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ENERGY OVERVIEW OF BOTSWANA: GENERATION AND CONSUMPTION

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Botswana has a basic need to explore its energy concept, this being its energy sources, generation and percentage of the population with access to electricity. At present, Botswana generates electricity from coal, which supplies about 29% (on average) of the country's demand. The other 71% is imported mainly from South Africa (Eskom). Consequently, the dependence of Botswana on imports posses threats to the security of its energy supply. As a result, there is the need to understand the bases for a possible generation expansion that would substantiate existing documentation. In view of this need, this study investigates the existing energy sources as well as energy consumption and production levels in Botswana. The study would be further developed by making projections of the energy demand up until the year 2020. The key techniques that were used include; literature review, questionnaire survey and an empirical study. The results presented indicated that, current dependable operation capacity (i.e. 100MW) should be increased to 2,595 MW or more assuming 85% plant efficiency. This would then be able to meet the growing demand for energy use. In addition, the installed capacity would be able to support commercial and mining activities for the growth of the economy.

Keywords: Botswana, energy, electricity generation, electricity production, electricity consumption

INTRODUCTION

The basic concept of energy generation is fundamental to the future prospects of identifying the sources of energy, installation capacity, consumption and eventually demand cycles of any country. This is because energy availability is the convertible currency of every aspect of economic development and without energy the whole world would crumble (Dincer, 1999). Global energy demand is estimated to be about 30% higher by 2040 compared to 2010 base figures (www.exxonmobil.com). As well publicised, the world's electricity consumptions was 17.8TWh in 2011 and this figure is estimated to rise to 27.4TWh by 2030 (www.iea.org; www.indexmundi.com). Energy consumption has been central to the function of human societies throughout history (Boyle et al, 2003). This is because energy boosts productivity and global networking as well as human and economic development (Essah, 2011). It is evident that energy consumption has increased over the years and is expected to increase for decades to come due to increased industrialisation and population growth (Dincer, 1999). This phenomenon is no different for individual countries worldwide and in this context, Botswana.

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Eng L. Ofetotse and Emmanuel A. Essah (2012) Energy overview of Botswana: Generation and consumption *In:* Laryea, S., Agyepong, S.A., Leiringer, R. and Hughes, W. (Eds) *Procs 4th West Africa Built Environment Research (WABER) Conference,* 24-26 July 2012, Abuja, Nigeria, 1011-1021.

To date, there is an overwhelming over dependence on fossil fuels such as coal, oil and natural gas for the generation of energy to meet the ever-increasing demand (Boyle, 2003). This has raised concerns over continual reserves and has given countries and policy makers a new impetus to meet the growing demand for energy usage and to develop alternative energy sources that would meet future demand. These alternative energy sources include renewable energy sources, in particular, solar energy and its derivatives in the form of bio energy, hydroelectricity, and wind and wave power that are increasingly considered sustainable energy sources (Boyle et al, 2003). However, in this study understanding only the basic energy needs and possible projections have been considered.

The most significant usage that affects the population of any country is its electricity usage. In Botswana electricity usage currently contributes 17% of the total energy distribution according to the 2008 statistics (www.mmewr.gov.bw). The demand for electricity has continued to increase since then, therefore for easy integration the term energy in this study refers to electricity.

This paper presents research that has been undertaken to investigate the relevance of current energy capacities in Botswana and possible capacity expansions to meet growing demand. It also includes analysis obtained from a comparative study of three other countries (United Kingdom, Ghana and South African) to develop the context of Botswana. Furthermore, there are detailed calculations of current sources against potential predictions for installed capacity until 2020.

BACKGROUND

The Republic of Botswana generates its electricity primarily from coal largely because of its abundance and alleged cost effectiveness (Fagbenle, 2001). In a study by Oladiran (1994), it is provided that electrical power generation is now primarily by medium thermal systems using pulverized coal fuel. However, it is estimated that less than 20% of the population obtains electricity from the national grid. Botswana has an estimated 212 billion metric tonnes of coal reserves found in several locations in the country of which 7 billion metric tonnes are proven. Nevertheless, only the reserves in Morupule (Palapye) are currently being mined for electricity generation (Fagbenle, 2001). The Morupule Power Station is a coal fired, steam turbine driven thermal plant owned and operated by the BPC (www.bpc.bw). BPC is a government owned company operating without external competition therefore operating as a monopoly.

Botswana depends on imports to meet its energy needs. In 2011, the BPC installed capacity supplied a little over 12% (a decrease from 15% in 2010) of the country's demands while 66% was sourced from South Africa. The rest (22%) was obtained from other providers such as Mozambique's Hydroelectrically De Cahora Bassa and electricidade de Mocambique (EDM) (www.mmewr.gov.bw).The overdependence on imports poses threats on the energy security for the future. For instance, Eskom is currently failing to meet its own demands hence electricity supplies to Botswana have had to be cut back (www.finance.gov.bw). In 2008 and 2009, Eskom supplied 350 MW of the country's electricity but cut back on supply to 250MW in 2010 and further cut back on supply to 150 MW in 2011 and 2012 (www.finance.gov.bw). Therefore, Botswana has had to find other means to meet its demands such as securing other imports from Mozambique (90 MW) (www.finance.gov.bw). This shows that relying on imports is erratic and therefore means of producing enough energy for the country locally have to be explored and established. In addition, imported power accounts for

30% of BPC annual expenditure, (www.bpc.bw) which shows that Botswana is losing out in terms of foreign currency outflows for importation of energy.

It is rather interesting compared to present day unit conversion that the supply figures quoted from Eskom and other suppliers are in Megawatts (MW). The same units are used in the BPC website, Botswana Energy Policy draft, National Development Plan (NDP) and other sources that provide information about electricity supply and demand in Botswana. This is rather un-conversional since, as highlighted by Boyle et al (2003) energy is measured in watt-hour (Wh) while power is measured in watts. Installed capacity is considered as power and hence should be measured in watts, while energy demand and supply should be measured in watts-hour. As a result, for Botswana to state its energy supply and demand in megawatts is rather questionable which develops a debate as to the actual concept from which the energy budget of the country has been developed.

Table 1 shows analysis from an 11-year period (2000-2011) of energy production against population variations. This period was chosen to enable the development of a credible understanding of the energy consumption and production, as well as to generate substantial data for analysis.

Table 1: Botswana population against electricity production available for sale (GWh)

Year	Population	Thermal	Import	Total	Station Usage	Transmission Losses	Available For Domestic Sale
2000	-	1027.0	967.9	1994.9	115.0	209.2	1670.7
2001	1,680,863	1034.6	1123.1	2157.7	115.0	200.1	1842.6
2002	1,667,498	1044.3	1241.6	2285.9	116.0	215.1	1954.8
2003	1,691,390	935.6	1605.7	2541.3	105.9	285.3	2150.1
2004	1,711,334	823.0	1915.2	2738.2	96.3	275.6	2366.3
2005	1,727,372	941.7	1898.3	2840.0	108.8	315.3	2415.9
2006	1,739,556	977.1	2050.4	3027.5	110.8	290.0	2626.7
2007	1,756,651	821.5	2393.6	3215.1	95.4	343.0	2776.7
2008	1,776,283	697.0	2585.0	3282	66.5	327.1	2888.4
2009	1,798,372	620.7	2748.5	3369.2	71.0	381.0	2917.2
2010	1,822,858	532.1	2954.5	3486.6	74.8	261.2	3150.6
2011	2,038,228	437.1	3180.1	3617.2	66.0	433.6	3117.6

Source: Annual reports (www.bpc.bw; www.ub.bw)

From Table 1 there was a steady growth in population until 2011 mainly because the 2002-2010 population figures were based on projections. Projections can be higher or lower than the actual population and in this case the 2011 population turned out to be higher than anticipated. Energy production was also increasing over the 11-year period. However, in 2011, the production fell by 1% and this is attributed to decreased plant availability due to maintenance and refurbishment (www.bpc.bw). Additionally, South Africa reduced the amount of energy supplied to Botswana from 77% (2,684 GWh) in 2010 to 66% (2,377 GWh) in 2011 (Eskom, 2012).

Deducing from the consumption figures provided by BPC and the production figures in Table 1, production and consumption figures are the same, which suggests that Botswana is able to account for all losses (technical and non-technical) taking place everywhere in the country. This

again becomes questionable because while technical losses are easy to measure and control, non-technical losses are not because they are caused by forces external to the power system (Singh, 2009). It is therefore accurate to say that if Botswana is able to account for all losses, then details of how this is done should be made available to the public.

In the light of concerns raised in this section and the general arguments in subsequent sections, a firm understanding of how the situation in Botswana can be resolved is paramount to the country's development. This has prompted the need to investigate and adopt relevant approaches from 3 other countries (i.e. United Kingdom, Ghana and South Africa) for possible implementation. United Kingdom (developed country) was selected because it is the current base location of the researcher while South Africa (developing country) was selected because it provides Botswana with more than 70% of its energy demand on average (www.mmewr.gov.bw). Finally, recent research by Essah (2011) formed the basis for choosing Ghana as another developing country. A summary of the population and production rates of these countries is illustrated in Table 2. Update for Ghana's 2010 and 2011 statistics have not been made available, hence the gaps.

Table 2: UK, Ghana and South Africa population against electricity production (2000-2011)

	POPULATION			PRODUCTION (GWh)		
Year	UK	Ghana	South Africa	UK	Ghana	South Africa
2000	59,511,460	19,533,560	43,421,020	329,416	7,835	178,193
2001	59,647,790	19,894,010	43,586,100	332,721	8,030	181,511
2002	59,778,000	20,244,150	43,647,660	333,400	8,029	187,957
2003	60,094,650	20,467,750	42,768,680	336,218	6,462	196,980
2004	60,270,710	20,757,030	42,718,530	338,948	6,681	206,799
2005	60,441,460	21,029,850	44,344,140	348,675	7,312	256,453
2006	60,609,150	22,409,570	44,187,640	345,230	8,689	207,921
2007	60,776,240	22,931,300	43,997,830	342,657	7,136	218,120
2008	60,943,910	23,382,850	48,782,760	342,167	8,245	224,366
2009	61,113,200	23,832,500	49,052,490	322,716	8,792	214,850
2010	62,348,450	24,339,840	49,109,110	328,317	-	218,591
2011	62,698,360	24,791,070	49,004,030	316,581	-	224,446

Source: www.indexmundi.com; www.decc.gov.uk; http://new.energy.gov; Eskom, 2012)

From Table 2 it can be suggested that increase in population does not always mean increase in energy production, which is a case for all the three countries. As already mentioned increase in population calls for increase in energy demand and consequently increase in energy production. Table 2 shows that the higher the population the higher the energy production. Botswana's population growth is inevitable hence, energy production should increase to meet the need.

PROBLEM STATEMENT

Current trends in Botswana indicate that 58% of the country's population have access to electricity with a possible 80% by 2016 (www.mmewr.gov.bw). Though this is encouraging, there are schools of thought (Oladiran 1994; Ketlogetswe et al. 2007) that argue that this is rather ambitious to say the least. This stems from the fact that since 1989 the installed capacity stated

within documentation in Botswana has remained at 132 MW (with an operational efficiency of 90%). This raises questions as to the accuracy of the data because as years go by, power station efficiencies depreciate and it cannot remain 90% efficient even after 23years. In addition, the Botswana Power Corporation's (BPC) development plan description makes available that scheduled and unplanned maintenance activities may result in a plant availability of less than 80%, resulting in a dependable capacity of 100MW (www.bpc.bw). This further implies that the power station cannot maintain its high level of efficiency over its whole life cycle.

The operational capacity of 120MW supplies on average an estimated 29% of the country's energy demand while the rest is imported from sister countries (i.e. mainly South Africa). With the growing demand for energy worldwide, a new power station of 1200MW capacity is being built to "*meet all*" the country's energy need with the potential for obtaining foreign exchange through surplus exports. This is rather a big challenge considering the country's ever-growing population currently now standing at 2.04 million. Significantly, the 2011 annual report and the BPC website (both of the same source) publishes different dates of the Morupule A power station's commission (1986 and 1989). The same contradiction has surfaced with the new Morupule B phase 1 commissioning dates; one view is for a 2011 deadline while others state first quarter of 2012. This is rather interesting as the proposed power station is still under constructions to date which further creates doubt as to whether the full 1200MW would be commissioned by 2013 as initially anticipated.

Undoubtedly, it is clear that there are disparities in information hence the need for critical review of the current infrastructure through research that would substantiate where possible existing documentation.

METHODOLOGY

To address the concerns raised above, three main approaches that have been used within this study are broadly characterised as:

- Literature review
- Questionnaire survey
- Empirical studies and statistical analysis.

Literature Review
The background information and current state of knowledge formed the backbone on which the structure and analysis was based. From the review it was clear that there was the need to understand the challenges surrounding Botswana's Energy generation and consumption. To investigate these challenges, a questionnaire was developed. The information obtained from the literature review informed the design and structure of the questionnaire.

Questionnaire Survey
A self-designed questionnaire that aligns itself with the context of this study was used to collect data that eventually formed the bases of the empirical study. The questionnaire was designed to understand and gather information that relates to;

- the range and quantity of appliances in households
- hours of daily appliance use
- the income category of domestic homes

Analysis are developed from the output, using simple statistical tools integrated within excel. The output was then developed in relation to other energy consumption sectors (i.e. Mining, and commercial) where percentage consumptions are used to estimate sector requirements.

Empirical Studies and Statistical Analysis

In the Empirical study, a comprehensive simple statistical analysis within Excel was used to analyse data collected through the questionnaire survey. These results were used as a measure for the stratification of other sectors based on the domestic sector survey. These analyses were done within limits, assuming linear transposition of percentage values by sector consumption. This was then used to determine total energy usage and hence the current energy budget of Botswana, against what has been stipulated.

In addition, regression analyses based on 10-years input values from 2000-2010 were developed to predict potential energy consumption levels from 2011-2020. This was essential, as it would enable strategic planning for the future of the country's energy budget.

ANALYSIS AND RESULTS

According to Essah (2011), depending on the population of a country, the basic energy needs of every individual must be met through the installed capacity of the energy sources. For this reason, Equations 1 and 2, which were developed by Essah (2011), were modified and used to assess the energy consumption of household appliances in the Botswana context. The results were then used to estimate possible energy demand and/or deficit of supply to meet the current population requirements.

$$W_K P_W C_{ons}\,(Wh/week) = AR\,(W) \times quantity \times hours/week \qquad \textbf{(1)}$$

$$A_{nn} P_W C_{ons}\,(kWh/year) = \frac{W_a P_W C_{ons} \times Weeks\,of\ the\ year}{1000} \qquad \textbf{(2)}$$

Where:

$\boldsymbol{W_k\ P_w\ C_{ons}}$ = Weekly Power Consumption: (Wh/week)

$\boldsymbol{A_{nn}\ P_w\ C_{ons}}$= Annual Power Consumption; (kWh/year)

$\boldsymbol{AR}$= Appliance Ratings; W

The calculations carried out were informed by a questionnaire survey. 50 questionnaires (of which 27 were returned and 6 discarded due to lack of completion) were administered to high income, medium income and low income houses in Gaborone (Botswana). Table 3 provides a summary of the results of the questionnaires. For an equal number of respondents high income earners use more energy than the other classes. This was attributed to the type of appliances available in such households.

The classification of houses into different income categories was based on the Botswana Housing Corporation (BHC) categorisation (www.bhc.bw). The Corporation classifies houses based on size, lease and mortgage costs as follows; low income, medium income and high income households. In addition, the Botswana Central Statistics Office provides that 38% of households in Botswana are low income while 46% are middle income and the remaining 16% are high income. This is the same categorisation that has been integrated in Table 3 upon analysing the questionnaires.

Table 3: Energy consumption per income category

RESPONSE CATEGORY *	HIGH INCOME (kWh)	MIDDLE INCOME (kWh)	LOW INCOME (kWh)
R1	5,291	3,024	1,529
R2	5,534	3,278	1,645
R3	4,522	3,257	1,524
R4	4,765	3,263	1,017
R5	5,632	3,209	861
R6	4,810	3,108	739
R7	5,682	3,228	887
Average	5,177	3,195	1,172

* The questionnaires were categorised into a set of responses (R1…..R7) for easy analysis

Though the 21 questionnaires do not represent the entire population it gives a general perception of the range of energy usage within households. It also forms the basis to develop and contribute to the empirical studies and hence predictions, which are essential aspects of this research. Therefore, using population statistics of 2011 provided in Table 1 population representation of the respective income category households were determined. These were then used to estimate the energy required by the domestic sector which gives a total of ***5,001 GWh***. Details of the breakdown are illustrated in Table 4.

Table 4: Energy demand per income category

	HIGH INCOME	MIDDLE INCOME	LOW INCOME
Average consumption per income category (kWh)*	5,177	3,195	1,172
Number of households**	291,657	838,515	692,686
Consumption per income category for the entire population (GWh)***	1,510	2,679	812

*Calculations based on the 21 respondents

**2011 Population break down was based on the percentages of the respective categories documented within the Botswana Central Statistics office website (www.cso.gov.bw).

***Calculated using the results of the questionnaire and the number of households in the entire population

Botswana has four key sectors, namely, government, commercial, mining and domestic. However, there is a grey area between government and commercial hence in this study; both sectors are augmented as commercial. On average the domestic sector accounts for 22% of electricity consumption, mining sector accounts for 44% and the remaining 34% is accounted for by the commercial sector. Therefore considering percentage usage the estimated energy budget

for Botswana is illustrated in Table 5.

Table 5: Average yearly energy consumption by sector

Sector	Consumption in (%)	Consumption in (GWh)
Domestic	22	5,001
Commercial	34	7,728
Mining	44	10,001
Country's total energy consumption	100	22,730

Assuming 1 MW (plant power) = **8.76 GWh** (power produced). Then the required operational capacity to meet the country's estimated energy demand (from Table 5) is **2,595 MW.** This is assuming 85% plant efficiency.

DISCUSSION AND FUTURE PREDICTIONS

Within BPC documentation, the completion of the second phase of Morupule B is set for 2013 by which time the complete capacity would allegedly provide Botswana with its desired level of energy security. However, this turns out to be rather ambitious since increasing the current installed capacity by 1200MW would still leave Botswana with a deficit of 1721MW. In the context of this study it must be noted that figures used are from the 2010 data base as using 2011 data would overestimate the country's energy demand.

The draft energy policy also states that the current percentage of the country with access to electricity is 58% with a possible expansion to 80% by 2016 (www.finance.gov.bw). However, the current installation capacity gives a supply figure of **1156 GWh**, which is **23%** of the domestic share in Table 5. Additionally, increasing the installed capacity by 1200 MW gives a supply figure of **11,668 GWh**, which is **51%** of the domestic share in Table 5. Consequently, the niche that percentage access figures would increase is unfounded, a case that is supported by studies by Oladiran (1994) and Ketlogetswe et al. (2007). Additionally, the aim to reach 80% access by 2016 may be farfetched.

It is worth noting that using 1332MW for these calculations assumes 100% plant efficiency, which is not practical hence, accounting for efficiencies would bring the percentage with access further down considering this, BPC's reported figures (www.bpc.bw).

Future Projections

Equation 3 was derived from the relationship between energy production and population growth obtained from Table 1. The regression of $R^2 = 0.981$ obtained, shows that there is a very good correlation between population growth and energy production. In this regard when population increases energy production increases concurrently.

$$E = 7487.6p - 10325 \qquad \textbf{(3)}$$

Where:

***E*=** Energy production projections

***p*=** the projected population for the study

Table 5 suggests that Botswana's current (as at 2010) energy production levels (i.e. 3150.6 GWh,

see Table 1) do not meet the country's requirements (22,730 GWh). Therefore, Equation 3 was modified to account for the deficit in supply. The revised equation is as follows:

$$E + 19579.4 = 7487.6p - 10325 \qquad (4)$$

Equation 4 was therefore used to make energy production projects from 2011 to 2020. The projections required population figures for 2011 to 2020 and these were projected using Equation 5 and the 2011 population as a base figure.

$$y = 26258.5x - 50756 \qquad (5)$$

Figure 1 indicates projections for current BPC production levels and estimated energy projections. The estimated production levels are projections of what this study recommends should be produced to meet the country's energy needs.

The output trend from both estimates (Figure 1) is similar however; the estimated energy required is on average an order of 4 times or more.

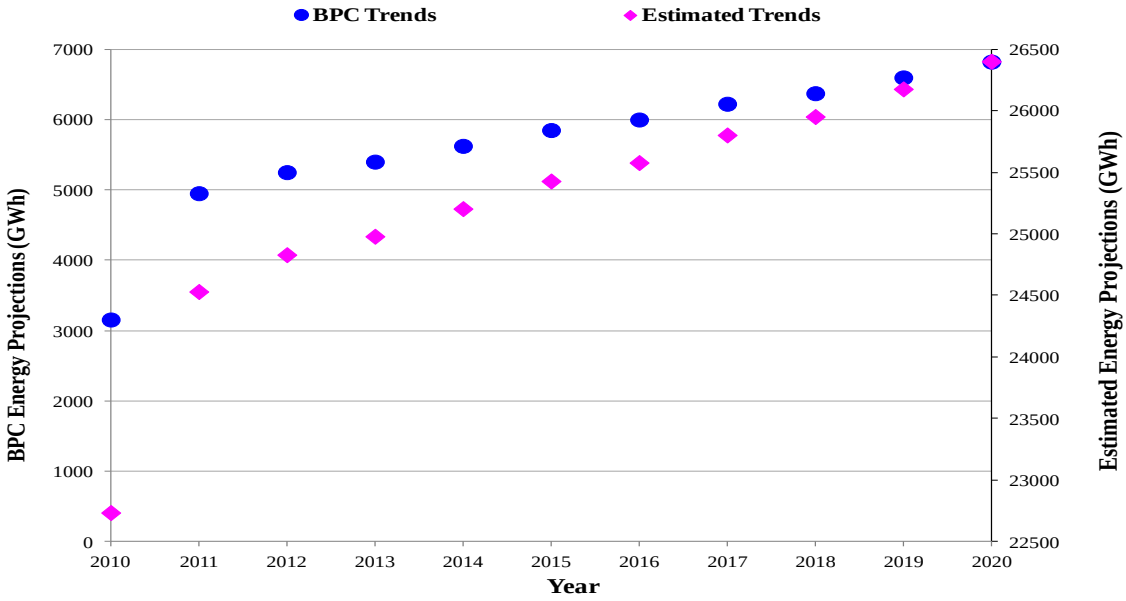

Figure 1: Current energy production projection vs. what the country should produce to meet energy demands

CONCLUSIONS

This study discusses the current state of Botswana's energy concepts, generation and production. With the ever growing demand for electricity use and the world gradually becoming a global village, there is a need for Botswana to develop its economy by meeting its energy challenges. Hence, the need to revisit and revamp its current energy strategies is eminent. In trying to address the aims and objectives set out in the introductory section, the following conclusions were drawn;

Current production levels do not meet the country's current energy demands

Botswana's over reliance on imports to sustain its economy influences the energy security. This is rather unfortunate because in the event that Botswana dependent countries face shortages, Botswana would not be able to sustain its economic growth.

The 58% access rate provided in documentations seems rather overstated, as data analysis has revealed that, as at 2010 the percentage of the country's population with access was

approximately 23% and if installed capacity increases by 1200 MW it would rise to 51%. Therefore, there is a need that documentation is revised.

Current energy supply and demand quoted in Watts (W) is rather deceptive hence the country's statistics should be reviewed to integrate the appropriate units: Watt-hour (Wh).

There is however positives in that more power stations are being built to at least achieve an appreciable level of supply to meet a significant level of demand.

SUGGESTIONS FOR POSSIBLE DEVELOPMENT

This study forms the basis for ongoing research that would integrate current sources with potential capacity for alternative sources. The possibility to achieve this goal is encased by the following prospect for further development:

Documentations must be updated in all regulatory and informative sectors to ensure the avoidance of current discrepancies.

Botswana subscribes to the Kyoto Protocol but its relevance is yet to be explored and where possible measures integrated to achieve the carbon reductions required.

There is the need for a nationwide education on energy usage to create the necessary awareness required.

Exploring the potential of renewable energy sources is vital for the growth and security of the country’s energy sector.

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