POWER GENERATION IN BOTSWANA, EXISTING AND ALTERNATIVE MEANS THE SOCIO-ENVIRONMENTAL IMPACTS

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ABSTRACT
The need for power and the awareness of the effect of different energy sources on the environment has grown significantly. This results in the need for better, wiser and cleaner ways to generate the much needed power. There are different energy sources that can be used to generate power and these include coal, water, wind, solar, gas, fossil fuels, and nuclear. All these and others have effects on the environment on different levels, and this may be in the gases/fumes produced, the after reactions that is the slug or slurry, ashes. The other factor about these sources of energy is that most of these are non-renewable and are commonly used in the generation of power and are most likely to become extinct.

This paper addresses methods currently used to generate power in Botswana, which is the use of coal. Since the history of power generation in Botswana this has been the only means of producing electricity. Thermal Power Station like any other power generating plant have its advantages and disadvantages, thus this paper will cover how the power is generated, conservation strategies, conversion of the coal to produce the electricity and its impact on the ecosystem.

The paper will also address the alternative sources of energy that the nation of Botswana can use for power generation which are both ecosystem friendly, clean and do not require much activity. Since the focus is Botswana these sources which are solar, CBM, biogas are in abundance.

KEY WORDS

1. Introduction

Energy is the fundamental precursor of all systems and life in general. Nothing can live without energy and no equipment can move without it in all its various forms. Every economy is dependent on energy to drive its success. In Botswana the major contributor to the national economy, the mining industry, needs energy to drive their process equipment and this energy is in the form of electrical power. Therefore, it is quite evident that power systems are a very critical subsystem of a country's infrastructure and/or their absence or inefficiency is inevitably detrimental to the economic development of the country.

The power generating plants in Botswana are the two Morupule Power stations, namely Morupule A and the newly built multi-billion Pula Morupule B station. All being thermal power plants, these two stations use coal as their primary fuel from the adjacent Morupule Coal Mine (Former Morupule Colliery).

The possibility of alternative sources of energy for power generation is available but underused. Exploring them will be beneficial and will take Botswana to greater heights in diversifying and generating income for future developments

1.1 Power Production Process

The power production process is a complex thermodynamic one with various forms of energy conversions. As already mentioned, Botswana’s power stations are the thermal type of power plants using the external combustion engine process done in the boiler to create steam which turns a steam turbine. These two plants employ different boiler technologies with Morupule A adopting the Pulverized Fuel (PF) boiler technology and Morupule B adopting the Circulating Fluidized Bed Combustion (CFBC) boiler technology. Consequently, the power production process slightly differs for the two plants especially on the aspects of fuel used, emissions control technology and the fluid mechanics inside the boiler furnace. Both power plants utilize the same energy conversion process from chemical energy stored in coal to heat energy in the furnace. This heat converts to mechanical energy in the turbine and lastly this mechanical energy changes to electrical energy in the generator. The power plants differ in terms of generation capacity, with Morupule A having four units of 33MW
capacity each, summing up to a station capacity of 132MW. Morupule B also has four units of 150MW capacity and a station capacity of 600MW.

With Morupule A’s PF boiler technology, there are three raw materials involved in the production of power. These are Coal, Water and Heavy Fuel Oil (HFO). Coal the primary fuel, is obtained on a contractual basis from the Morupule Coal Mine via a 1.5km overland conveyor belt. The coal is then ground in the coal mills to a powdery form known as Pulverized Fuel and later fed into the boiler furnace through the assistance of a primary air fan. Water is pumped from 10 boreholes in Paje, collected into a main tank and fed to the power station through gravity in favour of the land topography. The water is then treated into de-mineralized water in the water treatment plant and used as boiler feed water. This water is heated inside the boiler into steam which will be used to turn the turbine which is rigidly coupled to the generator and hence it will also be driven. Heavy fuel is procured from South Africa and transported to the station by train and tanker trucks. This HFO is used as start-up fuel for the boiler because of its low ignition point and also in the furnace burners to support the fire in the event of flame instability.

The Morupule B’s Circulating Fluidized Bed Combustion boiler technology is a newly adopted technology in Botswana and is the first of its kind in Southern Africa. Complex in its scope, the technology facilitates a very ozone-friendly platform with effective emission control systems put in place. The raw materials used in this boiler include Coal, Water, Limestone, Diesel and Bed Material in the form of sand.

Coal, as for the Morupule A station is from the Morupule Coal Mine. The coal is also ferried via a 2km overland conveyor belt and it is crushed to 10mm silhouette diameter in the crushers before being conveyed to the boiler bunkers from where it is gravitationally fed into the furnace past the coal feeders. Water is also pumped from Paje well-fields, treated to de-mineralized water in the water treatment plant and used as boiler feed water. This water is heated in the boiler to produce steam which drives the turbo-generator unit. Limestone is acquired from South Africa on a 30/70 % basis, 30% by road and 70% by rail. This limestone is also fed into the boiler furnace. Its primary function is to de-sulphurise the products of combustion from the furnace. The chemical reaction between all the oxides of sulphur and nitrogen (SOx and NOx) and limestone removes these ozone harmful gases before they exit the furnace. This ensures a very low carbon footprint in the atmosphere and therefore reducing global warming. Bed Material in the form of sand is also fed into the furnace to help in the disintegration of coal particles and furnace temperature control. All these form the fluidized bed which is fluidized by the high pressure fluidizing fans. The high pressure fans facilitate turbulence in the furnace and hence creating optimum combustion conditions and high fuel efficiency as the coal will be broken into smaller fragments with increased surface area.

Each boiler has two cyclone separators which separate combusted material depending on density of the material.
The lighter materials go out through the overflow pipe together with flue gases into the flue gas duct, past the Electrostatic precipitator (ESP) to the stack. The ESP removes fine ash from the flue gases before they go to the atmosphere. In the cyclone separator the heavier material slide down against the cyclone walls into the underflow duct and they are returned back into the furnace via the U-valve. This is normally coal which was not burnt completely and therefore it is circulated back into the furnace for further burning hence the name Circulating fluidized bed. This technology enhances boiler thermal efficiency at the same time reducing the carbon footprint value in the emissions via the emission control systems of ESP and Limestone addition for de-sulphurization. The last raw material for Morupule B plant is Diesel oil which is used in the induct burners for boiler start-up and fire support during flame instability.19[10]

1.2 Environmental Impact
As much as power is needed for any country’s economic thrive, the environment should not be jeopardized beyond reasonable limits. The flora and fauna are the first to be affected as they are displaced from their habitat during bush-clearing and construction of the power plant. Botswana Power Corporation recognizes its responsibility to minimize and mitigate all the impacts that can cause adverse effects to the environment through its operational activities. They have programmes in place to improve energy consumption and waste management.

The most detrimental impacts to the environment are the results of dangerous emissions and contaminated used oil which in the long run pollute underground and surface water.

Uncontrolled emissions in the form of sulphur oxides and nitrogen oxides have a very catastrophic effect on people as they can cause lung diseases including cancer and other respiratory diseases when breathed in. The production and release of carbon oxides or greenhouse gases in abundance will result in global warming which is catastrophic in the sense that it will end up raising the sea level by dissolving the icebergs. Therefore if proper emission control measures are not put in place for thermal power plants then they will be a contributing factor to the extinction of the human race as a result of global warming and acid rain which occurs when Sulphur and Nitrogen oxides reacts with rain water to produce sulphuric acid and nitric acid. This will raise the pH levels of surface water and eat away at the vegetation.

Fine ash from the furnace, if not trapped in the precipitator will eventually settle down on tree tops and slow down the process that removes carbon dioxide from the atmosphere (photosynthesis), and this will result in global warming due to the abundance of CO2. This is curbed by the use of multi-zoned Electrostatic precipitators to trap the ash in sequential steps further refining the flue gases as they move towards the stack. Fortunately for Morupule power stations stringent measures are put in place and the carbon footprint is within the allowable limits.

The other major pollutant is used oil and various chemicals used in the plants which may not be properly disposed of. These end up seeping down into the ground and polluting underground water. Some of these end up in the dirty water and storm water drains and this means they can be taken to nearby rivers and thus pollute surface water. This puts the lives of neighbouring communities and their livestock at stake. Most of the industrial and sanitary waste water from the station is pumped to a nearby waste water pond adjacent to Morupule A power station. Along the delivery pipeline there is an oil trapping mechanism to capture all the oil that might be carried away with waste water as a means of controlling pollution.

Management of the Morupule power stations has taken the pollution factor into much consideration and installed various pollution monitoring boreholes around the station to monitor the pollution trend lines over the years as caused by the station. The chemical department is responsible for taking samples at these boreholes and performing various tests to determine the level of pollution and the pollutants. The majority of these boreholes are strategically located towards the Eastern side of the plants because the Morupule land topography is low on the East and higher on the Western side towards Serowe. This automatically implies that most of the underground water will flow towards East together with its pollutants so that is where a real picture of the underground water pollution effect can be obtained.
Another pollution area which is normally overlooked is the ash lagoons. This is a major concern in the authors’ view in the sense that those ash lagoons are formed by slurring ash. This slurry is a mixture of dirty water and ash and therefore the chemical composition is not favourable at all to the environment. Dirty water is not treated so its pH levels may be higher or lower than normal. Ash is acidic with a pH level of about 5. At the lagoons the slurry is stagnant and this can only mean that the water seeps down into the ground with a very high pH level. This can have two effects; pollution of underground water by changing its pH value and an increase in the normal underground water stored in the water table thus facilitating landslides in the future.

1.3 Social Impact

The social impacts of the power stations on the neighbouring communities are many, some negative and some positive. Power generation process plants are large and require a lot of manpower therefore this creates jobs and thus empowers the community as most of them can afford to put food on their tables. The infrastructural development also improves as there are various projects associated with the construction of any big project like internal roads, recreational facilities and even housing projects. There is also an influx of people into the community who are employed to work in the power plants and this is a bonus to businesses in the neighbouring communities in the form of shops, taxis, banks just to mention a few. The business growth as a result of more customers results in a need for increase of staff members in those businesses to meet the demands and as such improving employment opportunities for the community.

Nevertheless, there are negative social impacts of these power plants on the neighbouring and surrounding communities. It is quite evident that the power plant industry is a male dominated sector and as such the influx of men into the community is overwhelming. This brings along an increase in the rate of new sexually transmitted infections, more families break up as a result of infidelity due to the unbalancing ratio of men to women in the community. The plant employees have more purchasing power and they are many, this results in increased demands of commodities and increased customer purchasing power. As a consequence the prices of commodities in the market increases and thus negatively affecting those commoners with low purchasing power who do not work in the power plants.

2. Alternative Forms of Energy

There are different alternative sources of energy that are available to generate power, some are renewable and others are non-renewable. The renewable sources include solar, wind and water. Botswana has infrastructure limitations and does not have the ability to use all of these natural resources to generate her power. It would have been very beneficial to the environment and the economy of Botswana if these measures of alternative energy were to be taken into consideration.

The use of wind to generate electricity in Botswana cannot be pursued on a large scale because the wind speed
or strength is not strong enough for turning the windmills. The annual average speed of wind is 2-4m/s \textsuperscript{[3]} which is not enough to generate power that is enough for the nation, again it will be expensive to set up such a station.

Hydroelectric Power (HEP) stations are not set up in Botswana because is a landlocked country, her rivers are not all perennial and the rainfall is inadequate to sustain this method of power generation so water is a scarce resource. The perennial flow that is available in Botswana is at the Okavango which is a tourist attraction centre and hence cannot be used to build dams for HEP. The available dams do not have enough capacity and ability to produce the water draft that is strong to produce power.

2.1 Solar Energy

Solar energy is the cleanest of all renewable energy sources that nature has to offer. Botswana experiences about 280-330 sunny days annually, the average of which is 21MJ/m\textsuperscript{2} a day \textsuperscript{[3]}. This rate is among the highest in the world. This being the case, the use of solar energy as an alternative source to produce electricity has vast potential and is ideal for rural areas in the country. Currently the main source of power in Botswana is coal, for the two Morupule Power Stations, which though have carried this nation for many years have their effect on the environment such as the greenhouse effect and hence global warming. Solar energy mitigates these greenhouse gas emissions produced by the current fossil fuel processes being used.

The use of solar energy as an alternative for this country is essential because not only is it clean but it will increase energy sustainability and self-sufficiency for Botswana, that is to say it is one of the platforms for sustainable development of Botswana. It also will increase energy security-it could be a backup source of energy if the power stations were to fail or since coal is non-renewable will come to its extinction and to lessen the need to import power.

Despite its vast potential and so many advantages solar power usage still remains insignificant in Botswana. It is normally and mostly used for solar water heating systems in homes, hospitals and other small scale electricity generation. This reduces demand on the electricity produced by Morupule Power Stations. Botswana Power Corporation Lesedi (BPC Lesedi), being one of the organisations in Botswana that works on alternative energy has implemented ways of benefiting from solar energy by creating and launching systems like the lantern charging systems where they provide lamps that use rechargeable batteries and are charged for use at homes, and remote areas where BPC transmission lines do not reach. Other enforced systems are the micro grid installation in some villages in Botswana, and also the rented photovoltaic (PV) electric systems where the people do not own the systems and BPC Lesedi provides them.

Botswana has the potential to start and fully operate a Solar Power station, but because of some limitations that could be easily rectified, it has not ventured into it even though research has been made that shows the possibility and advantage of such work. Soliciting funds and manpower to build and run a solar power station is the main concern, because it is expensive to build such a solar power station that can supply the nation. However, the advantage is that once it is built it does not require too much attention and maintenance and can run fully to generate and store power.

2.2 Coal Bed Methane

The coal bed in Botswana is vast in the North Eastern part of the country, and there is a large quantity of the methane gas as estimated by the developers at a commercially viable quantity of more than 12 trillion cubic feet. It also covers an area of about 3000km\textsuperscript{2} in the central district. It has been mined on a very small scale, and the development of such has been slow, so most of it is released into the atmosphere \textsuperscript{[5]}. In the exploration area tested, the potential for coal bed methane (CBM) was found to be 60Tcf \textsuperscript{[4]} and the associated carbonaceous shale had an additional 136Tcf; the more realisable quantity was about 12.8Tcf. Of this gas 15-20\% can be developed \textsuperscript{[6]}. It is believed 18\% of the greenhouse effect is caused by methane, putting it second on the list of offending gases behind carbon dioxide. Methane breaks down in the atmosphere to form carbon dioxide, ozone, and water, all of which absorb heat resulting in the temperature of the atmosphere rising-hence Global Warming \textsuperscript{[1]}. An Australian Petroleum and Exploration Association released a report stating that CBM has up to 87\% less greenhouse gas emissions as compared to coal \textsuperscript{[2]}. The result of this report shows that even though coal is our main source of energy for power generation it is harmful to this extent hence the need to mine and utilise the methane. The gas can be used in power generation for running turbines.

The 90 MW Orapa Power Station Operates on turbines known as Dual Fuel or Dual Fired turbines, that is to say they have the capability to operate either on diesel and or open cycle gas (methane, CH\textsubscript{4}) but the plant is currently operating using diesel as its main fuel to produce the electricity that is put in the BPC grid. The use of diesel is significantly expensive in the sense that not only does the plant use 35000 litres of diesel per hour \textsuperscript{[6]}; the price of diesel is high coupled with the economically catastrophic
oscillations in the price of oil, which are unreliable. Because of this fact the power produced by diesel in Orapa is expensive and hence cannot be afforded by many in this developing country. The sooner the plant uses CBM to generate power the better for the country’s economy, self-reliance and the nation citizens at large. Experts have shown that the use of CBM will cut cost for both BPC and the government by 60% [6].

Although CBM is non-renewable when explored and mined will be a beneficial alternative energy source not only for power generation but it could be used to produce liquid fuels. The mining of methane is environmentally friendly because if it is let to be released into the atmosphere the impacts may be irrevocable. In that there will be an increase in greenhouse gas emissions and these consequently will lead to global warming.

2.3 Biogas

Biogas production can be obtained from the anaerobic fermentation of dung, most preferably cow dung since it contains more methane gas of about 50-70% than any animal excreta [7]. In the year 2004, it showed that the population of cattle in Botswana was way more than that of people, it was at 1,700,000. Other livestock populations including sheep, goats, donkeys, poultry, horses sums to tens of millions [5].

![Image of a biogas digester]

Figure 3: A typical drawing of a Biogas Digester [11]

With the population of livestock available in Botswana a biogas plant can be raised to trap, and harvest methane. Currently Botswana has only one company Rural Industries Innovation Centre (RIIC) which has built an underground plant to harness biogas using cow dung. The use of this gas is small scale and limited to cooking and not for power generation.

Biogas is a combination of biological gases, Carbon dioxide, Methane, Nitrogen. This process provides a better disposal of organic waste and results in reduction of greenhouse gas emissions of which methane is the most potent. When the biogas is purified by the removal of CO₂, Nitrogen and other gases, methane gas remains and it can be used to generate electricity. Biogas production can be carried out at any area especially the rural or remote areas, where cattle rearing is an everyday practise hence the collection of the dung will be doable. They can be configured in small, modular systems with internal combustion or generator to generate electricity for household uses.

4. Conclusion and Recommendations

4.1 Conclusion

Power and energy systems in Botswana use the principles of energy conservation, and the possibility of the use of alternative, both renewable and non-renewable energy sources is high. The need to diversify Botswana’s power and energy systems is evident in that the current method of power generation, though productive, has its disadvantages that not only do they affect the environment but also the people that live in those environments. The energy source that is being used (coal) and its by-products cause these problems or impacts. Many countries and companies now are rising up and making campaigns against the mining of coal and its use taking into consideration its impacts especially the universal problem of Global warming.
All is not lost since Botswana has environmentally sound technology application in coal bed methane (CBM), biogas [4] and solar. Although this is so, the uses of these alternative energy sources for power generation have not been fully realised and exploited in Botswana and yet there is a lot of potential in these various areas.

4.2 Recommendations

A lot of research on the use of alternative energy sources for generation of electricity has been done, the government should now implement some of these, like the mining of CBM and hence the operation of the 90MW Orapa Power Station, the use of Solar systems on a much larger scale, because this indeed will be a platform for sustainable development, and Botswana will have cleaner means of generating her power.

Botswana is a developing country and in this case has many industries rising up especially mines to benefit her economy but the burden these industries have on the electricity that is currently generated is great. The government should on the least build power generation stations using some of the already mentioned alternatives so that the demand of power on the current national grid may be lessened.

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