluid consumption ratio and eficiiency is a constant. Meaning an inverse relationship exists between them. Thus, with the increase of the hydrogen consumption ratio, the efficiency of the turbine will decrease.

3.0 Results and Discussion

From the evaluated equation for working fluid consumption, the amount of CO2 required for a paticular CO2 turbine plant could now be estimated and analysed its probable power generation using the available amount of CO_2 emission level in the country and optimum power that cold be tapped from this promising alternatives.

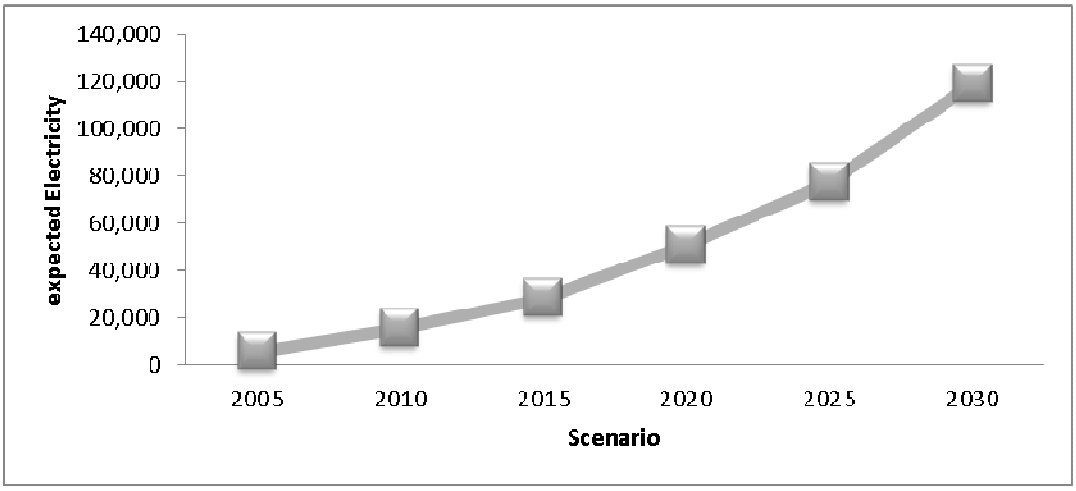

Figure 1: Pojected electricity Requirement (Source: Sambo, 2008).

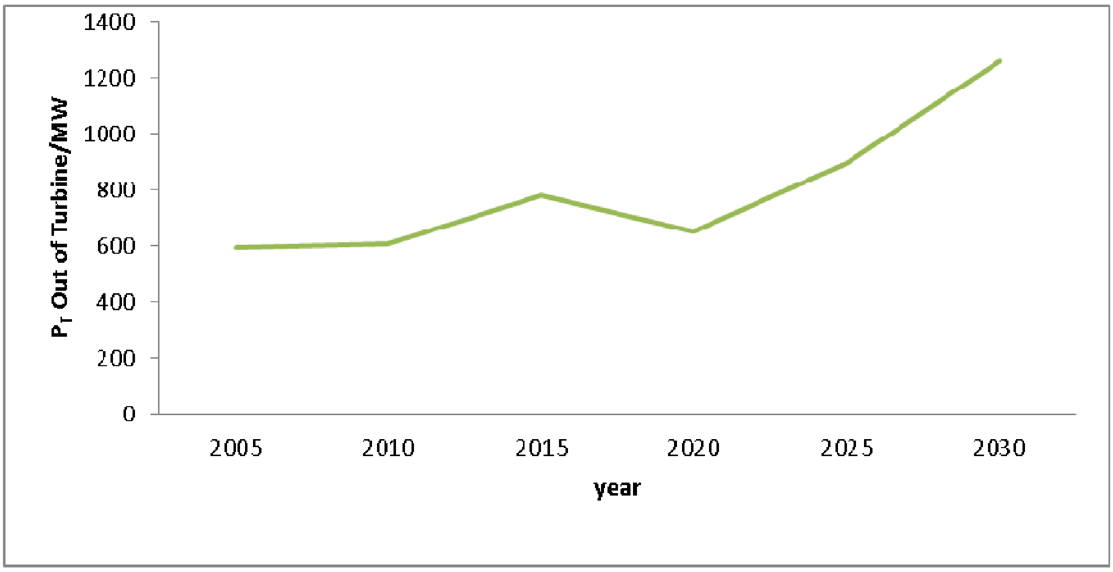

Figure 2: The plot of CO_2 power out of turbine and corresponding year.

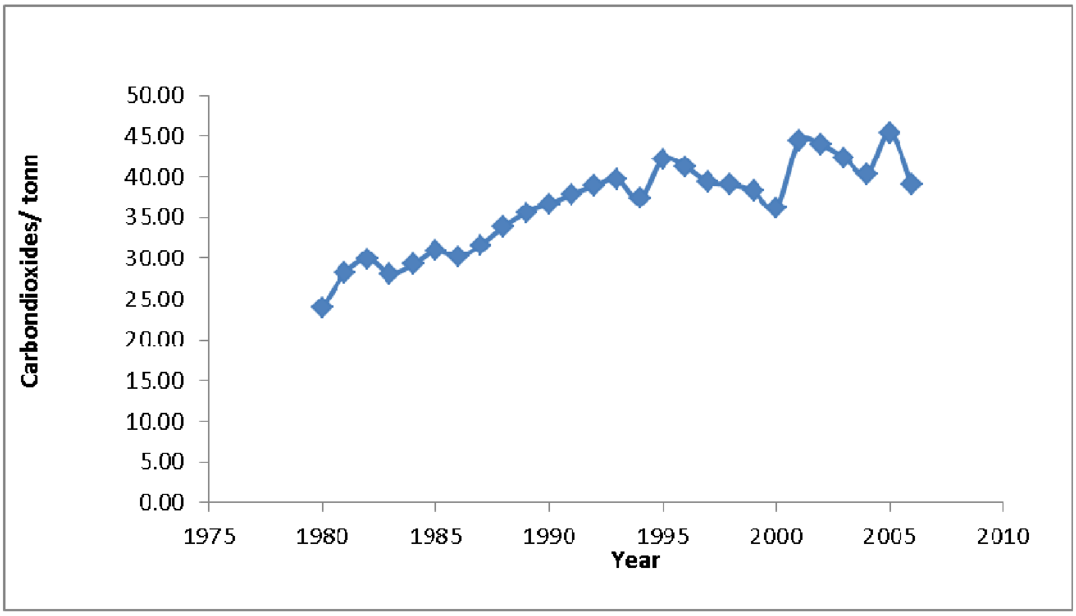

Figure 3: the relationship between carbondioxides emission rate per year.

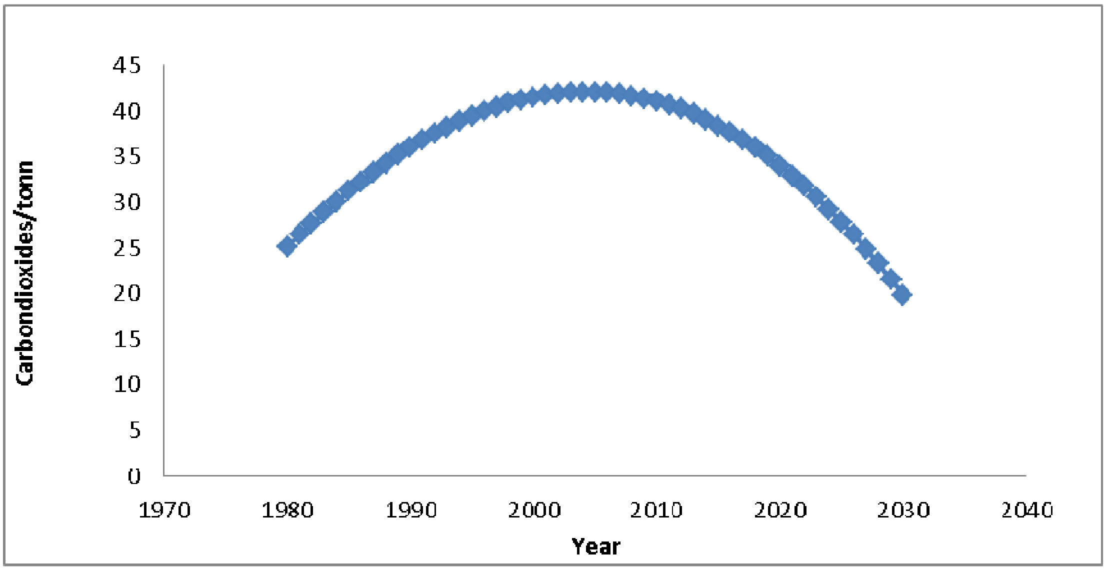

Figure 4: Projected CO_2 emission potential of nigeria per year (Source:IEA)

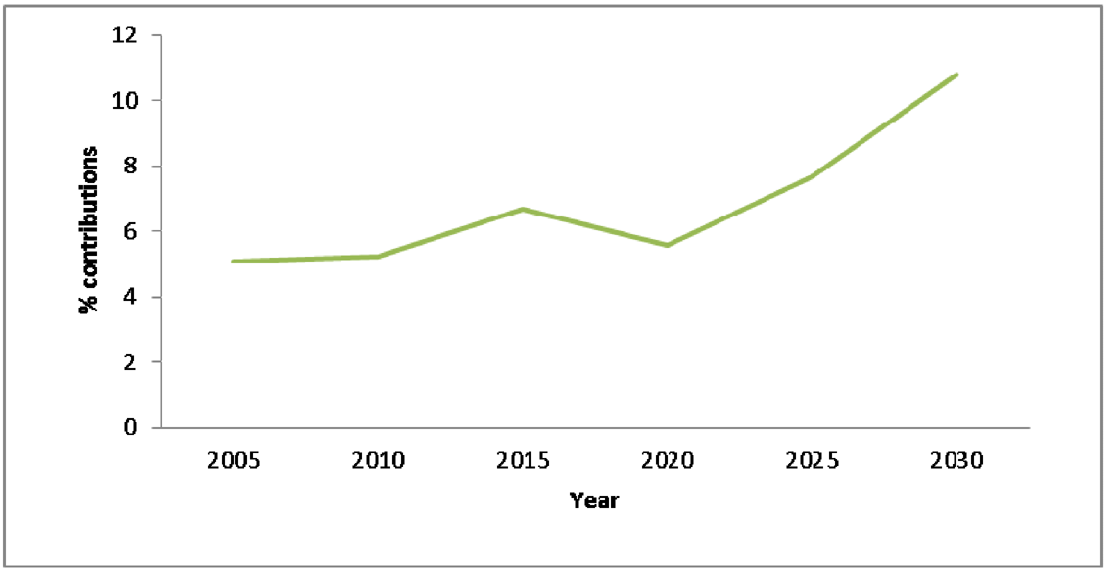

Figure 5: Percentage Power contribution per year.

From literature it has been established that the highest power that has been generated from CO_2 turbine is about 70MW using the earlier relation in equation 5 and 6 and the emmission potential of CO2 in the country. Figure 2 presents the graph of electrical power required for aperiod of 30 year from 2000 uptill 2030. This is a typical power projection that require about 11,686MW reinforcement per year said Sambo, (2008). Therefore using the amount of CO_2 emission potential in Nigeria a maximum of 45.5tonn of CO_2 could be generated from Nigeria industries, this is analysed by Figure 3. In figure 4, for period of twenty six years, 1980-2006 highest emission was 2005, this estimation according to the research is from industrial sector alone. These emission rates is then used to compute the acheivable amount of power out of turbine using this supercritical form of CO_2. Further more, in Figure 6 it could be seen that the energy projection by the CO_2 power is enomous reaching the maximum generation of 1260.12MWof electricity by year 2030 and a minimum generation of 593.17MW by 2005. Estimating the percentage contributions of this energy source to required megawatt in our national grids, a maximum of 10.78% is expected by year 2030; this gives an average of 6.68% contributions for year consider.

Hence, using the evaluated equation of working fluid consumption and the power out of turbine and compare this achievable megawatt of electricity with power require for the correspounding year about 10.78% contribution could be made by this energy source by 2030, thereby optimise the total national grids required for stable power consumptions.

4.0 Conclusion

The waste carbondioxide emission from heavy duty indurstries which happened to be the most common harmful green house gases,GHG. has been successfully used for the power generation. Using the supercritical steam generator, the temperature of the waste CO_2 gases raised from about 270^{o}C (CO_2 temperature out of turbine) to about 500-550^{o}C (supercritical temperature of CO_2) could be used to generate substantial electrical power out of turbine. The given emission potential from IEA is then used to estimate power that could be generated using this energy source and compared with the predicted amount of power required for socio-economics and Technological development uptill 2030. Finally, an average of 10.78% of electricity is achievable using this as a power source with an optimising efficiency of 45-47%. It is therefore recommended that a bottoming CO_2 rankine cycle should be made available for all heavy duties industrials setup as this will alleviate their efficiency, provide additional energy source and serves as a measured and contol for green house gases emission. Moreover, reforming with CO2-recycle appreciably and diminishes the discharge of this gas to the atmosphere. This further confirm its possible advantages compared to water as higher energy yield resulting from its lower viscosity, better chemical interaction, CO_2 storage through fluid loss and higher temperature limit.

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