Thermal Generation and Its Environmental Implications – A Lesson for Ghana

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ABSTRACT

Environmental issues are a major concern for any growing economy, especially amidst growing calls for efficient environmental management systems globally. On the other hand, electricity access is a crucial subject in developing countries, Ghana not excluded. With current posture towards increasing its thermal generation component due to unreliable hydro power supply, there is a high tendency of rising air pollution levels in Ghanaas thermal power is generated from fossil fuels.

Access to a clean, efficient and affordable energy source is an essential for any growing economy. Governments which are committed to achieving sustainable development for their countries require an understanding of the complex interplay between the systems of energy delivery and sustainable environments conducive for human habitation. As Ghana intends to rely more on thermal power within the short to medium term, there are implications for an integrated energy planning system that inculcates environmental sustainability. This requires the development and implementation of sound policies and legal frameworks.

This paper assesses the implications of thermal generation on the environment in Ghana, firstly by drawing a comparative analysis of carbon emissions from thermal generation in some selected developing countries. Secondly, the paper compares secondary sourced data on carbon emission levels with the Occupational Health and Safety Administration (OSHA) standards. Finally, it draws useful lessons for Ghana based on the experience of other countries. The analysis in this paper shows that Ghana's trend of CO_2 emissions from electricity and heat generation far exceeds OSHA's permissible exposure limit and can be detrimental for human health if this trend continues. The paper recommends that Ghana enacts a Clean Air Act to regulate air emissions andpromote high air quality standards. It further recommends that the country diversifies its power generation mix with renewable energy sources.

Keywords:CO_2, electricity, emission, thermal

Contents

1. BACKGROUND

Society has so evolved that industrialization has becomethe bedrock of socio-economicgrowth. With industrialization comes the reliance on power,on which the wheel of development is so driven. As the advancement of society is power-driven, from manufacturing, communication, transportation, and many more; it is not surprising that global electricity consumption as of 2014stood at 23 million GWh[1].Over decades, humanity has explored different forms of power generation, from both the non-renewable sources and the renewable. The renewables include hydro, solar, tidal and wind whilst the fossil fuels like crude oil, natural gas and coal are among the non-renewable.Before the advancement of technology to promote the use of renewable energy sources like solar for power generation, fossil fuels were more preferred. What informed this preference was primarily because of the huge capital investments associated with the deployment of renewable energy sources.

Fossil fuels such as coal, oil and gas are usually used for thermal generation through theprocess ofcombustion by internal combustion engines and turbines.Fossil fuel power plants cause environmental problems including air pollution, noise, climatic and visual impacts from cooling towers, solid waste disposal and ash disposal (from coal). Fossil fuels are rich in carbon and once combusted, emit amounts of carbon compounds into the atmosphere.

It is estimated that 40% of all energy-related CO_2 emissions is from electricity generation[2].Carbon emissions have significant environmental implications as they affect air quality, posing risks to human health as long exposures result in respiratory and cardiovascular diseases.Carbon emissions also contributes to climate change by releasing absorbed heat from the sun into the atmosphere.The World Health Organization (WHO) estimates that between 2030 and 2050, climate change is expected to cause approximately 250,000 [3] additional deaths yearly, apart from malnutrition, malaria, diarrhoea andheat stress. Carbon emissions from the power sector increases with increase in electricity demand (see Figure 1).Historically, as shown in Figure 1, there has been an increasing trend of carbon emissions from the power sector parallel toelectricity demand from 1990 to 2014. As of 2014, China's carbon emissions more than doubled compared to 2000[4].

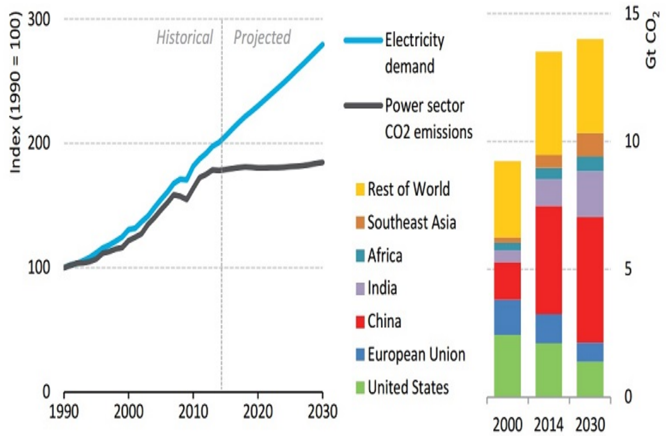

Figure 1: Historical and Projected trend of increasing carbon emissions and electricity demand

Source: International Energy Agency, 2016

Analysis from the International Energy Agency (IEA) shows that with appropriate investment, world CO_2 emissions from the power sector would remain broadly flat through to 2030 even as electricity demand increases by more than 40%. The analysis finds that full implementation of the Intended Nationally Determined Contributions (INDC) international agreement will require the energy sector to invest USD 13.5 trillion in energy efficiency and low-carbon technologies from 2015 to 2030, representing almost 40% of total energy sector investment [4].

Although may be quantified as relatively small compared to the other regions, Africa's emission of carbon compounds are mounting up and is by 2030 expected to be twice what it was in 2014 (see Figure 1). This is a significant development for Africa as the continent's rise as a major hub for industrialization provides new opportunities for power infrastructure expansion. One such opportunity within the region is seen with Ghana, which in recent times is increasing its installed capacity to meet increasing power demand. To this end, Ghana intends to increase its thermal component of the generation mix, and has installedabout 500MW [5] of thermal power barges to the already existing 1,562 MW of installed thermal capacity (see Tables 1 and 2). There is also a growing public concern that Ghana may be considering the deployment of coal for power generation[6].The deployment of these fossil fuel fired plants will come with the emission of considerable amounts of air pollutants.

With this in mind, this paper sets out to identify the environmental implications of thermal generation in Ghana especially at a time where a coal option is being critically considered. Already, Ghana's environment is fraught with issues of pollution and degradation which makes it highly vulnerable to any furtherpollution associated with thermal generation. Most research works on environmental impacts of thermal generation has been centered on Europe and Asia. Works done in Africa especially in East Africa have focused on the impacts of climate change on the continent with no specific link to thermal generation. This paper fills a gap in the environmental discussion by focusing on the environmental implication of thermal generation, specifically in Ghana within the African continent. This it does by analyzing the effect of thermal generation on air quality, comparing CO2 emission levels with the OSHA standards. It also considers the policy implications for Ghana's power sector and proposes mitigating measures to avoid irreversible environmental burdens for posterity.

1.1. Objectives of the research paper

The following are the objectives of this paper:

- ✓ Identify the environmental implications of thermal generation comparing CO_2 emissions in Ghana with the Occupational Health and Safety Administration (OSHA) standards for carbon emissions
- ✓ Identify how Ghana can avoid further environmental degradation from the lessons taken from other countries' experiences
- ✓ Identify the policy implications of thermal generation in Ghana

1.2. Overview of power generation in Ghana

Until the late 1990s, hydropower from the Akosombo dam was the solesource of Ghana's electricity generation.The initiative to go thermal begun when Ghana faced a severe power crisis in the early 1980s due to low rainfall in the Akosombo dam catchment. Although a number of already existing thermal plants were refurbished during the crisis, Ghana constructed her first thermal plant (220MW) in 1998 at Aboadze, Takoradi.The proportion of thermal componentin the total generation mixbegan to increase aspower consumption rate was also increasingbeyond what the Akosombodam could meet. In current times, thermal power leads Ghana's installed generational capacity though, contributing about 57% of total installed capacity.Hydro generation constitutes 43% of the installedcapacity whilst renewables accounts for just about 0.1% [5].

Ghana's power sector is unbundled into three main segments: power generation, transmission and distribution. Volta River Authority (VRA), the state-owned power producer isresponsible for power generation, although there are other independent power producers(IPPs) generating in the country. Power transmission is undertaken by the Ghana Grid Company (GridCo) whilst Electricity Company of Ghana (ECG) is responsible for power distribution in the southern part of Ghana. A subsidiary of VRA, Northern ElectricityDepartment Company (NedCo) is responsible for power distribution within the northern enclave of

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Ghana.VRA's total installed capacity is 2,434MW, contributing about 67% of the country's total installed capacity.A breakdown of VRA'stotal installed capacity is shown in Table 1.The remaining installed capacity of 1,210MW from other IPPs is also shown in Table 2.

Table 1: Breakdown of VRA's total installed capacity[1]

Plant	Installed Capacity (MW)	Type	Fuel Type
Akosombo	1,020	Hydro	Water
Kpong	160	Hydro	Water
T1 – Combined Cycle	330	Thermal	LCO/Gas
T2 – Combined Cycle	330	Thermal	LCO/Gas
TT1PP	110	Thermal	LCO/Gas
TT2PP	50	Thermal	DFO/Gas
MRP	80	Thermal	DFO/Gas
KTPP	220	Thermal	HFO/Gas
Takoradi 3 (T3)	132	Thermal	LCO/Gas
Solar Plant Project 1	2.5	Renewable	Solar

Source: Volta River Authority, 2017

Table 2: Breakdown of other IPPs' installed capacity

Plant	Installed Capacity (MW)	Type	Fuel Type
SunonAsogli (Phase 1)	200	Thermal	Gas
CENIT	110	Thermal	LCO
Bui Hydro Plant	400	Hydro	Water
Karpower Barge	250	Thermal	HFO
AMERI Power Plant	250	Thermal	Gas

Source: Volta River Authority's website, 2017

In 2015, the government of Ghana envisioned that by 2020, Ghana would have attained a universal electricity access. With an access of 80% as of 2015, the nation's electricity demand wasaround 16,000 GWh.Perthe Energy Commission of Ghana's forecast, Ghana's consumption is expected to be around 33,000 GWhby 2025 [7].As a developing country, Ghana's power infrastructure isinsufficient to match up power demand for industrial activities. Coupled with this, the country has been experiencing yet another episodeof power crisis since 2012. As a way out, the government of Ghana has made quite a number of investments into thermal generation.The government in December 2015added about 235MW to the national grid via the installation of power barges. As this increases the proportion of thermal component in the total electricity generation mix, it increases the potential of carbon emissions and other pollutants into the atmosphere. Ghana has a colossal opportunity to veer into solar energy as the nation is well endowed with an abundance of sunlight. The country has made efforts to harness solar energy through VRA's 2,5MW solar plant in Navrongo and 20MW solar plant in GomoaOnyeadze. However, the deployment of renewable energy has not been on a large and sustainable scale and more work remains to augment these efforts. As Ghana breaks frontiers to improve its energy security, the environmental implications of thermal generation must be assessed and subsequently mitigated so that electricitycan be utilizedin a fit environment.

1.3. Overview of environmental management in Ghana

Environmental management in Ghana is mainly the mandate of the Environmental Protection Agency (EPA). The EPA is mandated under the Environmental Protection Act, 1994 to formulate an environmental policy and set standards and guidelines for the protection of the environment. The EPA is responsible for ensuring compliance with environmental impact assessment (EIA) procedures in the design and implementation of any project likely to have potential adverse effects on the environment. Ghana is confronted with several environmental challenges, key among which is waste management, air pollution, and land and water degradation. The EPA has set environmental quality standards for Ghana's manufacturing industry including industries which use thermal energy [8].However, the standards are silent on air pollutants especially CO_2 emissions and particulate matter for power plants. This has implications for public health in Ghana as the country is predisposed to high rates of air pollution deaths. In 2013, Ghana recorded about 17,524 deaths from air pollution alone [9].Ghana needs strengthening of its environmental management systems to improve air quality in the country and the EPA has a crucial role to play in this.

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[1]KTPP means Kpone Thermal Power Plant; MRP means Mines Reserves Plant; TT1PP means Tema Thermal 1 Power Plant; TT2PP means Tema Thermal 2 Power Plant; LCO means light crude oil, DFO means Distillate Fuel Oil; and HFO means Heavy Fuel Oil.

2. LITERATURE REVIEW

2.1. Overview of thermal generation

Thermal generation is considered to be one of the most conventional ways of generating electricity. It involves the harnessing of heat energy from the burning or combustion of fuels such as coal, oil, gas or wood to produce electricity. During thermal generation, heat energy from the combustion process isused to generate steam which in turn drives a steam turbine. This process converts heat energy to kinetic energy. A generator, to which the steam turbine is connected converts the kinetic energy to electrical energy. To increase the efficiency of thermal plants, cogeneration and combined cycle technologies are mostly adopted. Cogeneration otherwise known as Combined Heat and Power (CHP) is the simultaneous production of electricity and heat energyfrom the same fuel source. Cogeneration does not in itself increase the power supply for a given plant; rather it increases overall energy efficiency by supplying useful heat in addition to useful electricity. Cogeneration allows 75% to 80% of fuel inputs, and up to 90% in the most efficient plants, to be converted to useful energy. By making more efficient use of fuel inputs, cogeneration allows the same level of end-use energy demand to be met with fewer energy inputs [10].A combined-cycle power plant uses both gas and steam turbines to produce up to 50 percent more electricity from the same fuel than a traditional simple-cycleplant [11].With combined cycle, after a fuel source is combusted to produce electricity, the exhaust heat from the gas turbine is used to generate steam to drive a steam turbine to generate additional electricity. This technology is more efficient than the conventional single-cycle plants as it harnesses the heat energy which would have otherwise been released into the environment as waste.

One major benefit of thermal energy is that it can provide continuous, reliable power which is not subject to the vagaries ofthe weather.Some fossil fuels used for thermal generation, for example, coal is considered a more reliable source of thermal fuel as it is cheaper and more abundant in supply. However, because fuels used for thermal generation are rich in carbon, they pollute the environment upon combustion.

2.2. Environmental implications of thermal generation

2.2.1 Air quality

Fossil fuel power plants generally have the most widespread effect on air quality, as the combustion process produces airborne pollutants (see Table 3) that spread over a wide area. Such air pollutants include particulate matter, sulfide oxide compounds (SO_x), nitrogen oxide compounds(NO_x), carbon monoxide(CO), carbon dioxide(CO_2) compounds and other hydrocarbons.

Table 3: Typical Power Plant Emissions (g/kWh)

Plant Type	CO	NO_x	SO_2	CO_2
Coal	0.11	3.54	9.26	1090
Oil	0.19	2.02	5.08	781
Gas	0.20	2.32	0.004	490

Source[12]

The World Health Organization (WHO)in 2011 compiled air quality data from 1,100 cities in 91 countries. The data showed that residents living in many urban areas are exposed to persistently elevated levels of fine particle pollution. The report states that in both developed and developing countries, the largest contributors to urban outdoor air pollution include motor transport, small-scale manufacturers and other industries,burning of biomass and coal for cooking and heating, as well as coal-fired power plants [13].Typical coal fired plants have been found to increase illness and death in the general population through air pollution. When coal is burned in power plants, it emits air-borne pollutants of particulate matter, sulfur dioxide, oxides of nitrogen, carbon dioxide, mercury, arsenic, chromium, nickel, other heavy metals, acid gases, hydrocarbons and varying levels of uranium and thorium in fly ash.Crude oil and natural gas fired power plants also emit large volumes of carbon compounds, sulfur and nitrogen oxides.

2.2.2 Effect of air pollution on human health

Crude oil fired plants cause air pollution which have detrimental effects on human health. Such pollution may cause dizziness, rapid heart rate, headaches, confusion, and anaemia. Air pollution is the world's fourth largest threat to human health, after high blood pressure, dietary risks and smoking, causing around 6.5 million deaths each year. Energy production and use, from unregulated, poorly regulated or inefficient fuel combustion, are the main sources of air pollutant emissions: 85% of particulate matter and almost all of the sulfur oxides and nitrogen oxides. These three pollutants are responsible for the most widespread impacts of air pollution [14].

Particulate matter causes about 3% of mortality from cardiopulmonary disease, about 5% of mortality from cancer of the trachea, bronchus and lung, and about 1% of mortality from acute respiratory infections in children under 5 years, worldwide. This amounts to about 0.8 million (1.2%) premature deaths and 6.4 million (0.5%) years of life lost. This burden occurs predominantly in developing countries; with 65% in Asia alone [15]. A report by the Clean Air Task Force (2014) finds that over 7,500 deaths each year are attributable to fine particle pollution from power plants in the United States [16].

CO, CO_2, and some hydrocarbons which are known as "greenhouse gases," have been found to be the cause of global warming. Carbon emissions raise global temperatures by trapping solar energy in the atmosphere thereby altering water supplies and weather patterns. Long exposure of about 5000 ppm of CO_2 affects respiratory health and results in organ failure. Carbon monoxide is far more lethal to human health than carbon dioxide. SO_X and NO_X produce acid when released into the atmosphere, leading to the production of acid rain [12]. These pollutants lead to respiratory diseases, inflammation, cytotoxicity, and cell death.

Air pollution causes more than 3 million premature deaths worldwide every year with global urban air pollution levels increasing by 8% from 2008 to 2013 [17].In 2013 alone, an estimated 5.5 million lives were lost to diseases associated with outdoor and household air pollution. In the same year 2013, air pollution deathscost the global economy about US$225 billion in lost labor income [9].

2.3. Country experience:environmental effects of thermal generation

China

A study by Rohde and Muller (2015) indicates that about 1.6 million deaths every year can be attributed to PM2.5 air pollution in China. According to the study, roughly 38% of China's population have PM2.5 concentrations of more than 55 μg/m3 and are classified as "unhealthy" with an additional 45% of the population averaging >35 μg/m3 classified as "unhealthy for sensitive groups". Almost none of the study areas averaged below the United States EPA's 12 μg/m3 standard for annual average PM2.5 exposure. 92% of China's population experienced unhealthy PM2.5 for at least 120 hours during the study period. 46% of China's population experienced PM2.5 above the highest EPA threshold, that is>250 μg/m3 (this is considered hazardous), during at least one hour in the observation period.In addition to the particulate matter, the study also found NO_2 and SO_2 emissions. The pollutants were altogether attributed to the burning of fossil fuels in power plants, specifically coal. In areas of dominant industrial activity such as south of Beijing, particulate concentrations were highest.

Bangladesh

A study by[18], shows that air pollution from thermal plants in Bangladesh have significant impact on air quality and human health. There are about forty power stations in Bangladesh; out of which 80% use gas and the remaining 20% is coal, liquid and furnace oil based. The study indicates that these power plants pollute the atmosphere significantly with the release of carbon, nitrogen and sulfur dioxides. It further identifies that although Bangladesh has only one coal power station, air pollution from coal-fired power plants is huge and contributes to health problems as the coal fired plants release a combination of carbon dioxide, nitrogen oxides, sulfur dioxide, particulate matter (PM), mercury, and dozens of other substances known to be hazardous to the environment. This has contributed to global warming, disrupting Bangladesh's weather patterns and ecosystems; thereby causing flooding, severe storms, and droughts. Most people living in close proximity to the power stations are mainly unhealthy as a warming climate leads toa range of infectious diseases.

Other countries

A study by [19], shows that there is an adverse effect of fossil fuel usage especially coal on life expectancy. The study found that the use of coal predicted a decrease in life expectancy in countries including Poland, China, Mexico, and Thailand. In India and China, years of life lost were estimated up to 2.5 years and 3.5 years, respectively. Infant mortality was also shown to increase with increased coal consumption in countries such as Chile, China, Mexico, Thailand, Germany, and Australia.

3. METHODOLOGY

The methodology adopts a qualitative approachin assessing the environmental implications of thermal generation.The lack of empirical data informed the decision to take a qualitative approach. With this, secondary empirical data was sourced from already existing data and research works. A three-step approach was adopted in assessing the environmental implications of thermal generation in Ghana. Firstly, a comparative analysis is drawn from four selected developing countries in addition to Ghana. The countries were selected based on their Gross Domestic Product (GDP) per capita; thus countries with GDP per capita within the same range as Ghana's were selected. Secondly, based on data obtained from external sources on the amounts of CO_2 emitted from electricity and heat generation in Ghana,a comparison was made with the permissible exposure limit for CO_2 emissions as set by the Occupational Safety and Health Administration (OSHA). Finally, in comparison to the experience of other countries, lessons were drawn for Ghana to avert the damaging effect of thermal generation on its environment.

The paper limits its analysis to CO2 emissions due to the lack of data on the other air pollutants (particulate matter, NOx, SOx).

3.1. Data sources and collection methods

Data was obtained from secondary sources including the websites of both local and international environmental agenciessuch as the Environmental Protection Agency of Ghana, United States Department of Labour Occupational Safety and Health Administration and the World Health Organization, and internationally recognized data services. Other secondary sources included reports, articles and news items.

3.2. Data variables

Based on data gathered from secondary sources, metrics were developed to evaluate how thermal generation through the release of air pollutants affectsair quality. The metrics included the amounts ofCO_2 emissions and air quality standards.

3.3. Approach to data analysis

The following steps were taken in analyzing the retrieved data.

1. Organization of data: from the information gathered from agencies, articles, reports and news items, the data was arranged based on CO_2 emissions over a time range from 1998 to 2013; and air quality standards as set by the OSHA. These became the metrics used for the analysis. The time trend was selected from 1998 because that was the period in which Ghana began thermal generation. The time trend ends with 2013 because that is the most recent year in which CO_2 emission data was accessed.
2. Sorting of data into framework: from a. above, the data were sorted according to trends and patterns identified. Related pieces of information were grouped together while recurrent issues were merged to highlight central ideas.
3. Descriptive analysis: Analysis was made based on other analysis and empirical data available from already existing research works.

4. RESULTS AND DISCUSSION

4.1 Environmental implications of thermal generation in Ghana

The Occupational Safety and Health Administration (OSHA) has set a permissible exposure limit (PEL) for CO_2 of 5,000 parts per million (ppm), equivalent to 0.5% by volume of air[2] (see Table 4). This means that beyond this, a person is likely to experience respiratory challenges and organ failure [20].[3] WHO has indicated the allowable limits for particulate matter as 10 μg/m3 annual mean for $PM_{2.5}$ and 20 μg/m3 annual mean for PM_{10}. However, data retrieved from the UK Data Service shows that Ghana's carbon dioxide emissions far exceeds the OSHA standards as shown in Table 4 and Figure 3 respectively.

Table 4: Air quality standards

Air Pollutant	Limit (ppm)
Carbon dioxide	5000
Carbon monoxide	50
Nitric oxide	25
Sulphur dioxide	5

Source: Occupational Safety and Health Administration, 2016

The paper compares Ghana's carbon emissions with four other selected developing countries with similar GDP per capita. The four countries selected are Cameroon, Zambia, Kenya and Cote D'Ivoire. Table 5 shows the CO_2 emission trends of the selected countries.

Table 5: CO2 emission trend of some selected developing countries

[2] This data was accessed at https://www.osha.gov/pls/oshaweb/owadisp.show_document?p_table=standards&p_id=9992 on 3rd November, 2016.

[3] Further information was obtained from an online publication (anon). Retrieved from http://www.blm.gov/style/medialib/blm/wy/information/NEPA/cfodocs/howell.Par.2800.File.dat/25apxC.pdf Accessed 30th June, 2016.

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Source[4]

Country	Cameroon	Zambia	Ghana	Kenya	Cote D'Ivoire
GDP per Capita (US$)	1,217.3	1,304.9	1,369.7	1,376.7	1,399.0
		CO2 Emissions			
1998	1.9	7.4	22.5	17.0	51.1
1999	1.7	6.1	20.1	20.6	37.4
2000	1.4	4.8	11.4	28.2	37.4
2001	2.2	5.1	17.7	22.3	39.3
2002	3.1	5.5	29.6	16.5	41.4
2003	4.0	5.2	27.6	15.9	42.3
2004	4.0	5.1	11.1	21.4	43.0
2005	5.5	4.7	18.6	22.8	53.9
2006	19.3	3.6	31.4	22.5	41.6
2007	32.3	3.0	31.5	22.4	44.1
2008	33.0	3.9	24.7	27.2	44.7
2009	32.4	3.1	18.7	28.3	42.6
2010	32.5	4.2	29.7	20.3	46.9
2011	30.4	3.0	24.2	22.5	47.8
2012	31.1	2.6	24.4	19.3	46.2
2013	34.4	2.0	26.7	21.9	46.8

[4]Drawn by Author with data from the UK Data Service at http://stats.ukdataservice.ac.uk/#

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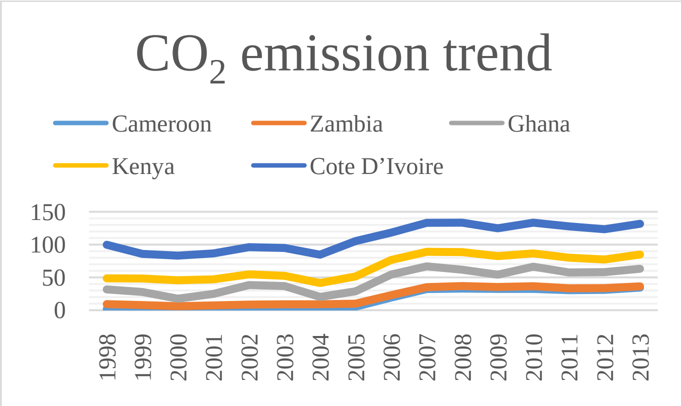

Figure 2: Trend of CO_2 emission from electricity and heat generation among some selected developing countries

As shown in Figure 2, Cameroon emits the least CO_2 among the developing countries under review. This is particularly because Cameroon has hydropower as the dominant component of its power generation mix. Thermal generation represents about 27% [21] of the total installed power capacity. Cote D'Ivoire, on the other hand, has about 75% [22] of its power generation mix from thermal sources, predominantly natural gas. This explains why among all the countries reviewed, Cote D'Ivoire emits the highest amounts of CO_2. Kenya has about 61% of its power generation mix from thermal sources while Zambia's thermal generation component accounts for only about 4% [22] of its total generation mix.As illustrated by Figure 2, the higher the thermal generation component of a generation mix, the higher the amounts of CO_2 emitted. However, an exception is seen with Zambia which emits higher amounts of CO_2 than Cameroon although its thermal generation component is lower. This is because Zambia's thermal sources are predominantly from diesel and heavy fuel oil fired plants while Cameroon generates from natural gas and crude oil.This means that the type of fuel used also influences the amounts of CO_2 emitted. Ghana's increasing trend of CO_2 emissions is a reflection of the increase in its thermal component over the years. As Ghana's thermal component increases over the next years, the implications are that CO_2 emissions will be higher resulting in higher levels of air pollution.

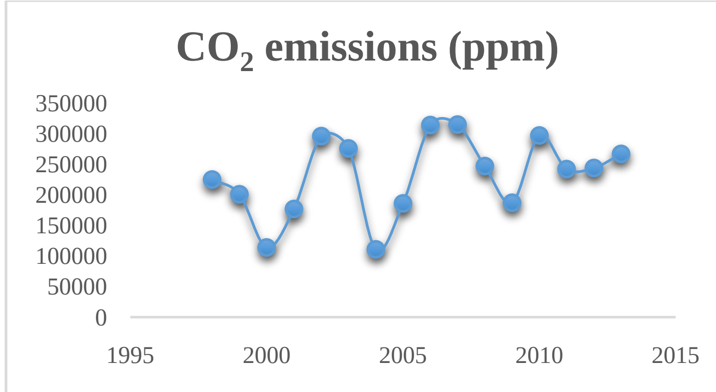

Figure 3: Trend of Ghana's CO_2 emission from electricity and heat generation

Source[5]

From Figure 3, it can be seen that Ghana's trend of CO_2 emission from electricity and heat generation far exceeds OSHA's PEL of 5,000 ppm. It is worrying that from 1998 to 2013, Ghana has not recorded CO_2 emissions below 111,000 ppm. From this trend, it is not surprising that the country recorded about 17,524 air pollution deaths in 2013 alone. This implies that the country's air quality has fatal health implications for Ghanaians. The lack of CO_2 standards for power plants by the EPA is a contributing factor to this. In the absence of stringent regulations on air pollutants specific to power plants, the trend of air pollution is likely to continue thereby resulting in more air pollution deaths across the country.

4.2 Lessons for Ghana

There are rich lessons that can be drawn for Ghana based on the experience of other countries. Although Ghana has not yet begun using coal as compared to the countries discussed in the literature, the current emission levels of CO_2 are already above the allowable limits. This implies that if Ghana does not learn now, future emission levels could heighten beyond control, especially if Ghana decides to utilize coal for power generation. The following are some lessons Ghana could draw from other countries:

Investment in empirical data: China has invested in gathering air monitoring data in many cities across the nation [23]. This is a good lesson for Ghana to emulate. Ghana must invest in gathering air quality data through periodic air monitoring which should be publicly accessible. Such information is useful especially in executing air pollution control measures to determine the progress made by implementing such measures. The data is

[5] Graph drawn by Author with data sourced from UK Data Service at http://stats.ukdataservice.ac.uk/# Accessed 20th March, 2017.

also useful in keeping the Ghanaian public abreast of their surroundings to take necessary precaution measuresfor their health.

Strategic siting of power plants: Power plants should not be sited in close proximity to residential areas or places where people frequently commute. In the case of Bangladesh, people sited close to power plants were affected the most. Ghana's thermal power station in Tema is sited in close range to areas which are frequented by people for business activities. Ghana's Town and Country Planning Department should take action to ensure that areas zoned for siting power plants should not house business activities or residents.

Ensuring fuel security: In the absence of a reliable and affordable fuel supply source, there is the tendency to grasp unto any readily available fuel source which may not be environmentally friendly. The tendency for Ghana to utilize coal for power generation can be seen in this light. It is therefore important that the country develops the needed infrastructure to harness liquefied natural gas (LNG)to reduce fuel supply constraintsinstead of deploying coal.

4.3 Policy implications for Ghana's power sector

Access to a clean, efficient and affordable energy source is an essential for any growing economy. Governments which are committed to achieving sustainable development for their countries must develop clear-cut policies that will guide the implementation of such commitment. However, developing energy policies that have adverse environmental implications requires understanding the complex interplay between the systems of energy delivery and sustainable, healthy human environments. There is the need to develop a sound policy and legal framework that will ensure an integrated energy planning system that inculcates environmental sustainability.The policy implications for Ghana's power sector are outlined as follows:

Integrated environmental management systems: Ghana's power generation mix comprises of about 57% thermal sources, 43% hydro and just about0.1% renewable energy source (solar). With such a significant proportion of the generation mix coming from thermal sources, it is important for the country to have strong environmental management systems in place. It even becomes increasingly imperative with current plans underway to deploy coal-fired plants to beef up power supply. This will come with a lot of challenges as the country has not yet put in place systems that will address environmental pollution issues associated with coal usage. It is therefore important for Ghana to integrate into its energy sector policies, environmental management policies that will assess potential environmental impact of power projects and their mitigation measures.

Equipment Procurement: There are concerns that Ghana,in collaboration with a Chinese company, Shenzhen Energy Group Company Limited, is planning to set up two 350 MW coal-fired generating plants at EkumfiAboano, in the Ekumfi District of the Central Region [6]. This poses concerns about the procurement process especially since China is moving away from coal fired plants. To ensure that Ghana does not procure already used coal plants which may even be in a deplorable state, power plants should be sourced through an open and competitive bidding process that will allow the best quality to be procured. Ghana therefore needs to establish procurement guidelines for sourcing power plants. The procurement guidelines must make it a priority to source power plants with built-in emission control systems.

Renewable energy policies and law: Ghana has options of deploying alternative energy sources to boost up its power sector. The country has abundance of sunshine and can generate power from solar energy. There are also other options of using liquefied natural gas and biogas from animal and plant feedstock. Renewable energy is cleaner and a significant portion of it in the power generation mix will reduce CO_2 emissions. AlthoughGhana has developed a Renewable Energy Act and a sustainable energy action plan to boost the deployment of renewable energy, they are silent on the specific proportion of renewable energy to be included in the power generation mix. The renewable energy section of the Sustainable Energy for All Action Plan should be reviewed to specifythe proportion of renewable energy to be included in the generation mix. This must be coupled with actionable steps (with clear timelines) to be taken in integrating renewable energy into the national grid.

Developing power generation sector specific environmental regulations: Ghana needs to develop regulations that are specific to the power sector. This will allow for environmental standards to address specific environmental issues that emanate from the power sector instead of the general standards that are not targeted.

Implementation of energy sector policies and laws: Ghana is known for developing good policies and laws which are not implemented to the core. Ghana must develop the attitude of implementing its energy sector policies and laws. The first step to this is tohave legal provisions that give responsible agencies the powers to prosecute defaulters.

5. CONCLUSION AND RECOMMENDATIONS

The impact of thermal generation on human health cannot be overemphasized. Amidst growing calls for sustainable development among many economies the world over, Ghana must be committed to adopt effective environmental interventions that will promote the utilization of energy resources in a safe environment. In view of this, the following are recommended:

- Ghana must adopt a Clean Air Act that will control air pollution on the national level. This act will set and regulate national environmental emission standards for all machinery including power plants, automobiles and industrial appliances and machines.
- The capacity of Ghana's Environmental Protection Agency (EPA) must be strengthened through technical training of staff and adequate financing to carry out regular air monitoring and environmental audits on power plants across the country. In addition, the EPA must include standards for CO_2 emissions and particulate matter specifically for the power generation sector. The EPA must also be granted prosecution powers in order to sanction power generation companies which fall short of maintaining environmental standards.
- Ghana must develop comprehensive procedures for the procurement of new power plants in a transparent and competitive manner. Instead of sole sourcing, procurement must be done in a competitive and transparent way. This will ensure that plants procured into the country are efficient and of the best quality.
- Ghana needs to diversify its energy mix with cleaner forms of fuel sources. Asubstantial portion of renewable energy (solar, wind, etc.) should be included in the power generation mix. This will reduce the country's reliance on fossil fuel thereby ensuring that Ghanaians have access to a cleanersource of energy. Additionally, the decision to bring in LNG cannot wait any longer and Ghana must within the short term deploy LNG.

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