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Power Generation and Its Impacts on the Environment

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Authors' contributions

This work was carried out in collaboration between all authors. Authors KKO and AMO designed the study, performed the statistical analysis, wrote the protocol and wrote the first draft of the manuscript and managed literature searches. Authors KKO, AMO and AOA managed the analysis of the study and literature searches. All authors read and approved the final manuscript.

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ABSTRACT

Power generation is the means of generating power supply into the society. This paper tells how power is being generated from various sources (nuclear, coal, solar, wind, natural gas, water, geothermal, biomass), its major impacts on the society and the possible solution to problems that arise from the process of power generation through the various means considered. The various methods of generating power, no matter how beneficial, still have one or two short-comings which might constitute threat to the peaceful coexistence of living things in the environment. Some of these shortcomings are considered in this paper with possible solutions suggested. Over-aged transmission and distribution lines, unequal phase loads, etc. contribute to electrical power losses in transmission and distribution in Nigeria.

To solve these problems, control measures such as introducing more substations, implementing pre-paid metering systems, using conductors of appropriate sizes and re-aligning the lines are suggested. In order to ensure sustainable power generation, foreign participation based on experience should be encouraged in the Nigerian power sector, the sources of fuel for electricity generating stations should be diversified, etc.

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1. INTRODUCTION

In engineering process, power generation deals with the various processes through which electricity is being generated. These processes include: combustion, fission, etc. The various sources of power includes nuclear, natural gas, coal, oil, and the renewable sources like wind, water, solar, etc. The consumption rate of fossil, nuclear and renewable fuels in the year 2005 is revealed on pie chart in Fig. 1. From the figure, it can be deduced that the source of energy which was mostly depended upon is oil (40%), followed by natural gas (23%), coal (23%), nuclear (8%) and finally, the renewable energy sources (6%). However, the safest sources of energy, which is environment friendly, are the renewable sources of energy. They include; wind, water and solar. They pose the minutest threat to the habitats. When using the renewable energy sources to generate electricity, release of poisonous gases into the atmosphere is absent.

2. OBJECTIVES OF STUDY

The objectives of this study are as follows:

- To consider the sources of power generation,
- To shed light on ways by which electricity is being generated from the various sources,
- To observe the impacts of the various sources of power generation on the environment; either positive and/or negative,
- To suggest possible solutions to the problems that arises during the process of power generation.

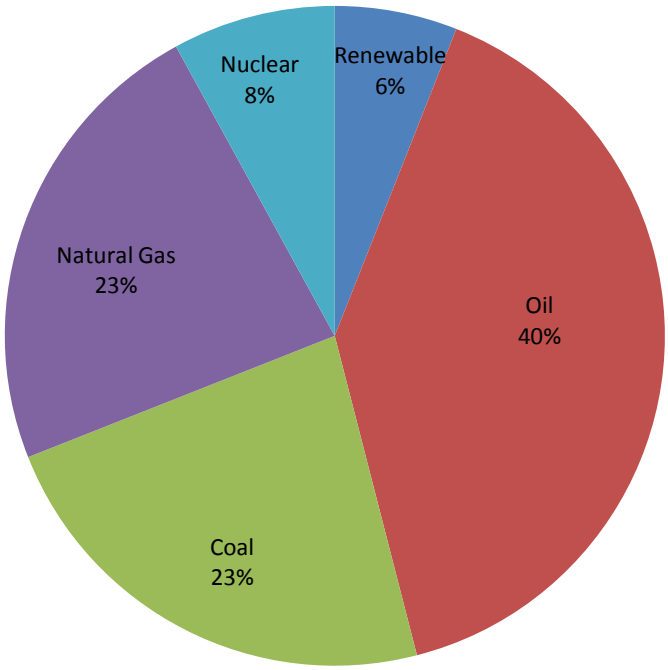

Fig. 1. Statistics of worldwide fossil, nuclear, and renewable fuels consumption in 2005 [1]

3. EVOLUTION OF POWER GENERATION

Electricity became available for use in technology by the help of Michael Faraday when he invented the electric dynamo. This became a practical solution to the problem of electricity generation. He did this in the year 1831, by the movement of a loop of wire or disc of copper between the poles of magnets [2].

Electricity was also generated from a water fall in Niagara River located at the border of Ontario, Canada, and New York in the United States, under the leadership of Jacob Schoellkopf in the year 1881. He built the first hydro-electric power generating station there.

In the year 1878, Joseph Swan and Thomas Edison independently invented the carbon filament which produced light from electricity-incandescent lamp. In 1879, Thomas Edison founded the Edison Electric Light Station.

Also, in the year 1882, Carl de Laval invented the steam turbine that drove electric generators more efficiently than the earlier reciprocating steam engines. Charles Parsons, in 1884, constructed the first practical steam turbine electric generator which can be driven by fuel-burning power plants in the electric power industry.

Furthermore, in 1895, Niagara Falls which was the world's first large-scale central generating station transmits power 20miles away to Buffalo and it employed 2-phase Alternating Current (AC) technique of Nikola Tesla.

Albert Einstein, in 1905, published his "theory of relativity" and the equation $E=MC^2$, which is the foundation of nuclear power.

In the year 1907, a new material called "Tungsten" was used to replace carbon strips of bamboo, as filament in the incandescent lamp.

By 1970s, about 1,701MW (megawatts) power was being generated and population of over 567,000 people were involved in the power usage. 100% of the power was generated from Gas until the year 1980 when the technology was advanced to the use of Gas and Coal. 75% of the total population of people were using gas-steam, while 25% used power generated from coal. Then, the total capacity generated was 3,452MW, being used by a total population of 681,000 people. By the year 1990, the means of power generation were gas, coal and nuclear. 53% of the generated power was from gas, 31% from coal and 16% from nuclear. The total power generated was 4,632MW, being managed by 972,000 population up to the year 2000 when gas-steam, coal, nuclear and gas were being made use of for power generation. 48% of the power came from gas-steam, 28% came from coal, 15% from nuclear while 9% came from gas. The total amount of power produced was 5,113MW, being managed by 1,393,000 population till the year 2012. As at 2012, the means of power generation were from gas-steam, coal, nuclear, gas and renewable sources such as wind, solar, biomass, etc. 23% power was generated from gas-steam, 29% from coal, 14% from nuclear, 22% from gas, and the remaining 12% was from other renewable energy sources. The total power produced was 7,478MW, which is being used by over 1,715,000 population up to date [3].

4. MEANS OF GENERATING POWER

Electricity production in Nigeria over the last 40 years has varied from gas-fired, oil fired, hydroelectric power stations to coal-fired stations with hydroelectric power systems and gas fired systems taking precedence. There are various means through which power can be generated; some, out of all will be discussed. They include coal, water, nuclear, natural gas, solar, wind, geothermal and biomass. The renewable means of power generation include water, solar, wind, biomass and geothermal. However, their environmental impacts will also be made mention of.

4.1 Coal

Coal is a black rock formed from prehistoric plant remains, composed largely of carbon and burned as fuel.

Coal is being used for power generation by first pulverizing it i.e., crushing it into fragments or powdery form, and then combusting it in a furnace with a boiler. The furnace heat converts the boiler water into steam which is then used to spin turbines which turn generators and then create electricity, see Fig. 2. The thermodynamic efficiency of this process has been improved over time. Some older coal-fired power stations have thermal efficiencies of about 25% [4], but the newest "super-critical" and "ultra-supercritical" steam cycle turbines, operating at temperatures over 600ºC and pressure over 27MPa (over 3900 psi) can achieve thermal efficiencies of over 45% (LHV basis) using anthracite fuel or around 43% (LHV basis), even when using lower-grade lignite fuel [5].

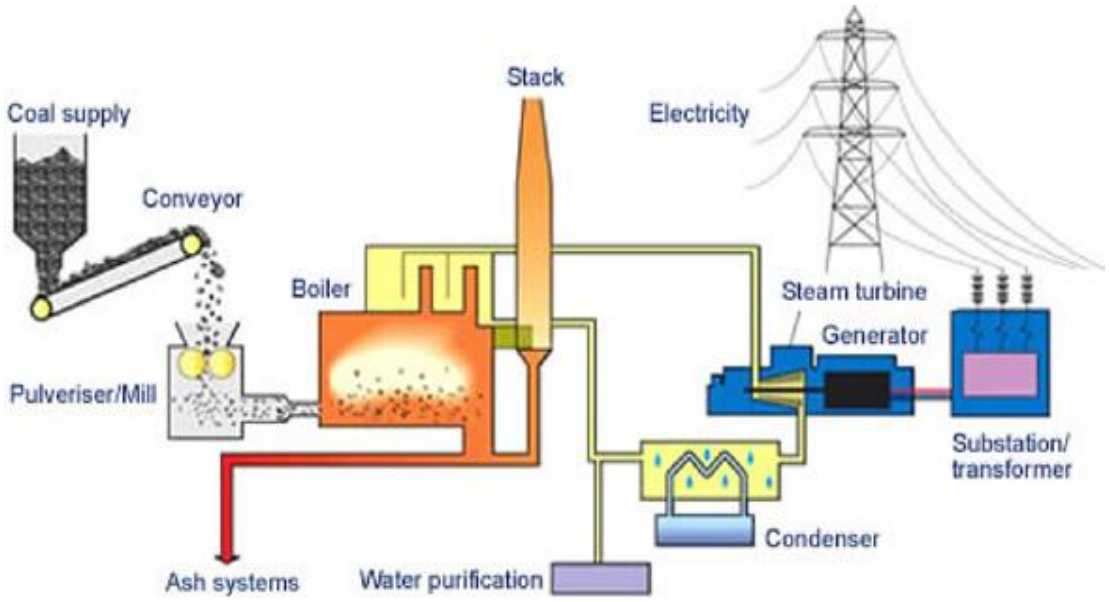

Fig. 2. Coal power generation plant

Furthermore, thermal efficiency improvements are also achievable by improved pre-drying (especially relevant with high-moisture fuel such as lignite or biomass) and cooling technologies. At least 40% of the world's electricity is generated from coal. The major problem related to the use of coal is air pollution. Coal is composed majorly of carbon, therefore, in the process of burning; gases such as Carbon dioxide (CO_2), Nitrogen oxides (NO_x), and Sulphur dioxide (SO_2) are being emitted into the environment.

4.1.1 Effects on the environment

The effects of use of coal for power generation are as follows:

- ⇒ Coal-fired power plant causes nearly 24,000 premature deaths annually in the United States, including 2,800 from lung cancer [6].
- ⇒ Coal-fired power plants without effective fly-ash capture systems are one of the largest source of human-caused background radiation exposure
- ⇒ Approximately 75Tg/s per year of sulphur dioxide (SO_2) is released from burning coal. After release, the sulphur dioxide is oxidized into H_2SO_2 which scatters solar radiation; hence, its increase in the atmosphere exerts a cooling effect on the climate. It contributes to some of the warming caused by green house gases. SO_2 combines with water to form sulphurous acid, which acidifies rain. Therefore, release of sulphur dioxide contributes to the widespread acidification of the ecosystems [7].
- ⇒ Combustion of coal produces a family of nitrogen oxide, NO_x. NO competes with oxygen in the human system by binding with haemoglobin in the blood. NO_2 is a major component of photochemical smog.

4.1.2 Possible solutions

- ⇒ To minimize the harmful effects caused by the emissions from coal, the use of refined coal is advisable. Refined coal is the product of a coal-upgrading technology that removes moisture and certain pollutants from lower-rank coals such as sub-bituminous and lignite (brown) coals. It is a form of several pre-combustion treatment processes for coal, which alters coal's characteristics before it is burned.
- ⇒ Lowering the combustion temperature of the furnace in electric power plant is a viable control strategy for nitrogen oxides (NO_x).
- ⇒ To control the harmful effects of sulphur dioxide, it is best advised to use alternative sources for power generation, i.e., discouraging fossil fuel based power plants.

⇒ Another promising method of controlling air pollution is the Polish solution based on electron beam application [8].

4.2 Water

Hydro-electric power is obtained from running water which is used to turn the propeller-like piece called turbine, which is used to turn a metal shaft in an electric generator. This metal shaft is the motor that produce electricity. Some power plants are located on rivers, streams, and canals, but for a reliable water supply, dams are needed.

In a hydro-electric power plant, the dam is used to store up lots of water behind it in the reservoir. Near the bottom of the dam wall the water intake gravity causes water to fall through the penstock inside the dam. There is a turbine propeller at the end of the penstock, which is turned by the moving water. The water continues past the propeller through the tail race into the river past the dam. The shaft from the turbine goes up into the generator, which in turn, produces power. For the generator, a hydraulic turbine converts the energy of flowing water into mechanical energy. The hydroelectric generator then converts the mechanical energy into electricity. Power lines are connected to the generator that carries electricity to the various destinations, See Fig. 3.

The operation of the generator is based on the principles discovered by Faraday. He discovered that when a magnet is moved past a conductor, it causes the flow of electricity. In large generators, electromagnets are made by circulating direct current through loops of wire wound around stacks of magnetic steel laminations. These are called field poles and are mounted on the perimeter of the rotor. The rotor is attached to the turbine shaft and rotates at a fixed speed. When the rotor turns, it causes the field poles (electromagnets) to move past the conductor mounted in the stator. This, in turn, causes electricity to flow and it causes a voltage to develop at the generator output terminals [9]. Hydroelectric power have low failure rate, low operating cost, and is reliable.

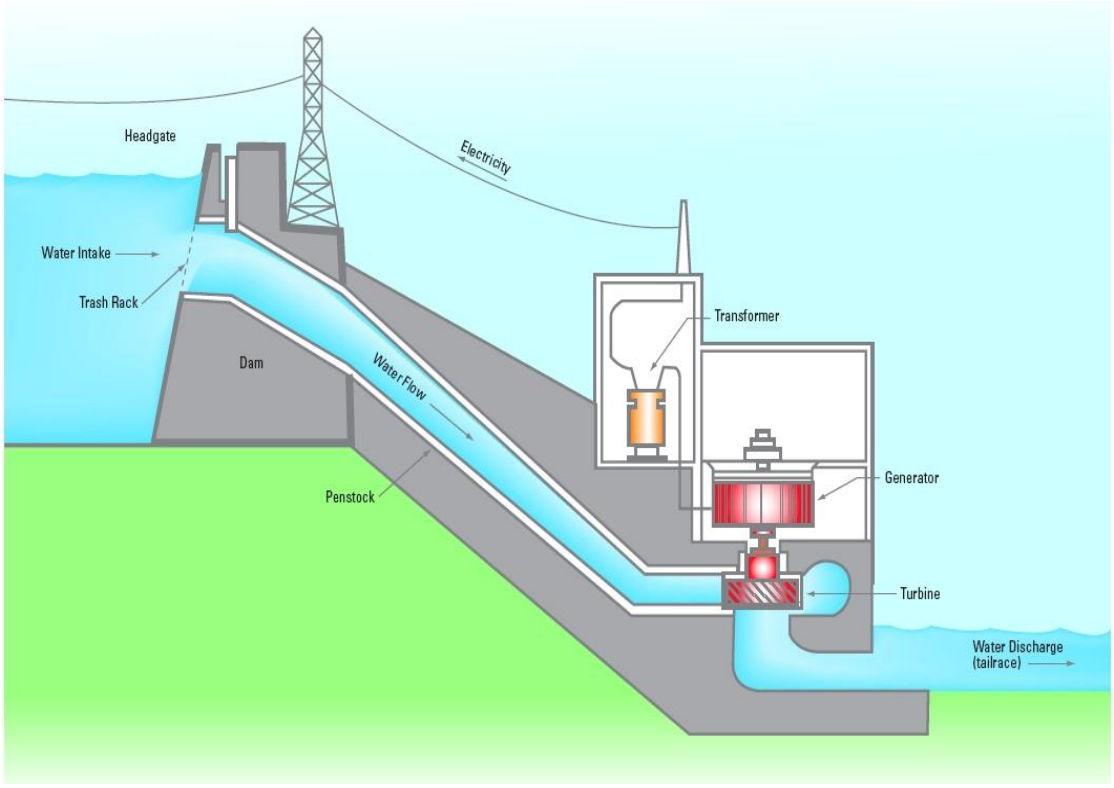

Fig. 3. Hydroelectric power plant

4.2.1 Effects of hydroelectric power generation on the environment

⇒ Reservoir creation creates the release of green house gases such as methane, CO_2, etc. The release is as a result of microbial decomposition when upland forests and peat land are flooded in the course of reservoir creation. The above-water decay of standing trees causes pollution by contributing to the emission of CO_2 and methane [10].

⇒ Hydroelectric power plant can cause the reduction of soil fertility and big reservoirs can cause earthquakes as the weight of water pressing on the rock weakens the earth crust. This is known as reservoir-induced seismicity [11]

⇒ Reservoir of the hydroelectric power causes reduced spawning success of fishes and it reduces animal population [12].

4.2.2 Possible solutions

⇒ Fish passages should be created to aid the migration of fishes [13].

⇒ New dam sites should be chosen with the environmental impacts in mind. Dams should not be erected near residential areas or near the town, but it should be erected further up or down the river to prevent ill-feeling [13].

⇒ Endangered species should be relocated.

4.3 Nuclear

It deals with the generation of power from the rapid release of atomic energy from Uranium when an atom is split by a neutron. In a nuclear fission chain reaction, a Uranium-235 atom absorbs a neutron and splits into two new fission fragments, releasing three new neutrons and a large amount of binding energy. An atom of Uranium-238 absorbs one of these neutrons and does not continue the reaction, while another neutron leaves the system unabsorbed. The single neutron left collides with an atom of Uranium-235, which in turn splits and releases two neutrons and more energy. The two neutrons then collide with Uranium-235 atoms, each of the uranium atoms splits and releases few neutrons, which can then continue the reaction. This nuclear chain reaction occurs when a single nuclear reaction leads to one or more subsequent reactions, thereby leading to a self-propagating series of reactions. The energy released during a nuclear chain reaction is several million times greater than that released during any chemical reaction, see Fig. 4.

Storing and monitoring the radioactive waste materials demands a very high cost.

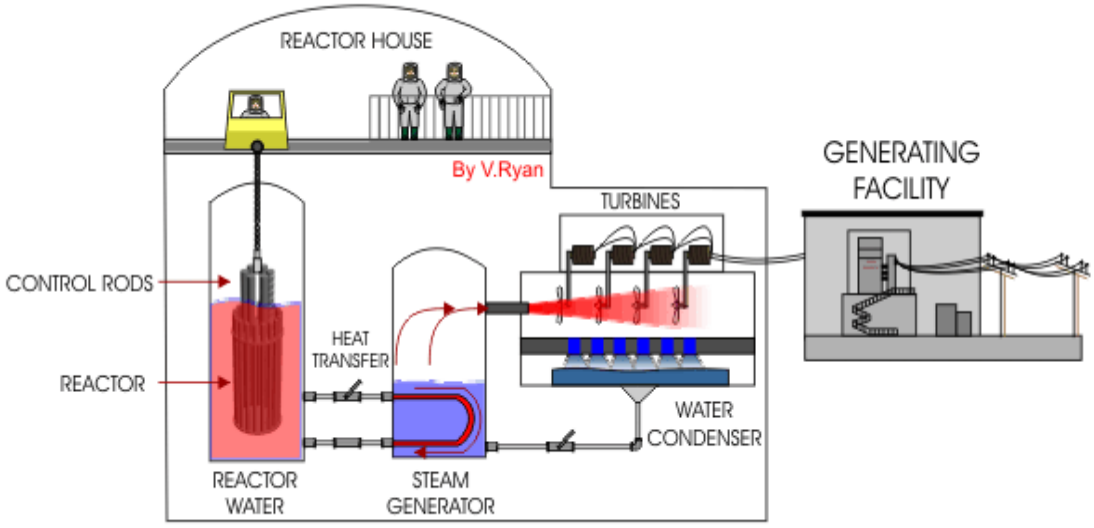

Fig. 4. Nuclear power generation plant [14]

4.3.1 Effects on the environment

⇒ Nuclear powered ship and submarines pose a danger to marine life and the environment. Old vessels can leak radiation if they are not properly maintained or if they are dismantled carelessly at the end of their working lives.

⇒ People living near nuclear power stations or waste storage deport are prone to nuclear accidents and radioactive leaks. Serious accidents have been recorded concerning a small number of nuclear power stations. The accident at Chernobyl (Ukraine) in 1986, led to the death of 30 people with over 100,000 people being evacuated. In the later years, another 200,000 people were resettled away from the radioactive area.

⇒ Radiation was even detected over a thousand miles away in the United Kingdom as a result of Chernobyl accident. It was discovered that over time, 2,500 people died as a result of the accident [15].

⇒ Nuclear power plants use large quantities of water for steam production and for cooling. Some nuclear power plants remove large quantities of water from a lake or river, which could affect fish and other aquatic life [16].

⇒ Waste generated from uranium mining operations and rainwater runoff contaminate ground water and surface water resources with heavy metals and races of radioactive uranium [16].

4.3.2 Possible solutions

The possible solutions to minimizing the risk of nuclear power generation include:

⇒ Dramatically improving efficient energy use and green house gas emissions intensity by updating technology and functionality through its entire life cycle.

⇒ Eliminating all radioactive wastes at the end of its life and minimizing the environmental impact during the nuclear fuel cycle.

⇒ Improving nuclear security to reduce nuclear power risk and making sure that the nuclear industry can operate without large public nuclear accident insurance subsidies [15].

⇒ To minimize the effect of this method of power generation on aquatic life, power plant operators should install and maintain proven fish protection technologies, depending on the species in the habitat, kind of water body, geographic location of the plant, etc [17]. Such fish protection technologies include:

- Physical barriers which prevent fishes from entering the intake structure,
- Collection systems (e.g. baskets) that gather the fishes and transport them to a recovery pond where canals help them to return to their habitat,
- Diversion systems which direct fish away from the intake structures, etc.

4.4 Natural Gas

Natural gas is a fossil fuel formed when layers of buried plants and animals are exposed to intense heat and pressure over millions of years. The energy that the plants and animals originally obtained from the sun is stored in the form of carbon in natural gas. Natural gas is combusted to generate electricity, enabling the stored energy to be transformed into usable power. Natural gas is a non-renewable source of power generation because it cannot be replenished on a human time frame.

The process of power generation from natural gas begins with the extraction of natural gas, followed by its treatment and transport to the power plants and it ends with its combustion in boilers and turbines to generate electricity.

The process is explained as follows:

Initially, wells are drilled into the ground to remove the natural gas. After the extraction, the natural gas is treated at the gas plants to remove the impurities such as hydrogen, sulphide, helium, carbon dioxide, hydrocarbons and moisture. Pipelines then transport the natural gas from the gas plant to the power plants.

Power plants use several methods to convert gas into electricity. One of the methods is to burn the gas in a boiler to produce steam which is used to drive the steam turbine to produce electricity. Another method is to burn the gas in a combustion turbine to generate electricity [19], see Fig. 5.

4.4.1 Effects on the environment

The burning of natural gas has series of effects on the environment, they are as follows:

⇒ Air emissions: at the power plant the burning of natural gas produces nitrogen oxides and carbon dioxides, though in lower quantities than that of coal or oil. Also, sulphur dioxide and mercury compounds are emitted in negligible amounts.

⇒ Methane is a primary component of natural gas and a green house gas. This can also be emitted as the result of incomplete combustion of natural gas. It can also be emitted as a result of leaks and losses during transportation.

⇒ Natural gas-fired boilers and combined cycle systems require water for cooling purposes. When power plants remove water from water bodies, fishes and other aquatic life can be killed, thereby affecting animals and people who depend on these aquatic resources [19].

⇒ The extraction of natural gas and construction of natural gas power plants can destroy the natural habitat, which is home for plants and animals. Other effects include erosion, loss of soil productivity and landslides.

⇒ Hydraulic fracturing is linked to low-magnitude seismic activity usually undetectable at the surface. However, injection of fracking waste water at high pressure into deep Class II injection wells has been linked to larger earthquakes in the United States (injection-induced seismicity) [20].

4.4.2 Possible solutions

The following solutions are suggested to the above listed problems:

⇒ Mandating the strongest well siting, design, construction and operation standards and best drilling practice.

⇒ Public disclosure of information regarding chemicals being used in fracking process should be fully mandated [21].

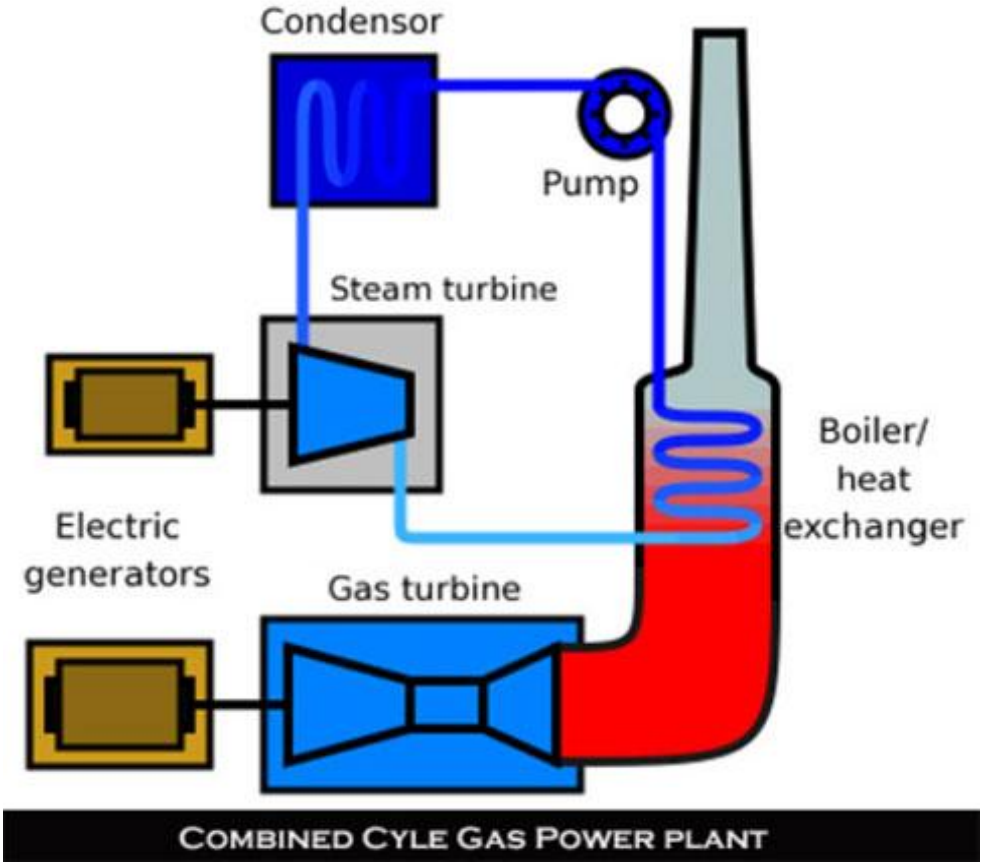

Fig. 5. Natural gas power plant [18]

4.5 Solar

Due to technological improvements, solar energy has experienced phenomenal growth in recent years. This results in reduction in the cost of energy production and utilization. Solar energy represents our largest source of renewable energy supply. Power is generated from the sun by the use of photovoltaic cells, which convert the radiation from the sun into Direct Current (DC) power. The DC power can then be converted into Alternating Current (AC) power and it is then fed into the grid, see Fig. 6. Although the cost of production of solar photovoltaic power is high, it is a clean source of power supply and can be a very good alternative to fossil fuels.

Also, we have a concentrated solar power. This technology makes use of various types of mirrors to concentrate sunlight energy and produce heat. This heat is used to generate electricity in a standard Rankine cycle turbine. Like most thermoelectric methods of power generation, this consumes water. The major problem that arises from this method is the fact that solar power plants are commonly located in the desert environment due to the need for sunlight and large expanse of land. Many concentrated solar systems also use exotic fluids to absorb and collect heat while remaining at a low pressure. This fluid could be dangerous if spilled [22]. Solar power is a renewable source of power generation and provides a clean source of energy generation, as the new manufacturing process does not contribute to environmental pollution.

4.5.1 Effects on the environment

⇒ The exotic fluids used by concentrated solar systems could be dangerous if spilled [22].

⇒ Manufacture of solar cells primarily from silica (from sand) imposes a negative impact on the environment because the extraction of silicon from silica requires the use of fossil fuels, which contributes to air pollution through the production of carbon dioxide.

4.5.2 Possible solutions

⇒ Proper care should be taken when dealing with the exotic fluids used in concentrated solar systems, so as to avoid its spillage.

⇒ The new manufacturing process employed in the manufacture of solar cells from silica have eliminated CO_2 production, therefore, the new manufacturing method should be employed.

4.6 Wind

The wind flow, when trapped by the wind turbine, can be used to produce mechanical power. Wind turbines convert the kinetic energy in the wind into mechanical power. The wind turbine, like the aircraft propeller blades, turns in the moving air and power an electric generator which, in turn, supplies electric current. Wind turbine uses wind to make electricity. The wind turns the blades, which spins a shaft that connects to a generator and produces electricity, see Fig. 7. Wind energy can serve as an alternative to fossil fuels. Wind energy is clean, environmental friendly, and cheaper compared to other sources of renewable energy. It protects the earth from atmospheric contamination. It was also found that wind energy has minimal impacts on the habitat compared to other sources of energy. It doesn't produce green house gas emissions during operation and it uses little expanse of land.

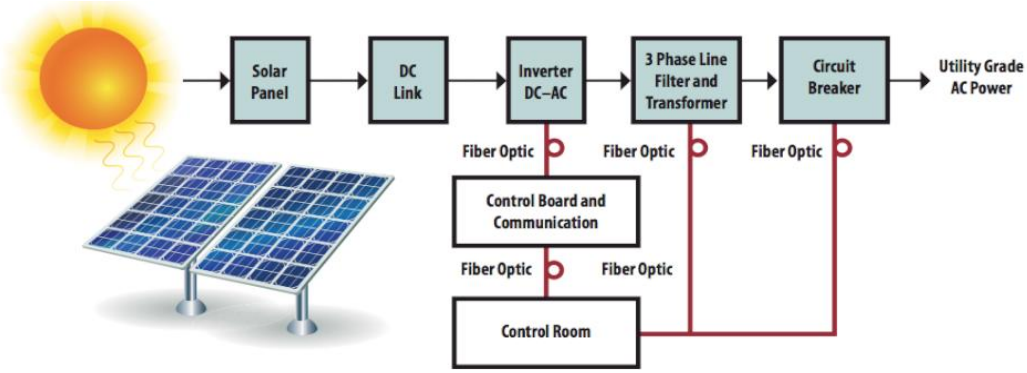

Fig. 6. Solar power plant

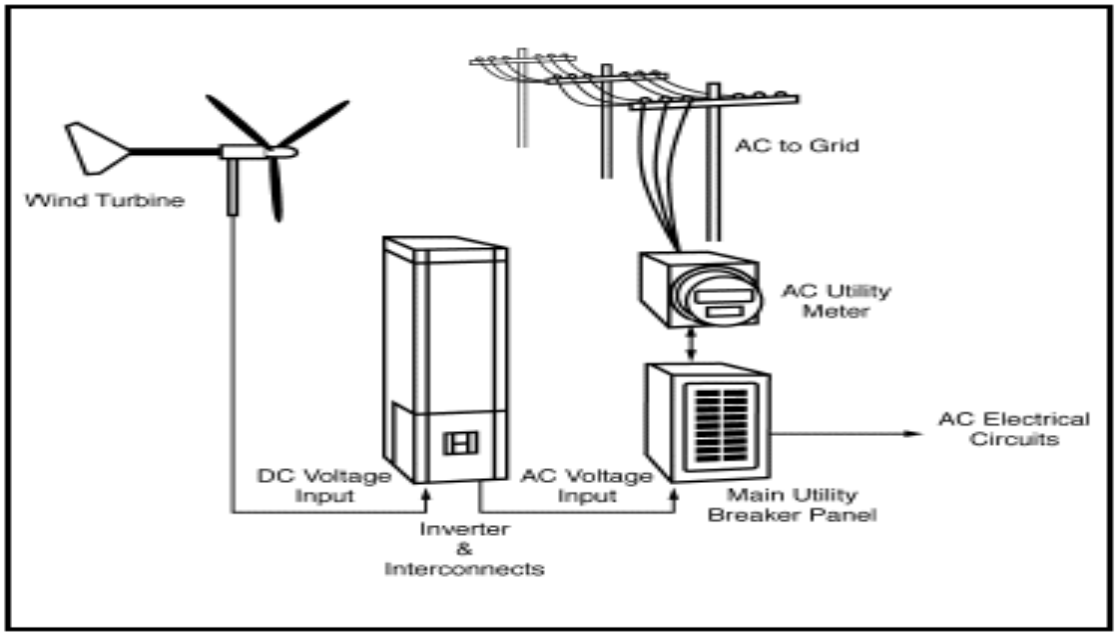

Fig. 7. Diagram of a grid-tied wind electric system
(Source: Phantom Electron Corp)

Arrays of large turbines have become an increasingly important source of renewable energy and they are used in many countries as a strategy to reduce their reliance on fossil fuels.

Wind turbines are manufactured in a wide range of horizontal axis and vertical axis types. The smallest turbines are used for applications such as battery charging for auxiliary power. Slightly large turbines are used for making small contributions to domestic power supply. Although wind turbines have contributed positively to the environment, it also has few negative impacts, which are discussed below.

4.6.1 Effects on the environment

- ⇒ People who live very close to wind turbines are prone to negative health effects due to the noise pollution caused by the turbines [23].
- ⇒ The siting and location of the turbine affects wildlife and their habitats. It has been discovered that wildlife (e.g. migrating birds) is killed on collision with the wind turbines [24].
- ⇒ Aesthetic aspect of wind turbine and resulting changes of the visual landscape are significant [25].
- ⇒ Most migrating birds that are less versatile in flight or have poor sight and might not be able to alter their flight paths accordingly. This can lead to the collision of the birds with the turbine [26].

4.6.2 Possible solutions

- ⇒ Wind turbines should be sited at a far distance from residential areas and property lines in order to minimize noise pollution and to enhance the safety of the people living in the neighbourhood [27].
- ⇒ The location and operation of the turbine should be modified so as to avoid or minimize its impacts on threatened species and their habitats [28].
- ⇒ Before building wind turbines, engineers should be conversant with the types of noise a wind turbine produce so as to know the prevention method to apply. The types of noise produced by a wind turbine are divided into two; mechanical and aerodynamic noise.
- ⇒ Mechanical noise, which is produced by the moving components such as gear box, electrical generator, and bearings as a result of wear and tear, poor component designs or lack of preventative maintenance. It can be minimized at the design stage by using side-toothed gear

wheels, and it can be reduced during operation by using anti-vibration support footings and acoustic insulation curtains [27].

⇒ Aerodynamic noise is developed by the flow of air over and past the blades of a turbine. This type of noise increases with increase in the speed of the rotor. Aerodynamic noise can be reduced by careful design of the blades by the manufacturers who can minimize this type of noise [29].

⇒ Wind farms should not be sited along known important migration paths for the birds. Also, wind turbines should be larger and further distance apart, offering flight corridors [26].

4.7 Geothermal

It involves the drilling of wells; perhaps a mile or two in depth in search of rock temperatures in the range of 300 to 700° F. The heat energy is converted into electricity at a geothermal power plant. Water is pumped down this well where it is reheated by hot rocks. It travels through natural fissures and rise up a second well as steam, which can be used to spin a turbine and generate electricity [30], see Fig. 8.

4.7.1 Effects on the environment

⇒ In open loop system, geothermal power plant produces hydrogen sulphide (which has a distinctive "rotten egg" smell), carbon dioxide, ammonia, methane and boron. When hydrogen sulphide changes to sulphur dioxide (SO_2), it contributes to the formation of small acidic particulates that can be absorbed by the blood stream and causes heart and lung disease [31]. SO_2 also causes acid rain, which damages the vegetation and acidifies the lakes and streams.

⇒ Water mixed with the steam from geothermal power plants contains dissolved salts that can damage pipes and harm aquatic ecosystems. Some subsurface water associated with geothermal sources contain high concentrations of toxic elements such as boron, lead and arsenic [32].

⇒ Other effects include the drying out of hot springs, soil erosion, noise pollution and chemical pollution of the atmosphere, surface and ground waters [33].

4.7.2 Possible solutions

The following solutions are suggested:

⇒ Stations experiencing high levels of acids and volatile chemicals should be equipped with emission-control system to reduce the exhaust. The gases can also be injected back into the earth as a form of carbon capture and storage.

⇒ Scrubbers can reduce air emissions if used and the sludge produced from it must be disposed of at hazardous waste sites [34].

4.8 Biomass

This refers to vegetation used as fuel or source of energy. They are used to generate electricity by providing direct heat and can be converted into biofuel as a direct substitute for fossil fuel, see Fig. 9. It is derived from wood waste, landfill gas, crop and alcohol fuels. Traditional biomass, including waste woods, charcoal and manure has been a source of energy for domestic cooking and heating throughout human history.

4.8.1 Effects on the environment

⇒ 75% of existing biomass plants requires cooling using wet-recirculating technology while 25% of the plants use once-through cooling technology. For both methods, when cooling water is returned to its source from where it was taken, it is much warmer than when it was taken from the source and this often has negative impacts on plant and animal life [36].

⇒ Burning of biomass to produce electricity can affect the air quality. Pollutants emitted during combustion of biomass include NO_x, SO_2, CO, and particulate matter. NO_x emission causes smog which causes the burning of lung tissue and makes people more susceptible to chronic respiratory diseases such as asthma, bronchitis, etc. SO_2 and NO_x also lead to acid rain.

4.8.2 Possible solutions

⇒ As an alternative to wet-recirculating and the once-through cooling technologies, dry-cooling systems could be employed, as it does not withdraw or consume any water [36].

⇒ Net zero global warming emissions can be achieved if forest managers harvest in sustainable manner and replant with fast-growing tree species [37].

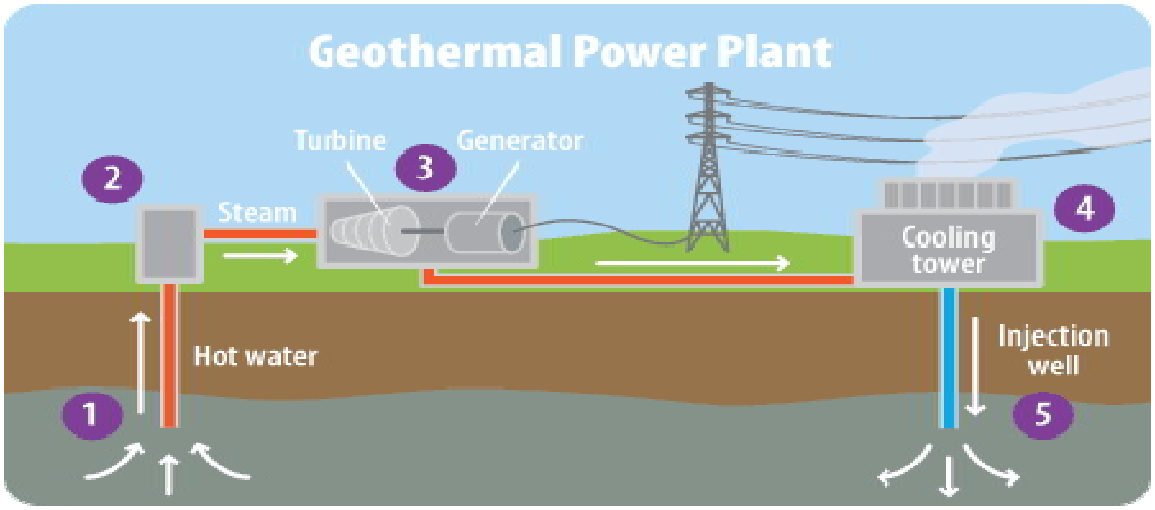

Fig. 8. Geothermal power plant

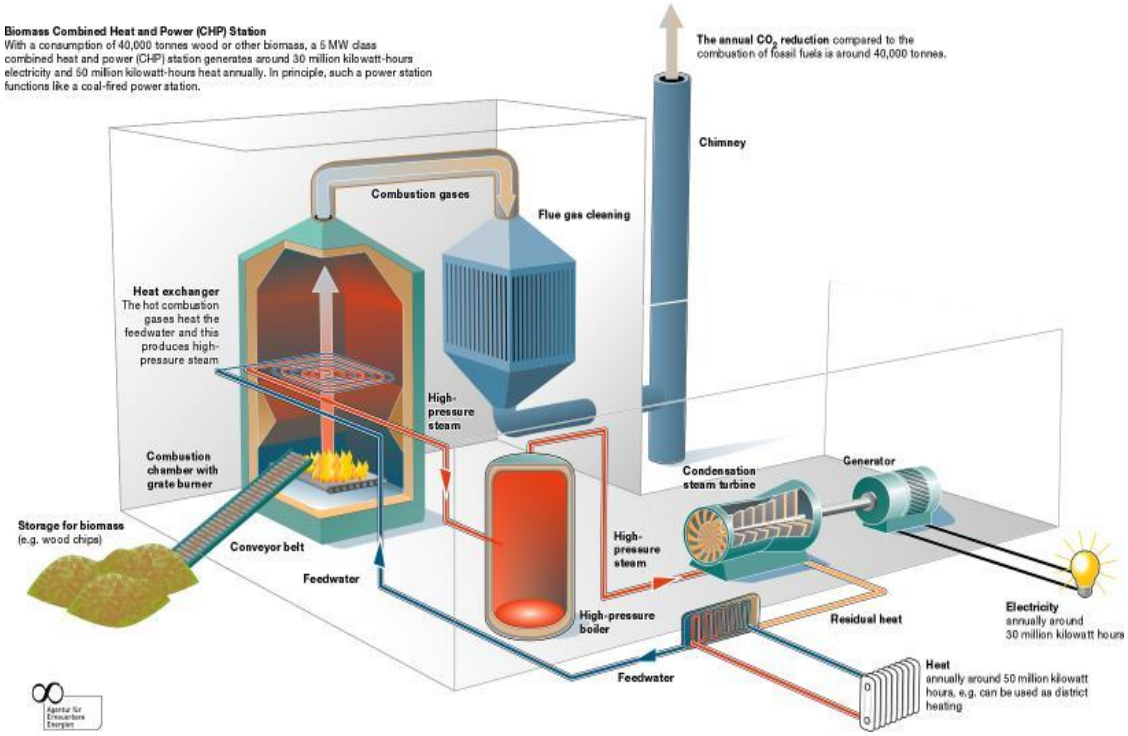

Fig. 9. Biomass combined heat and power station [35]

5. CONCLUSION

From the research carried out, it has been clearly noticed that the renewable sources of energy are the safest sources of generating electricity. This is due to the fact that they are much more environment friendly than other sources of power generation. Although safe, it is not solely relied upon for power generation; therefore, other sources like the natural gas, coal, oil, etc are also being utilized for effective power generation.

Industrialization thrives well in a country with stable electric power supply; therefore, a major key that can boost Nigeria's development is stable Electric power supply. But unfortunately,

the electricity supply in Nigeria is characterized by frequent power failures and load shedding, thereby making the lack of stable electric power supply one of the biggest problems faced by Nigerians. According to Emovon et al., the total grid capacity was 8,876 MW but only 3,653 MW was available as at December 2009. This however shows that the available power is less than 41% of the total installed capacity [38].

Unhealthy electric power supply affects numerous sectors which cannot do without electricity in the country such as the telecommunication, water supply sector, health sector, etc. Problems encountered during power generation include; inadequate funding, poor maintenance plan, lack of adequate manpower, poor inventory management, poor location, etc. therefore, to boost the economy of this country, adequate attention needs to be given to the power generation sector.

In Nigeria, electrical power losses in transmission and distribution is due to very long and over-aged transmission and distribution lines, unequal phase loads, inadequate reactive compensation and energy theft. However, control measures proffered to these problems of power losses include undertaking regular energy audit, introducing more substations, implementing pre-paid metering systems, using conductors of appropriate sizes and re-aligning the lines [39].

Furthermore, some power policies have been recommended. They include: fully accounting for energy generated and distributed, enforcement of strategic marketing of power, deterring energy theft and meter tampering [39].

Finally, to ensure a bright future for the Nigerian power sector and a sustainable power generation, the following measures are suggested:

- Encouraging foreign participation in the power sector, based on experience, financial capacity and performance record [40].
- Set up an effective environmental agency for carbon emission control.
- The loading of transmission and distribution transformers should be reduced. That is, number of consumers per transformer should be trimmed down to about 10 consumers per distribution transformer [41].
- The sources of fuel for electricity generating stations should be diversified i.e., instead of relying solely on oil, gas and hydro potentials, we should also make use of coal, uranium, biomass, wind, solar, etc. [41].

The Nigerian educational sector contributes to the effectiveness of the Nigerian power sector, as the technical and vocational education specializes in

- ✓ Providing students with skills, knowledge, and attitudes needed to prepare them for employment in occupation/career for national development [42].
- ✓ Helping young people to develop occupation competencies for industrial work [42].
- ✓ Building and training skilled manpower needed in the power sector.

Furthermore, the reforms in the power sector, power roadmap, and privatisation in the power sector promised radical changes in the power sector and electricity delivery to the citizens and it indeed signalled significant policy inputs [43].

There are however, some laws which relate primarily to the protection of the whole/part of the physical components of the environment. These are called the environmental laws/legislation. Some of these laws are stated in the acts below:

Nuclear Safety and Radiation protection Act CAP N142, LFN 2004.

- → Section 4 provides the authority to make regulations for the protection of the environment from harmful effects of ionizing radiation [44].
- → Section 40 emphasizes that the same regulations guiding the transportation of dangerous goods by air, land or water should also apply to the transportation of radioactive substances [44].

Petroleum Act, CAP P10, LFN 2004.

- → Section 17(1)(b) places restriction on licences from using land within fifty (50) yards of any building, dam, reservoir, public road [45].
- → Sections 23 and 27 prohibit the cutting down of trees in forest reserves without lawful permission [45].

Moreover, companies operating within the energy production schemes help in the provision of infrastructures in the communities e.g., clinics, and provision of portable water in order to prevent the intake of polluted water, which is harmful to the human health [45]. They also power programs like the “Health Scheme”

These acts are measures to protect the environment from pollution and make it friendly to the inhabitants.

6. RECOMMENDATIONS

Considering the various methods of power generation that were discussed, the following recommendations were drawn:

- ⇒ To choose a method of power generation, the location must be put into consideration, i.e., they should be located in areas that will be favourable for adequate power generation.
- ⇒ Refined coal should be used in order to minimize the harmful effects caused by the emissions from coals; also the combustion temperature of the furnace in electric power plant should be lowered as a viable control strategy for nitrogen oxides (NO_x) emission.
- ⇒ Hydroelectric power generating plant should be located in an area with adequate water supply, e.g. rivers, seas, ocean, etc.
- ⇒ Technology and its functionality should be updated in order to increase efficient energy use and reduce green house gas emissions intensity
- ⇒ The best drilling practice should be employed during natural gas collection.
- ⇒ Solar power generating plant should be located in an area with intense/sufficient exposure to the sunlight, e.g. deserts, temperate regions, etc.
- ⇒ Wind mills should be located far from residential areas due to noise pollution, and it should be located in windy areas.
- ⇒ When employing the geothermal means of power generation, scrubbers should be used so as to reduce air emissions.
- ⇒ Forest managers should harvest trees in sustainable manner and replant with fast-growing tree species.
- ⇒ To ensure adequate power generation and a problem-free/pollution free environment, the various risks involved in using the various methods of power generation should be put to consideration before deciding whether to use them or not.
- ⇒ In the planning and implementation of all aspects of the power sector reform program in Nigeria, the Nigerian engineers should be adequately represented.
- ⇒ Structured maintenance and adequate funding of the power sector should be ensured.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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