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Energy supply, consumption and access dynamics in Botswana

Emmanuel A. Essah[a,b,*], Eng L. Ofetotse[b]

[a] Key Laboratory of the Three Gorges Reservoir Region's Eco-Environment, Ministry of Education, Chongqing University, China
[b] School of Construction Management and Engineering, University of Reading, Whiteknights, PO Box 219, Reading RG6 6AW, UK

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ABSTRACT

The growing dependence on electricity for economic growth in all countries prompts the need to manage current resources for future sustainability. In today's world, greater emphasis is placed on energy conservation for energy security and for the development of every economy. However, for some countries understanding the basic drivers to such achievements are farfetched. The research presented in this paper investigates the electricity generation and access potential for Botswana. In addition detailed documentation and 13 years energy consumption and generation trends are investigated. Using questionnaires and empirical studies the energy demand for the entire nation was estimated. From the research it was established that current energy generation trends account for 38–39% of the country's population with access to electricity. Considering the percentage rate of sector energy demand, the proposed total installed capacity of 1332 MW, would not meet the country's energy demand at 100% access. The likely consequence of the lack of adequate supply would cumulate to significant increase of imports and/or load shedding to meet demand.

1. Introduction

The relationship between energy and economic development has been the centre of debate over the past 30 years with many researchers arguing that there are conflicting views as to the exact relationship between the two (e.g., Ang, 2008; Apergis & Payne, 2009; Kraft & Kraft, 1978; Yu & Choi, 1985). Nonetheless the underlying argument is that, access to affordable and reliable energy services especially electricity is a significant aid to human, social and economic development in every country. It is also closely linked to the achievement of the Millennium Development Goals (MDGs) (Kanagawa & Nakata, 2008; Kaygusuz, 2012; Ouedraogo, 2013). Therefore, greater emphasis is placed on energy conservation for energy security and for the development of every nation's economy as Swan and Ugursal (2009) affirm.

Intermittency of supply, increasing demand and lack of access to energy have been acknowledged to undermine energy security hence are major challenges for policymakers and organisations all over the world. These challenges became more prominent in the 1970s when energy became a major concern due to the aftermath of the oil crisis (Bhattacharyya & Timilsina, 2010). It goes without saying that underdeveloped and developing countries suffer the most when it comes to energy shortage and the lack of energy security. Notably, 95% of the 1.3 billion people in the world who do not have access to electricity and 2.6 billion people who are without clean cooking facilities reside in either sub-Saharan Africa (made up of 47 Countries most of which are either developing or underdeveloped) or developing Asia (IEA, 2012). This is a substantial percentage which will eventually impact on the economic development and growth of these countries. It is therefore pivotal that every country makes it a key objective to provide efficient and affordable access to modern energy services for all its citizens.

Although energy access is a fundamental issue for policy makers, there is no universally accepted definition of energy access. However, household (or affordable) access and grid access are often considered to be the two acceptable distinctions (IEA, 2006). Household access refers to when one is able to use electricity in the home depending on the purchasing power of a household, the cost of energy and the cost of energy using equipment. Whereas grid access is described in terms of penetration rate which refers to the proportion of a geographical area covered by the electrical grid regardless of the number of households connected (IEA, 2006). Brew-Hammond (2010) also states that in most cases energy access is taken to mean the ability to connect to energy, namely: electricity, Liquefied Petroleum Gas (LPG), charcoal, coal and natural gas which can either be grid connected (*gc*) or non-grid connected (*ngc*).

There are many forms of energy outlined by authors such as Brew-Hammond (2010), nevertheless, electricity is acknowledged to be one important ingredient for economic development that also improves the way of life (Winkler et al., 2011). This paper therefore focuses on electricity. Hence energy would be taken

* Corresponding author. Tel.: +44 1183788563.
E-mail addresses: e.a.essah@reading.ac.uk (E.A. Essah), e.l.ofetotse@pgr.reading.ac.uk (E.L. Ofetotse).

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to refer to electricity and the terms would be used interchangeably.

In this paper a comprehensive picture of the current energy system characteristics of Botswana is provided. Botswana currently depends largely on imports for its electricity supply which poses energy security instabilities. Considering the proposal for a new power station it is worth determining whether the country's energy demand would be met taking into account the losses in efficiencies as years go by. Additionally, with load shedding currently being a common occurrence, it is worth determining the current access levels of the country. Understanding these implications would assist the country in determining its energy budget hence the amount of energy that needs to be produced or imported. Furthermore, there is an increasing need for documentation regarding energy loads in Africa, with Botswana being no exception hence it is essential that detailed research is carried out to substantiate existing knowledge.

Determining the characteristics of any energy system and energy assessment is made possible through the use of energy models which are usually classified as either top down or bottom up as indicated by Swan and Ugursal (2009). There are several studies related to the application of energy models in energy assessment at national level in literature. For example Chen et al. (2008) used a statistical method to investigate national energy consumption in the Chinese residential sector. In this study real time energy consumption measurements for different appliances were investigated for 60 families over a period of a year. Yohanis, Mondol, Wright, and Norton (2008) analysed patterns of electricity use in 27 representative households in diverse locations of Northern Ireland over a 20 month period. In this study half-hour load metres were used to measure electricity use over the 20 months period and a supporting detailed survey of householders aimed at establishing an understanding of appliance use and energy related behaviour was conducted. In another study by Widén and Wäckelgård (2010), a high resolution stochastic model which made use of occupants' schedule of living activities as well as appliance ownership and ratings was investigated to generate energy load profiles for a representative number of Swedish households. The increased application of models in developed countries is encouraging and should be something developing countries should learn from and aim to adopt. However, developing countries are limited by the lack of necessary data and required institutions which hamper the implementation of the models. Nonetheless models can be adjusted to suit the conditions of a country. For example, Howells, Alfstad, Victor, Goldstein, and Remme (2005) applied the MARKAL model to a non electrified rural village in South Africa. Though the use of these models is not detailed in this study, the fundamental basis of work done in other countries using such models and methods is worth noting. In this study a statistical method has been used to investigate energy consumption of the Botswana residential sector and consequently that of the whole country.

The paper is organised as follow: Section 2 gives an outlook of Botswana's energy supply. Section 3 gives an overview of the country's energy consumption and access situation. Section 4 outlines the methodology adapted for the research. Section 5 gives the research analysis and results while Section 6 presents the concluding remarks.

2. Energy supply outlook of Botswana

The Republic of Botswana is a landlocked country (Fig. 1) with a total land area of 581,730 km^2 (CSO, 2011). The country generates its electricity primarily from coal largely because of its abundance and alleged cost effectiveness (Fagbenle, 2001). Although there are abundant coal reserves (estimated at 212-billion tonnes) found in different parts of the country (Fagbenle, 2001), only those in

Fig. 1. Map of Botswana and its neighbouring countries with an inset of Morupule Colliery.
Source: Asenjoenergy (2008).

Morupule Colliery (estimated at 70-billion tonnes) located between Palapye and Serowe villages (see Fig. 1) are currently being mined for electricity generation. The Morupule Colliery supplies coal to the Morupule A Power Station (adjacent to the Morupule Colliery) which is the only power station currently operating in Botswana.

2.1. Morupule A power station

The Morupule A power station is a coal fired station with steam turbine driven thermal plants owned and operated by the Botswana Power Corporation (BPC) (BPC, 2011). The BPC is a government owned company operating without any external competition therefore acting as a monopoly (Ofetotse & Essah, 2012).

The coal-fired power station was commissioned in 1986 with an installed capacity of 132 MW and an operational capacity of 120 MW (BPC, 2011), i.e. 91% conversion efficiency. As it would be expected this capacity decreased as years went by, reducing the station's dependable operational capacity to 100 MW (76%) as stated in BPC (2011). The power station generates on average 27% (based on a 13 year input, see Table 1) of the country's total energy supply with the rest of the country's requirements obtained through imports. In 2012, the Morupule power station supplied a little under 7% (a decrease from 12% in 2011 and 15% in 2010) of the country's supply while 70% was sourced from Eskom in South Africa and 23% from other providers such as Nampower in Namibia, Electricidade de Mocambique (EDM) in Mozambique and Societe Nationale d'Electricide (SNEL) in Democratic Republic of Congo (BPC, 2012).

The decrease in generation was attributed to a decrease in operational capacity, which was 40 MW in 2011 compared to its normal 100 MW (BPC, 2011). Although it was not stated as to what the operational capacity in 2012 was, it is clear that it had reduced from the 2011 value due to even lower national generation shown in Table 1 and Fig. 2. In addition, the Morupule A Power Station (commissioned in 1986) is nearing the last years of its useful life which was anticipated to be between 25 and 30 years from the year it was commissioned (BPC, 2010). This ageing trend has significant implications which are reflective in the reduced operational capacity hence reduced electricity generation. In light of all these causes of low generation the role that a second power station would play in the energy supply system of Botswana cannot be over emphasised.

After a residual life assessment was carried out on the plant in 2009 it was suggested that if extensive refurbishment can be carried