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Use of Solar Technology as a Viable Option for Zero GHG Emission and Abatement of the Earth's Environmental Pollution

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Abstract

In this research work, the various energy resources available for electric power generation with emphasis on how clean these energy resources are in relation to the environment are discussed. The theoretical method is used to compute the Greenhouse Gas (GHG) Emission from 3 types of non- renewable energy resources namely; petrol generators, diesel generators and coal power plants. In carrying out the computation, the default GHG emission factors are used to compute the magnitude of CO_2, N_2O and CH_4 emissions from these stationary combustion sources. The total CO_2 Equivalent emission (CO_{2T}) from these power sources are also computed. Results obtained showed that CO_{2T} varied from 21.1 to 79.24 pounds/8 hours for petrol generators and 291.63 to 582.65 pounds per 8 hours for diesel generators. Total CO_2 Equivalent emission from coal power plants averaged at 1946.61 Pounds of CO_{2T}/MWh and is about 94.66% above the regulatory limit of 1000 Pounds of CO_{2T}/MWh. These sources of electricity generation with high total CO_2 Equivalent emission contribute to global warming and when compared to solar electricity technology with zero CO_{2T}, it can be inferred that solar electricity technology is a viable option for abatement of environmental pollution.

Keywords

Solar Technology, GHG Emission, Abatement, Pollution

1. Introduction

There are lots of energy resources available for energy generation (particularly electricity generation). According to the United States Energy and Information Administration, energy sources are classified into renewable and non renewable sources [1]. Non renewable energy sources do not form or replenish in a short period of time whereas renewable energy is energy that comes from sources that replenish themselves as they are being used.

The four common non-renewable sources include crude oil, natural gas, coal and uranium. The non- renewable sources can further be classified into fossil and non-fossil fuels. Fossil fuels originated from the remains of plants and animals buried some million years back and include coal, crude oil and natural gas. Uranium ore is a source of non-renewable energy that is non-fossil in nature and is a solid mineral that is naturally deposited in the subsurface of the Earth.

Renewable energy sources when compared with the non-renewable sources are more environment- friendly as they emit little or no green house gases or pollutants. They are referred to as clean energy and are ecosystem-friendly. Some common renewable energy sources include hydroelectric energy, wind energy, tidal energy, solar energy, geothermal energy and biomass energy.

Hydro-energy is the leading renewable source of energy for electricity generation globally, supplying 71% of all electricity from renewable sources [2]. It is the most common form of energy in use worldwide. It is generated from high speed flowing waters mostly through the building of dams and installation of turbines. This requires high initial cost to set it up but in the long run, it is more cost-effective as it generates continuous electricity provided there is continuous high speed flow of water. It is a clean energy source although in the course of construction of the dam, the ecosystem is destroyed. Also, its collapse can lead to devastating flooding in the environment.

Wind energy is another form of clean energy whereby electricity is produced through the use of natural wind in driving a turbine. This source of energy generation is uncommon as it can only be built where we have strong and long-lasting wind source.

Tidal energy is clean energy and anti-global warming. Its usage can only be adopted in places with high tidal range. Its usage causes permanent flooding of wetlands.

Geothermal energy can be utilized in electricity generation as heat generated in places with volcanic eruption can be seized to produce steam by passing cold water through rock and then back to the surface with the aim of using the steam produced to propel a turbine for electricity generation. This, however, can only be obtained in places with active volcanic activities like New Zealand, Kenya, Iceland, etc.

Biomass energy generation is another important source of electricity generation. This form of energy is got from organic matter such as plants' and animals' refuse. Animals' and plants' wastes are utilized in the production of biogas capable of being used as cooking gas, car fuel and for electricity generation. This form of energy can be used in any part of the world because of its universal availability but is not completely environment-friendly as it emits methane which is a green house gas.

Solar energy is energy generated from the sun. It has a very wide range of applications and its flexibility makes its usage available to a wide social range in terms of size and cost. Apart from its usage as a solar dryer, solar water heater and solar cooker, it can be utilized for electricity generation. Radiation from the sun is ubiquitous and if properly channeled and converted can generate electricity. It is the cleanest form of energy; it is pollution free, noise free, does not alter the vegetation and other forms of the ecosystem, does not enhance the background radiation of the environment and can be tapped and harnessed through the use of appropriate tools.

Generation of electricity from solar energy involves trapping radiant energy from the sun through the use photovoltaic cell (PV Cells) to excite electrons from the cells so as to generate electric current [3]. Since electrons excited from a single PV-cell may not be strong enough to generate the required electrical energy, PV-cells are usually arranged in modules which are an assemblage of electrically interconnected PV-cells for the purpose of generating reasonable current and protecting the PV-cells from environmental damage. The power supply output from the assemblage of the modules is typically in the range of 100 to 365 Watts [4]. In order to generate electricity, a typical photovoltaic system consists of an array of PV-modules, an inverter, a battery pack for storage and wires for interconnections.

Research results reported in the literature show that the use of solar energy technology/PV-cells for electricity generation is, in addition to other advantages, far more environment-friendly when compared with fossil fuel generators and other sources of energy production. According to Sharma *et al*. [5], solar energy conversion to electrical energy takes place silently and instantly with no environmental or atmospheric pollution. There are no mechanical parts to wear out relative to other sources of electricity generation and may not require maintenance after the initial cost of installation. No fuel is required to run the system. PV-cells are often used to generate electricity in remote areas far away from national grids and power lines. Solar electricity can be used for small appliances especially in areas where the normal electricity production is below capacity as it is the case in Nigeria and some other developing countries. Its modular nature makes it viable for use by both the rich and the middle class. Another great advantage of solar energy is that it is abundantly available; its availability on the Earth's surface is about 10,000 times larger than the total energy consumption of mankind [6].

United States Energy and Information Administration [1] reports that the common anthropogenic sources of environmental pollution are combustion of fuel and diesel from fuel and diesel power generators. These power plants represent the source of the largest concentration of GHG relative to other domestic sources in the United States [7]. According to [8, 9, 10], the current United States of America's CO_2 emission averages to about 1,768 pounds/MWh of electricity generated and is greater than the regulatory limit of 1,000 pounds of CO_2 emission /MWh of electricity generated, which is due to combustion of fossil fuels in power plants and generators. These greenhouse gases trap heat and make the planet warmer. They also deplete the ozone layer. This throws up a deep concern and is a major reason for which the Earth must be protected.

Galetovic and Munoz have shown that conventional combustion of coal in coal plants to generate heat which is used to boil water to produce high pressure steam for the purpose of electricity generation leads to generation of some pollutants (N_2O, CH_4, CO_2, etc) which are released into the atmosphere as GHGs and they contribute to global warming and climate change [11].

Chmielewski [12], in his paper, further emphasizes the environmental impacts of fossil fuels combustion. The paper reports that fossil fuels are the major source of heat and electrical energy but contain, besides the major constituents (carbon, hydrogen and oxygen), other materials including metals, sulphur, and nitrogen compounds. During the combustion process, different pollutants like fly ash, sulphur oxides, nitrogen oxides and volatile organic compounds are emitted. Fly ash contains trace elements (heay metals). These pollutants are present in the atmosphere in such conditions that they can affect man and his environment. Air pollution, caused by particulate matter and other pollutants, not only directly affects the environment but by contamination of water and soil leads to their degradation. Wet and dry deposition of inorganic pollutants leads to acidification of the environment. These phenomena affect the health of people, increase corrosion, destroy cultivated soil and forests, and contribute to global greenhouse effect.

It has also been shown that fossil fuels are the largest GHG emitters in the world contributing three-quarter (3/4) of all carbon, methane and other GHG emissions [13]. Burning coal, petroleum and other fossil fuels at extremely high temperature is the primary means by which electricity is produced but also leads to heavy concentration of pollutants in the air and water. Statistics by the Energy Information Administration show that 3.2 billion tons of additional CO_2 is emitted annually from the combustion of fossil fuels and 2.5 million metric tons of carbon is produced by power plants. In this paper, it is reported that though much has been written about environmental problems with nuclear power, environmental problems arising from burning of fossil fuels – coal, oil and gas – has been found to exceed those of any other human activity. The most significant impacts are the GHG effect which is changing the Earth's climate, acid rain which is destroying plants/forests and killing fish, and air pollution which is greatly affecting human health.

Frederica also reveals in his paper [14] that fossil fuels combustion is the world's most significant threat to children's health and future and the major contributor to global inequality and environmental injustice. The emissions include a myriad of toxic air pollutants and carbon dioxide which is the most human-produced climate-altering greenhouse gas. Synergies between air pollution and climate change can magnify the harm to children. Impacts include impairment of cognitive and behavioural development, respiratory illness, and other chronic diseases, all of which may be seeded in the uterus and affect health and functioning immediately and over the course of life. By impairing children's health, ability to learn and potential to contribute to society, pollution and climate change cause children to become less resilient and the communities they live in become less equitable. The developing fetus and young child are disproportionately affected by these exposures because of their immature defence mechanisms and rapid development. Federica finally shows that both those living in the low-income, middle-income, and high-income countries are experiencing these impacts of fossil fuels-related pollution, climate change and resultant widening inequality and environmental injustice.

Bjorn et al. [15] focused their study of greenhouse gases emission on its associated socio-economic and environmental impacts. They report that a reduction in the overall petroleum production is not anticipated over the next two decades, despite decline in the currently existing fields. This is because according to estimates by the International Energy Agency (IEA), an additional 1.2 to 1.3 trillion barrels are still available for consumption. Analysis of the associated socio-economic effect in the paper reveals that particularly those states rich in resources are affected by strongly negative socio-economic impacts in regards to child mortality, life expectancy, and average income. In the environmental impact analysis, the study reveals that fossil fuels have massive negative environmental effects on human beings and natural assets of air, soil, and water, etc. This conclusion on the massive negative effects of burning fossil fuels on human health is also supported by the study carried out by the Union of Concerned Scientists on '' a Healthy Planet and Safer World'' [16]

Apart from GHG emission from the power plants which forms the basis of the current study, substances emitted from power generator exhaust pipes have the capability of elevating the background ionizing radiation of its immediate environment. Also, the use of fossil fuel generators in electricity generation enhances the level of background noise within its immediate environment. Enyinna carried out studies on background noise and radiation levels perturbation within Rumuodara Residential Area, Port Harcourt, Nigeria [17]. A mean exposure rate of 13.8μR/hr was recorded whereas the area mean background exposure rate was 11.6 μR/hr. This result indicated an area mean deviation of 18.9% from normal background radiation exposure. Also, the average noise level measured during the active period (when the generators were functional) ranged from 61.0 to 82.0 dB (A) with a mean noise level of 73.2 dB (A) whereas the area mean background noise level recorded was 48.5 dB (A). This result indicated an area mean deviation of 50.9% from normal background noise level.

Also solar energy conversion to electricity when compared to other sources of electrical energy production such as conversion of geothermal energy to electricity shows that though geothermal energy can be utilized in electricity generation as heat generated in places with volcanic eruption can be seized to produce steam to propel turbines, this form of energy generation is not entirely clean as the water-volcanic interactions lead to emission of carbon dioxide- a green house gas. Water flow through underground geothermal reservoirs can pick up trace amounts of toxic substances such as mercury, arsenic and selenium and may expose same to the environment if not properly managed [18].

This study is intended to compute the magnitude of green house gases (GHG) emitted by some electrical energy generation sources (outside the solar energy source) and compare these results with that of solar energy source to see the extent of abatement of the Earth's environmental pollution through the use of solar energy technology for electricity generation.

2. Method of Computation of GHG Emissions from Electric Power Generators

Emission of CO_2 from fuel combustions during electric power generation is dependent on the amount of carbon in the fuel which is specific to type and grade of fuel. The quantity of CO_2 emitted during this process can be measured through Continuous Measurement System (CMS) or computed theoretically using default emission factors.

In this study, the magnitude of GHG emission from stationary combustion sources that generate electricity is computed using theoretical methods.

In order to compute the magnitude of CO_2 emission, the following formula [19] is used:

$$\mathrm{GCO_2} = \mathrm{F_q} \times \mathrm{F_{cc}} \times \mathrm{RMW} \quad (1)$$

$where\ F_q$= quantity of consumed fuel (in litres), F_{cc} = Fuel carbon content (0.72 kg/litre of diesel and 0.652 kg/litre of petrol), RMW = Ratio of Molecular Weight of CO_2 to carbon = 3.67.

In order to compute the magnitude of N_2O or CH_4 emission, the following formula [19] is used:

$$\mathrm{G_i} = \mathrm{F_q} \times \mathrm{EF_i} \quad (2)$$

where G_i= Quantity of N_2O or CH_4 emitted, EF_i = Emission factor for N_2O or CH_4.

Table 1 shows the emission factors for N_2O and CH_4 for diesel and petrol.

In order to compute the GCO_2 or G_i for coal-fired plants, the following formula [19] is used:

$$\mathrm{GCO_2}\ \text{or} G_i = \mathrm{F_q} \times \mathrm{HHV} \times \mathrm{EF_H} \quad (3)$$

where F_q= quantity of consumed fuel (in metric tonnes), HHV = Average higher heating value for various forms of coal combustion and EF_H = Average emission factor for HHV. Table 1 shows the emission factors for N_2o and CH_4, while Table 2 shows the HHV and EF_H for various types of coal used as fuel for electricity generation.

Table 1. *Emission Factors for N_2O and CH_4 for Diesel and Petrol [19].*

Type of Fuel	CH_4 Emission Factor (kg/l)	N_2O Emission Factor (kg/l)
Diesel	0.00010	0.00002
Petrol	0.00011	0.00002

Table 2. *HHV and EF_H for Various Types of Coal Used as Fuel for Electricity Generation [19].*

Types of Coal	Heat Content in mmBtu/T (HHV)	Emission Factors		
		Kg of CO_2/mmBtu	g of CH_4/mmBtu	g of N_2O/mmBtu
Anthracite	25.09	103.69	11	1.6
Bituminous	24.93	93.28	11	1.6
Sub- Bituminous	17.25	97.17	11	1.6
Lignite	14.21	97.72	11	1.6
Average	20.37	97.97	11	1.6

In order to have a uniform assessment of the impact of the three GHGs considered in this research, G_i to CO_2 equivalent emission ($\mathrm{CO_2eqv_i}$) is converted using the formula given, by the United States Environmental Protection Agency, as:

$$\mathrm{CO_2eqv_i} = \mathrm{G_i} \times \mathrm{GWP_i} \quad (4)$$

where GWP_i = Global Warming Potential for N_2O =298 or CH_4 = 25 [19]

The total CO_2 Equivalent emission (CO_{2T}) from stationary combustion sources is computed using:

$$\mathrm{CO_{2T}} = \mathrm{GCO_2} + \mathrm{CO_2eqv_i} \quad (5)$$

3. Results and Discussions

3.1. Presentation of Results of Total CO_2 Emission from Diesel and Petrol Generators

The results of GHG emissions from diesel and petrol generators are presented in Table 3. The results show that the computed CO_2 emission per day varies from 132.12 kg to 262.24 kg and 9.57 kg to 35.89 kg respectively for the diesel and petrol generators considered in this research.

The results show that the computed N_2O emission per day varies from 0.001 kg to 0.001 kg and 0.00008 kg to 0.0003kg respectively for the diesel and petrol generators. Also, the results show that the computed CH_4 emission per day varies from 0.0055 kg to 0.011 kg and 0.0008 kg to 0.0015 kg respectively for the diesel and petrol generators.

The results of total CO_2 equivalent emission (CO_{2T}) per day from diesel and petrol generators are presented in Table 4. The CO_{2T} varies from 291.63 pounds to 582.65 pounds and 21.1 pounds to 79.24 pounds respectively for the diesel and petrol generators. Although these results are relatively low when compared to regulatory limit of 1000 Pounds of CO_{2T}/MWh of electricity generated through combustion of coal [20], the emission of CO_2 into the atmosphere contributes to build-up of greenhouse gases which contribute to global warming. Continuous accumulation of GHGs in the atmosphere can lead to climate change as a result of global warming and this has been attributed to combustion of fossil fuels like coal and petroleum products [8, 9, 12-15].

Table 3. *GHG Emissions from Diesel and Petrol Generators.*

Power Rating of Generator	Volume of Diesel (litres/ day)	Volume of Petrol (litres/ day)	Kg of CO_2 Emitted	Kg of N_2O Emitted	Kg of CH_4 Emitted
200 kWh	100	___	264.24	0.0020	0.011
80 kWh	50	___	132.12	0.0010	0.0055
4 kWh	___	15	35.89	0.0003	0.0015

Power Rating of Generator	Volume of Diesel (litres/ day)	Volume of Petrol (litres/ day)	Kg of CO_2 Emitted	Kg of N_2O Emitted	Kg of CH_4 Emitted
2.4 kWh	___	10	23.93	0.0002	0.001
1.44 kWh	___	8	19.14	0.00016	0.0008
0.76 kWh	___	5	11.96	0.0001	0.0005
0.52 kWh	___	4	9.57	0.00008	0.0004

Table 4. *Total CO_2 Equivalent Emission (CO_{2T}) from Diesel and Petrol Generators.*

Power Rating of Generator	Kg of CO_2 Emitted	Kg of CO_2eqv Emitted for N_2O	Kg of CO_2eqv Emitted for CH_4	Kg of CO_{2T}	Pounds of CO_{2T}
200 kWh	264.24	0.5960	0.275	264.84	582.65
80 kWh	132.12	0.2980	0.138	132.56	291.63
4 kWh	35.89	0.0894	0.038	36.02	79.24
2.4 kWh	23.93	0.0596	0.025	24.01	52.82
1.44 kWh	19.14	0.0477	0.020	19.21	42.26
0.76 kWh	11.96	0.0298	0.013	12.00	26.4
0.52 kWh	9.57	0.0238	0.010	9.59	21.1

3.2. Presentation of Results of GHG Emission from Coal Power Plants

The results of GHG emissions from coal power plants are presented in Table 5. The results show that the computed CO_2 emission from the power plants varies from 1053702.62 kg to 3090861.02 kg. The results show that the computed N_2O emission varies from 17.21 kg to 50.48 kg and the computed CH_4 emission varies from 118.31 kg to 347.04 kg respectively for the coal power plants. Also, the results of total CO_2 Equivalent Emission from coal power plants are presented in Table 6. These results range from 2335935.69 Pounds of CO_2 to 6852076.13 Pounds of CO_2 with an average emission of 1946.61 Pounds of CO_2 per MWh. From Table 7, the average emission of 1946.61 Pounds of CO_2 per MWh exceeds the regulatory limit of 1000 Pounds of CO_{2T}/MWh [20] by 94.66% and is dangerous to the environment due to the negative impact of CO_2 on global warming. Among the heat-trapping gases in the atmosphere, CO_2 has the greatest negative impact as it causes irreversible climate change if allowed to accumulate.

CO_2 relative to other GHGs remain in the atmosphere for a very long time (about 10,000 years) and any emission today will affect our future generation in terms of global warming. Table 7 also shows that solar electricity technology has zero GHG emission and therefore environment-friendly.

Table 5. *GHG Emissions from Coal Power Plants.*

Location of Coal Power Plant	Power Rating of Generator	Quantity of Coal Consumed in Metric Tonnes	Kg of CO_2 Emitted	Kg of N_2O Emitted	Kg of CH_4 Emitted
*Itobe Plant, Kogi State, Nigeria	1200 MWh	528.0	1053702.62	17.21	118.31
**Robert W. Scherer Plant, Juliet in Georgia	3520 MWh	1548.4	3090861.02	50.48	347.04
**Gibson Plant in Michigan	3345 MWh	1471.8	2937196.05	47.97	329.79
**Bowen Plant in Georgia	3200 MWh	1408.0	2809873.65	45.89	315.49

(* proposed coal Plant: Source of location and Power Rating [**21**]; ** Source of location and Power Rating [17].
N/B: F_q was computed on assumption that an average of 44 Tonnes (34 – 53.8 Tonnes) of coal are consumed/100 MWh of electricity [11].

Table 6. *Total CO_2 Equivalent Emission (CO_{2T}) from Coal Power Plants.*

Location of Coal Power Plant	Kg of CO_2 Emitted	Kg of CO_2eqv Emitted for N_2O	Kg of CO_2eqv Emitted for CH_4	Kg of CO_{2T}	Pounds of CO_{2T}	Pounds of CO_{2T}/MWh
*Itobe Plant, Kogi State, Nigeria	1053702.62	5128.58	2957.75	1061788.95	2335935.69	1946.61
**Robert W. Scherer Plant, Juliet in Georgia	3090861.02	15043.04	8676.00	3114580.06	6852076.13	1946.61
**Gibson Plant in Michigan	2937196.05	14295.06	8244.75	2959735.86	6511418.89	1946.61
**Bowen Plant in Georgia	2809873.65	13675.22	7887.25	2831436.12	6229159.46	1946.61

Table 7. *Comparison between Computed Total CO_2 Equivalent Emission (CO_{2T}), Total CO_2 Equivalent Emission from Solar Electricity Power Source and Regulatory Limit of Coal Emission during Power Generation.*

Location of Coal Power Plant	Power Rating	Pounds of CO_{2T}/MWh	Solar Electricity CO_{2T}/MWh	Regulatory Limit (Pounds of CO_{2T}/MWh)	Remark
*Itobe Plant, Kogi State, Nigeria	1200 MWh	1946.61	0	1000	Limit Exceeded by 94.66%
**Robert W. Scherer Plant, Juliet in Georgia	3520 MWh	1946.61	0	1000	Limit Exceeded by 94.66%
**Gibson Plant in Michigan	3345 MWh	1946.61	0	1000	Limit Exceeded by 94.66%
**Bowen Plant in Georgia	3200 MWh	1946.61	0	1000	Limit Exceeded by 94.66%

4. Conclusion

Computation of the magnitude of greenhouse gas emissions from petrol, diesel and coal power plants has been successfully carried out. From the results obtained, it can be inferred that combustion of fossil fuels for power generation is an unclean method of power generation with its attendant hazardous impact on the environment as the gases emitted from such combustion of stationary power sources aid in heating up the earth's surface.

The use of solar technology (PV- panels/plants) for electric power generation remains the best in terms of clean energy generation as it has zero GHG emission. Solar energy is abundantly available. Its availability on the Earth's surface is about 10,000 times larger than the total energy consumption of mankind. It is cost-effective in the long run within its life shelf as it has no mechanical parts to be repaired or replaced. It is also modular in nature and one can install the size one can afford based on one's financial capability. Indeed, solar electricity generation is good and serves as a viable option for zero GHG emission and the Earth's environmental sustainability.

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