Access to grid electricity in Botswana: Implications for energy transition in the Okavango Delta

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Abstract

This paper discusses access to grid electricity in Botswana, particularly in the Okavango Delta, in order to advance knowledge on access to energy and the adoption of renewable energy technologies (RETs). The objectives of the study were to identify and assess the challenges of national and local electricity distribution, assess rural electrification initiatives, and determine the implications for energy transition to renewable energy sources. This is a cross-sectional study that used secondary data from literature sources and primary data derived from in-depth interviews with stakeholder representatives. Findings indicate that universal access to electrical energy in Botswana cannot be achieved solely through grid systems. Solar energy has the potential to provide electricity in remote areas. However, its development and adoption have neither been supported through subsidies nor placed at the centre of planning to achieve universal access to electricity in Botswana. Improved access to grid electricity has inadvertently reduced the importance of RETs, slowed down their development and even reversed initial gains in their adoption. Coupled with lack of enforcement policy for adoption, there is slow progress in the uptake of RETs in all sectors, including in the tourism sector in the Okavango Delta. There is need for policy, legislative and economic instruments, to support RETs adoption in all sectors of the economy in Botswana.

Key words: Energy access, Okavango Delta, renewable energy

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Introduction

Access to grid electricity is a challenge for most developing countries, including Botswana. Currently, out of an estimated global population of seven billion people, 1.5 billion people living in developing countries lack access to electricity (International Energy Agency [IEA], 2008). This lack of access to electricity is often referred to as energy poverty due to its close links to pervasive hardships among the poor and other vulnerable groups (United Nations, 2002). It adversely impacts people's well-being given that basic needs become difficult to meet (Haines et al., 2007). Access to grid electricity is unevenly distributed as shown in the differences in access to electrical energy between sub-Saharan Africa (29%) and south Asia (60%) (IEA, 2008; Khennas, 2012). Lack of access to electricity is a result of lack of infrastructure development and the disparity of infrastructural development between urban and rural areas (Khennas, 2012). Studies have demonstrated that investment in programmes and projects that promote access to electricity reduces the cost of healthcare and improves livelihoods of poor communities (Haines et al., 2007; Spalding-Fecher, 2005; Olla and Onwudinjo, 2012; World Bank, 2010).

Universal access to electricity has often been achieved through the extension of the grid, the provision of off-grid and standalone systems which are mostly powered by fossil fuels. Although renewable energy technologies could help improve access to electricity in most countries, they have not been adequately adopted. For example, the 2011 global energy mix consisted of only 13% renewable sources, whereas fossil fuels constituted 82% (World Energy Council, 2013). In southern Africa, various initiatives, including regional agreements, policies, strategies and development plans have also been undertaken to improve access to electricity (SADC, 2010). For instance, the SADC Infrastructure Development Master Plan and the Energy Sector Plan which emanated from the implementation of the SADC policy were also developed. The Master Plan emphasises the need to develop renewable energy sources, and the SADC Energy Sector Plan aims to achieve 100% renewable energy generation in the region by 2050. According to the sector plan, the share of renewable energy in the regional grid will be increased from less than 20% in 2010 to 21% by 2017, then to 33% by 2022 and to over 37% by 2027 (SADC, 2012).

Despite these efforts and related achievements, access to grid electricity in the SADC region is very low. Overall access stands at 27% compared to other African sub-regions of West Africa (44%) and East Africa (36%) (SADC, 2012). Access is even lower in rural settlements than in urban areas. Improved access to electricity has been marginal in many countries, which casts doubt on whether these countries will meet the set targets for universal access. The challenges identified include "low tariffs, poor project preparation, no off-takers for single buyer Power Purchase Agreements, lack of policy and regulatory framework, and inadequate investment and financing" (SADC, 2012, p.6). Additionally, there are no incentives for the development of large-scale renewable energy grid systems; there are no regional standards for renewable energy hardware systems and components; there are no independent regulatory systems, and there is chronic lack of finance to meet energy needs (Colman, 2010). Coal-fired power plants provide most of the grid electricity in the SADC region, accounting for 75% of all the power produced (SADC, 2012). However, the combustion of coal is currently viewed as one of the main contributors of greenhouse gas pollutants that serve as agents for global climate change, and there is an increasing call for major reductions in emissions globally. Due to lack of infrastructure and foreign commitments, petroleum and gas do not play a significant role in power generation in the SADC region (SADC, 2012). From the above challenges there arises a need for southern African countries, including Botswana, to set up regulatory policies to promote the adoption of renewable energy technologies to meet demand for electricity in areas where it remains expensive and difficult to supply. Regulatory policies aimed at widening grid extension and promoting access to electricity may be in the form of "pay-as-you-go" systems where connection charges are included in tariffs to enable low-income users to pay for electricity (Alessi and Ranci, 2016). Above all there remains a major gap in knowledge on why electrical energy based on solar energy remains so difficult to access in remote locations of developing countries, including Botswana.

In Botswana, electricity generation and distribution are vested in the state through the Botswana Power Corporation (BPC), a parastatal organization. For any transition to occur in the power generation sector, the Botswana Government has to drive it, and other stakeholders play subsidiary roles (Coleman, 2010). Government documents (such as Vision 2016, NDPs 6, 7, 8, 9, 10, and the current Draft Energy Policy) have expressed the aim for sustainable development and the need to reduce emissions. However, there are no clear targets to be achieved in the contribution of renewable energy to the national energy mix.

This paper discusses access to grid electricity in Botswana, particularly in the Okavango Delta in Ngamiland District. Botswana emerged from being the poorest country in the world at independence in 1966 to an upper middle-income country. The country serves as an example of how energy access can be incrementally improved in developing countries, particularly those in sub-Saharan Africa. Ngamiland District is one of the last regions in Botswana to develop from being one of the poorest districts to a blossoming tourism hub in Botswana. This is mainly due to the presence of vast ecological resources in the Okavango Delta. The paper hopes to enhance knowledge on access to energy and the use of renewable energy technologies (RETs) in Botswana's Okavango Delta, and in the tourism-supporting wetlands of developing countries with similar challenges. The specific objectives of the paper are to: a) identify challenges experienced in the distribution of national and local electricity, b) assess rural electrification initiatives, and c) determine implications for energy transition to renewable energy sources in the tourism sector in the Okavango Delta. The next sections comprise the conceptual context of the study, the study area and methods, the findings, discussion and conclusion respectively.

Conceptualising energy access and transition

This paper is informed by the discourse on energy access in developing countries, as well the links between energy access and energy transition. Energy access is important for the eradication of extreme poverty around the world (World Energy Council, 2013). There is no universal definition for energy access, and this poses challenges in its measurement considering its multi-dimensional nature (Bhatia and Angelou, 2014; IEA, 2012). Energy is used in various quantities for multiple purposes, and it is derived from many different sources (Bhatia and Angelou, 2014; IEA, 2012). In this paper, access to energy is defined as "access to clean, reliable and affordable energy services for cooking and heating, lighting communications and productive uses" (UN Secretary General's Advisory Group on Energy and Climate Change [UNSG-AGECC], 2010). There is need to distinguish "energy services" and "useful energy". Pachauri and Spreng (2004) categorize energy consumption levels into four types: a) primary energy, which is found in energy sources such as firewood (extraction level) b) end use energy, which is usually sold to consumers by non-energy producing firms (the user level), c) useful energy (e.g. heat), which is ultimately obtained from appliances, and d) energy services (the end products used by consumers). In other words, access to energy comprises the ability of users to obtain energy sources, and energy converters/appliances in order to derive benefit from energy services. This echoes the definition of access proposed by Ribot and Pelusso (2003) who state that it is "… the capacity to benefit from things" and it is made up of a bundle of powers rather than rights which one has in relation to others and/or existing institutions. Access to energy has until recently been measured in terms of having a connection to grid electricity, and using electricity for lighting, whereas access to energy for cooking has been measured in terms of using non-solid fuels. Effectively, access is not the availability of energy in the form of a nearby power grid, but the capacity of individuals and groups to derive substantive utility from the grid. Energy access and transition are the underlying concepts for this study, and they are related in that the former complements the latter and may allow transition to be achieved.

Energy transition

Past thinking on energy transition, as embodied in the well renowned 'energy ladder' hypothesis, was that as individuals and/or groups become wealthy there is a gradual shift from the use of indigenous energy sources, such as fuelwood, to clean energy sources such as liquefied petroleum gas (LPG) and electricity (Hosier, 1987). Indications from current studies are that a total shift from one energy source to another does not necessarily occur. There is a tendency to substitute the contribution of some energy sources for others within a given basket of energy sources, and this depends on access and other factors, including culture and the local context of users (Leach, 1992; Heltberg, 2004; van der Horst and Hovorka, 2008). Furthermore, there is a general tendency for "energy stacking", where different forms of energy may be used almost simultaneously for the same purpose (Bhatia and Angelou, 2014; Masera et al., 2000; Mekonnen and Kohlin, 2008). Therefore, in this paper energy transition refers to variations in the contribution of specific energy sources within a given energy source basket over time. This view recognises the need to reduce the use of high pollution energy sources (e.g coal)within a given basket and simultaneously increasing the contribution of environmentally-friendly renewable energy sources.

The study area

Ngamiland District, in north western Botswana, was the broad study area. It has a population of 149 754 people, 65% of which is settled in 55 mainly rural settlements, and hundreds of isolated and remote localities (Statistics Botswana, 2012). The population density in the northern regions of Botswana stands at 1.4 persons/km^2, which is among the lowest in Botswana, compared to 13.8 persons/km^2 and 4.5 persons/km^2 in South-eastern and Eastern regions respectively (Statistics Botswana, 2012). Households in the Ngamiland District are generally poor, particularly in Ngamiland West which has 33.4% of households living below the poverty datum line compared to the national figure of 16.3% in 2015/16 (Statistics Botswana, 2018).

The specific study area is the Okavango Delta (Figure 1) in Ngamiland District, a world-renowned tourism destination, and a pristine wetland of international importance listed in 1992 under the Ramsar Convention as the world's 1000th UNESCO Heritage site. The Delta comprises numerous river channels and expansive flood plains that serve as the main source of water for the flora and fauna as well as for human livelihoods within a generally arid Kalahari desert environment.

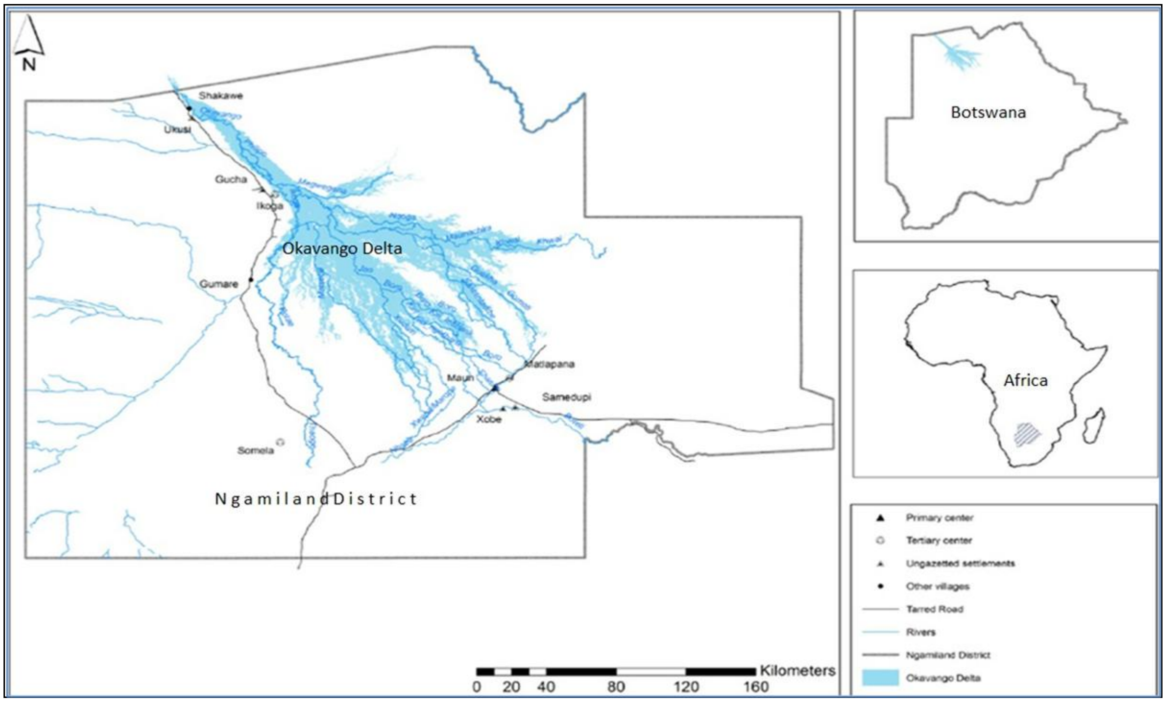

Figure 1: Map of Ngamiland District showing the Okavango Delta in Botswana

The Okavango Delta is endowed with hundreds of bird, insect, reptile, animal and plant species, some of which have been identified by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), as endangered or threatened with extinction. Within the Delta, there are about six small settlements with a total population of 2688 people (Statistics Botswana, 2012). Communities living within the Delta do not have access to grid electricity. Their source of energy is mainly fuel wood. Energy transition from fuel wood to other sources of energy is limited by among others, low household income. Additionally, there are 107 tourist camps and lodges, most of which are in remote locations, beyond the reach of the national grid (Mbaiwa, 2011). Most of these rely on fossil sources of energy, including petroleum products, which are increasingly disfavoured for their contribution to greenhouse gas emissions.

Methods

In this study, a qualitative desktop review was augmented with empirical data. Secondary data were obtained through desktop searches and critical review of published and unpublished sources including journal articles, global and regional energy (and other) organisations' reports, national energy policy and strategy documents, district development plan documents and management plans of five tourism establishments. Data from these literature sources included long-term national development of electrical energy infrastructure, policy approaches to energy supply, level of access to electricity and the related sources.

Primary data were obtained from empirical in-depth interviews with a) policy makers and implementers from the Department of Energy Affairs at the Ministry of Minerals, Energy and Water Resources (MMEWR), North West District Council (Energy Division), b) service providers such as the Botswana Power Corporation (BPC) and c) service users such as tourist companies and some private entrepreneurs. The interviewees were purposively selected based on their knowledge and administrative positions. The basic assumption was that these individuals had reliable information relating to energy access and use. Therefore, the interviewees included four officers from the Department of Energy Affairs, two from the Botswana Power Corporation, two from the North-West District Council, and five managers of tourist camps. The key informants were selected based on their position in the organisation as well as knowledge and communicability about the subject as suggested in Marshall (1992). Additionally, two private entrepreneurs were also interviewed to obtain their views on energy access and use of electricity. An interview schedule was used to capture the respondents' views. Furthermore, raw data on energy use, from the 2011 Botswana National Housing Census database, were obtained with permission from Statistics Botswana. The data provided insights on national and district-level household energy access. Given that the study also used human subjects, ethical clearance was obtained from the Ministry of Local Government, which issued a research permit for the work to be undertaken.

Access to grid electricity in Botswana

Since the 1970s, Botswana's energy policy documents have recognised the need to improve access to energy from fossil fuels, particularly coal, and from renewable energy sources such as solar and wind energy. The country relied on imported petroleum products for electricity generation, she but was highly endowed with coal resources. Therefore, the National Development Plan 5 (NDP5) of 1979/85 emphasised energy substitution and conservation. It underscored the substitution of petroleum products with coal in electricity generation and industrial use, as well as solar and wind energy for pumping water (Ministry of Finance and Development Planning [MFDP], 1979). It also encouraged thrift in the use of petroleum products through controlled open hours for fuel stations in accordance with the Southern African Customs Union (SACU) regulations of the time (MFDP, 1985).

In urban areas such as the capital city Gaborone and some mining towns, coal-fired electricity generation plants and grid inter-connections were developed. Low cost options, including the importation of electric power, were also considered, culminating in the first connection to an international grid, from South Africa, which was completed in 1981. However, in most rural settlements, electricity was generated from standalone diesel generators meant to supply government institutions. These had high initial development capital, operation and maintenance costs (MFDP, 1985). Access to electricity for private individuals and commercial entities was limited, due to high connection fees and tariffs, as well as non-availability of subsidies. Independent power systems for government institutions were replaced with centralised ones to reduce installation and maintenance costs but the tariffs remained high and variable by regions (MFDP, 1985).

In the NDP5 planning period renewable energy sources were mainly considered as part of the traditional energy sources, including biomass, particularly wood fuel. Renewable energy technologies for wind and solar energy harvesting were at the early stages of development and adoption. Research and development in the use of solar and wind energy for water pumping was initiated. The use of solar water heaters in government buildings and parastatal organisations was promoted. Photovoltaic electricity was tested and used in government clinics, schools and offices (MFDP, 1985). By the end of NDP5, the Botswana Housing Corporation, a parastatal organisation responsible for the provision of housing, had installed solar heaters and photovoltaic electricity in 406 houses in Gaborone (MFDP, 1985). Most of the initiatives started in NDP5 continued in NDP6 and informed policy direction in NDP7.

NDP6 of 1985/91 continued to encourage thrift in the use of petroleum products and their substitution with coal in electricity generation, but it viewed solar energy as economically unviable (MFDP, 1985). The use of solar energy had several challenges, including lack of skills, the poor quality of equipment and high installation costs (MFDP, 1985). However, the Government continued to promote its adoption through staff training, and the installation of solar heaters and lighting systems in government buildings. Moreover, pilot projects aimed at testing its feasibility and improving knowledge on the related technology were undertaken in some rural settlements such as Manyana, where a solar photovoltaic power station was constructed. This was mainly because grid electricity was still not accessible in many parts of the country. Emphasis was then placed on the extension of the national grid to the main rural settlements, which by 1991 accounted for 54% of the national population (Central Statistics Office, 2002). At the national level, access to the national electricity grid stood at 10.1% of households (MFDP, 1985).

NDP 7 of 1992/97 promoted the use of clean energy, a reduction in the use of fuel wood, and further extension of the national grid and expansion of local connections to rural areas; it also emphasised an integrated, rather than supply-side energy planning. The plan period was dominated by an emphasis on decentralisation of services, privatisation and improved productivity in the public service (MFDP, 1992). The Botswana Vision 2016, a national planning programme indicating national interest and aspirations towards the year 2016 was formulated during this period. National access to grid electricity was still very low at 15% and 3% of households in urban and rural areas respectively (MFDP, 1992). Access to grid electricity was further expanded to major settlements under the Rural Electrification Programme.

NDP8 of 1998/2003 continued the emphasis on integrated energy planning and adopted an accelerated rural electrification programme from the initially planned 14 villages to be electrified in a year, to 70 villages in two years (MFDP, 2003). The Rural Electrification Collective Scheme (RECS) was also reviewed; this resulted in the reduction of upfront costs from 10% of total cost to five per cent (5%) with a repayment period of 15 years instead of the original 10 years (MFDP, 2003). The total number of consumers increased by 12.5% from 86 165 to 96 961. Furthermore, a policy of balancing local generation with imported electricity, which also continued in NDP9, was adopted (June 2002), leading to a generation/import mix of 45/55 from the initial 70/30 (MFDP, 2003).

During NDP9 of 2003/2009, the accelerated programme of rural electrification was continued, and the focus was on supplying adequate and reliable energy at a minimal cost to the economy (MFDP, 2003). The accelerated rural electrification programme had a target of 145 villages to be electrified in the NDP9 planning period. Through this programme the Government provided funding of up to US$90 million (MFDP, 2009; BPC, 2010; Eltel TE AB, 2010). This programme achieved significant progress, and by 2010 the last 100 villages were electrified. This improved access to grid electricity which increased from 46.8% to 55.6% between 2009 and 2010 (BPC, 2010). However, national access to electricity varied from one district to another. The Southeast District had 86.4% of households electrified whereas the Southern District had 40.5% of households with access to grid electricity (BPC, 2010). The extension of the grid has to date proven unviable given that after the electrification of 145 villages, at the end of NDP9, the proportion of new connections stood at 51% of expected adoption rate (MFDP, 2009). Furthermore, the government had decided to subsidize the cost of new connections for individual households so that the cost of connection dropped from the actual cost of BWP 30 000 (≈US$3000) to BWP 6000 (≈US$600) standardised subsidised connection charge (MFDP, 2009). As a result, the Government decided to stop any further extensions of the national grid to remote settlements. However, the extension of back-bone grid lines in electrified villages was continued to enable new connections (MFDP, 2009). The programme also covered some villages which were previously supplied from solar photovoltaic stations such as Manyana and Motshegaletau. The electrification of these villages led to the phasing out of solar photovoltaic electricity. This was because access to the grid electricity provided a more cost-effective option at a time when solar photovoltaic systems required expensive maintenance.

The policy of obtaining affordable and reliable energy enabled the country to benefit from low cost energy from the Southern African Power Pool [SAPP] (mainly South Africa). However, this was short-lived, and the policy proved to be ineffective for Botswana's energy security. By the end of the NDP9 planning period, the country's electric energy self-sufficiency had declined significantly, with local production contributing 24% of the total supply, the rest being imported mainly from South Africa (MFDP, 2009). The Botswana Power Corporation faced several challenges, including a) the weakening of the national currency (Botswana Pula) against the South African Rand, b) the rising price of coal, the main source of electric energy, and c) the difficulty of obtaining low cost energy from SAPP due to increasing local demand in South Africa (MFDP, 2009). These challenges prompted the Government to revive the implementation of the previously deferred plans to develop power generation infrastructure.

A new coal-fired power station, the 600 MW Morupule-B Power Station, was constructed at the beginning of NDP10 and was completed in 2012. Although this power station was expected to meet national demand, at a time of great uncertainty of supply from South Africa, it has not been operating at full capacity (Kgathi et al., 2015). The reasons for this poor performance may have included lack of energy integrity in the tendering process and poor workmanship in the construction phase. Although lack of energy integrity could not be confirmed from government sources, private news media highlighted the choice of contractor for the advanced fluidized bed technology under underhanded deals as the underlying challenge (*Sunday Standard*, 2008). The power station could not sustain high power generation during and after the preliminary testing. It broke down frequently, leading to unprecedented power shortages and outages throughout the country. Repairs and technical corrections to the power station resulted in extra costs to the Government, estimated at BWP1.5 billion (≈US$150 million) (Raleru, cited in MmegiOnline, 2015).

Other projects undertaken during the NDP10 period include the expansion of the Rural Electrification Programme and the construction of 1.3 MW grid-connected solar photovoltaic power station, at Phakalane in the capital city Gaborone. The Rural Electrification Programme was continued; in 2013/14 the BPC electrified 43 villages, 28 of which were new village connections to the grid, and 15 were internal network extensions (BPC, 2013). The National Electrification Fund was established and a new levy, of BWP 0.05 /KWh was also imposed. The standardized connection fee was also reduced from BWP 6000 (≈US$ 600) to BWP 5000 (≈US$ 500). These initiatives were meant to supplement government subsidies for new connections.

Access to grid electricity was further improved through: a) rollout of pre-paid meters, b) nation-wide increase in the number of pre-paid vendors from 120 to 1200, c) increased distribution channels including points of sale, short-message-systems (SMSs), auto-teller-machines, and website sales (BPC, 2013). This improved access to grid electricity, which currently stands at 63% of households nationally (Statistics Botswana, 2011). In the rural areas, access to grid electricity increased from 49% in 2011/12 to 55% in 2013 (BPC, 2013). However, consistent supply of electricity remains a major challenge for both urban and rural settlements. Due to the power shortages, the BPC has since reduced peak demand for electricity through scheduled power-cuts, an exercise commonly known as load-shedding. The extension of grid systems and subsidies has led to a steady growth in access to energy estimated at 72% of the population in 2016 and 76% in 2017 (BPC 2016; 2017) as summarised on Table 1 below.

Table 1: Grid electricity development and energy access in Botswana 1970s to 2016

Policy document	**Policy**	**Energy access**
• NDP5 1979/85	• Energy substitution and conservation • Thrift in petroleum products use • Solar and wind for water pumping	• Very low, • Solar viewed as economically unviable
• NDP6 1985/91		• Urban 15%, rural 3% • Solar promoted in Govt/BHC buildings
• NDP7 1992/97	• Integrated energy planning • Promoted clean energy • Emphasised grid extension	• National access 36.7 % (MFDP 1998)
• NDP8 1998/2003	• Integrated energy planning • Accelerated rural electrification • Balancing local/exported energy	• National access; urban 24%, rural 3% (MFDP 2003)
• NDP9 2003/09	• Supply adequate and reliable energy at least cost • Accelerated rural electrification	• National access 46.8%; urban 43%, rural 18% (BPC 2010)

• NDP10 2010/16	• Target, increase access from 50% to 80% by 2016 • Accelerated rural electrification	• National 55.6% in 2009 (BPC 2010), then 63% in 2013 (Statistics Botswana 2014); 72% in 2016 (BPC 2016)
• NDP11 2017/23	• Integrated Water and Energy Resource Management (IWERM) strategy; RETs emphasised	• National; 72%, 76% (BPC 2016, 2017)

In 2010 the BPC, in line with Renewable Energy-based Rural Electrification Programme, entered into a partnership with the French company, Electricity de France (EDF), and formed a private company, BPC-Lesedi. This company was meant to operate through a franchise system to provide integrated services for renewable energy technologies, including solar-photovoltaic systems, biogas systems, wood-efficient stoves and heat retention bags (UNDP and Government of Botswana, 2012; BPC, 2013). The company set a target of 400 000 people having access to integrated services by 2021. By March 2013, BPC-Lesedi had availed solar home systems to 600 households, with a total capacity of 100 kW, and its franchisees had sold 475 efficient cooking stoves, 1200 rechargeable lanterns, 75 heat retention bags and 10 Bush Solar Geysers (BPC, 2013). Numerous small businesses in 14 rural settlements, five clinics, and seven tourist facilities had solar-photovoltaic systems. Furthermore, a 12 kW solar/biogas hybrid mini-grid was installed and the Sustainable Village Concept Project, which aimed to 'facilitate uptake through development of economic activities', was piloted in the Sekhutlane village in the Southern District (BPC, 2013: 20). Despite these achievements the BPC-Lesedi project faced sustainability challenges, including under-capitalisation, high investment costs and limited returns (Dikuelo, 2015; Botswana Daily News, 2014). The BPC-Lesedi was finally liquidated in order to devise a new model for providing renewable energy technologies for non-electrified rural settlements.

Access to grid electricity in Ngamiland District and the Okavango Delta

In Ngamiland District, large scale electric power was obtained from a standalone diesel generator until the early 1990s. Access to grid electricity was limited to government facilities and major private commercial enterprises. The Ngamiland District capital, Maun, was connected to the grid from the City of Francistown through a 132 kV power line in 1994 (BPC, 2015). This enabled direct connection of Maun and other small settlements in the Ngamiland District. The villages of Gumare and Shakawe, located about 230 km and 350 km in the north of Maun, respectively, were also connected through an international grid from Divundu in Namibia. Overall access to grid electricity in Ngamiland District is estimated at 39% compared to other sources of energy used by households for lighting (Figure 2).

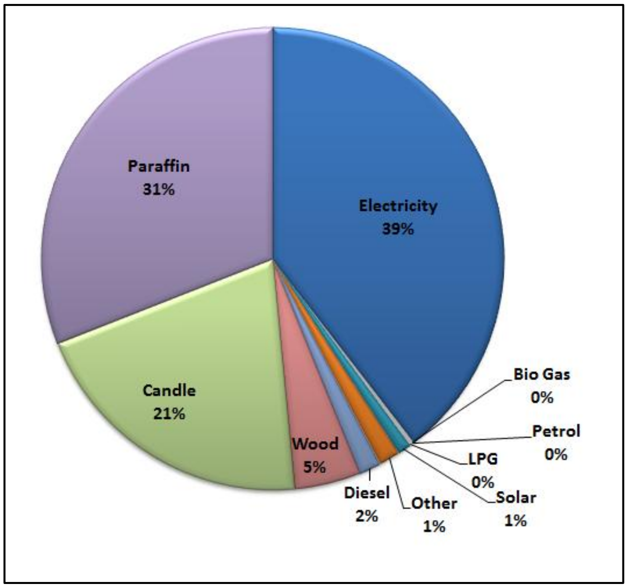

Figure 2: Proportion of households by main source of energy for lighting in Ngamiland District, Botswana.
Source: Census raw data, Statistics Botswana (2011)

Many rural villages in the Ngamiland District are without access to grid electricity; out of a total of 75 settlements, only 19 have access to grid electricity. Villages located deep in the Delta may remain without grid electricity due to construction difficulties and the high costs of construction. This was revealed in key informant interviews with officials at the BPC, who indicated that it was difficult and unviable to construct high voltage power lines in generally flooded and sparsely populated areas.

Access to grid electricity in the Ngamiland District has also been affected by frequent power outages and load shedding since 2012. Households and private commercial entities have resorted to the use of diesel/petrol generators, solar photovoltaic installations and micro-solar lighting systems, including solar lanterns. The latter were commonly used by households who could not afford to purchase generators or install in-house photovoltaic systems, which may have been unaffordable for most households. The cost of installing a solar photovoltaic system ranged from BWP 8000 (≈US$ 800) for an electrified house, to BWP15 000 (≈US$ 1500) for a non-electrified house (Personal communication with retailer). The smallest generator cost BWP 1000 (≈US$100) whereas solar lanterns ranged from BWP 60 (≈US$ 6) to BWP 200 (≈US$ 20).

Solar photovoltaic electricity has been supplied in rural and remote villages through standalone installations, particularly in public facilities such as schools, clinics and government staff housing. Key informant interviews have revealed that the maintenance of such installations was very expensive leading to their phasing out as soon as grid electrificity reached these villages. According to key informants, the adoption of renewable energy technologies in most remote villages has been very slow and limited to individual households.

Many tourist camps in the remote parts of the Delta remain without access to grid electricity given that they are located in inaccessible environmentally sensitive parts of the wetland. Most camps are designed to be temporary and may be decommissioned as and when they are no longer needed. Most of the camps use diesel generators to meet their energy needs for space cooling, water heating, lighting and refrigeration. Additionally, petroleum products are used for running utility and tourism service vehicles. To meet this demand for energy, it is estimated that 21 400 litres of diesel, 9600 litres of petrol and 1316 litres of oil are transported into and used in the Okavango Delta on a monthly basis (Aqualogic, 2008). Some studies have revealed that oil spillages are common. The storage of petroleum products and disposal of waste oil in many of the camps in the Okavango Delta results in environmental contamination (GIS Plan, 2012).

The Botswana Tourism Policy encourages the use of solar energy in tourist camps through a grading system that allocates high credit to camps that use solar energy than those that use fossil fuels for electricity generation (BTO, 2010). Currently, some lodges use both petroleum products and solar on a complementary basis. For instance, interviews with one camp manager indicated that a diesel generator was used for about two hours daily to provide energy for high use. During these two hours, all high consumption activities are undertaken and completed. A diesel generator is used during cloudy/rainy weather and this usually lasts a few days. In another lodge, solar energy was used as the only source of electricity and the solar installation at the lodge was fitted with energy transformers which enabled high energy consuming activities to be undertaken.

Interviews with North West District Council[5] officials have revealed that some of the challenges associated with the adoption of photovoltaic electricity systems in Ngamiland District were that, a) most appliances in the market are not suitable for use with solar photovoltaic electricity, b) solar-compatible appliances are very expensive compared to non-solar ones, c) the maintenance of solar photovoltaic and water heating systems is riddled with man-power and other resource challenges, and d) most private installations are not regularly serviced due to the misconception that these systems are maintenance-free.

Discussion

Improved national grid systems, coupled with high capacity electricity generation, have been viewed as the mainstay for achieving access to electric energy in most developing countries for many decades. Many governments in developing countries focused on building and expanding infrastructure for electricity generation and distribution at a national scale (Cabraal et al., 1996). Even in cases where isolated power systems existed, the intention has been to expand their capacity in order to meet the demand for electricity. This approach to electric energy provision has proven unviable in developing countries due to the high cost of serving sparse and isolated communities in rural and often very small settlements. It has also been identified as one of the impediments to renewable energy technology adoption and diffusion in many developing countries (Cabraal et al., 1996).

This study has demonstrated that electricity generation and distribution in Botswana has been steadily growing. This has been enhanced by the construction of power stations, the extension of power lines including connecting to regional grid networks through the SAPP. Connecting to regional power

[5][The district name used to be North West District until 2006 when it was changed to Ngamiland District, but the name of the district authority was not changed.]

distribution networks has enabled the country to obtain electricity from neighbouring countries, and has enhanced access to clean and affordable energy available from hydropower stations in southern African countries. Despite these efforts, access to electricity remains low the country's rural settlements.

Rural electrification has been implemented through initiatives such as the Rural Electrification Programme, group electrification schemes and subsidies. As a result, many of the main rural settlements, including Maun in the Ngamiland District, have been electrified. Access to grid electricity has been improved and in many of these settlements productive activities increased leading to urbanisation and improved well-being of the residents. For instance, in many of these settlements where agricultural activities used to be dominant in the 1970s and 1980s, the proportion of the population involved in non-agricultural activities has increased to more than 70% by the 1990s (Ministry of Local Government Lands and Housing [MLGLH], 1996). These achievements cannot be attributed to electrification of these settlements alone, but there is overall household-level transition from rural dependence on biomass energy sources such as fuel wood to liquefied petroleum gas for cooking, and from paraffin and candles for lighting to electricity. The Rural Electrification Programme and other initiatives have enabled access to clean and affordable energy for low income households, leading to improvements in their well-being. However, access to national grid electricity still stands at 63% suggesting that there is an urgent need to improve access to clean and affordable energy to the remaining 37% of Botswana's households.

Although the Government invested in the Rural Electrification Programme, availed subsidies and expanded grid electricity to many settlements, including those of Ngamiland District, this study has revealed that there has been a low adoption of grid electricity which may be due to low incomes and general poverty in rural areas. Furthermore, power outages and load shedding were frequent in the period 2012 to 2016. These were due to low power generation and the frequent shut-down of the Morupule-B Power Station, as a result of inefficiencies, linked to poor project preparation, management and delivery, which have also been noted for most SADC countries (SADC, 2012). Other challenges identified include the high costs of expanding the grid to remote and sparsely populated settlements, and in the Okavango Delta, these include inaccessibility due to flooding and isolated tourism camps and lodges which made expanding electricity to these areas unviable.

The study also indicated that the Government has invested in renewable energy technologies, particularly solar photovoltaic and solar water heating systems in order to improve access to electricity in remote and sparsely populated settlements. However, these were limited to government facilities such as clinics and schools, and they were often abandoned as soon as grid electricity was available. The use of solar systems has also had challenges, including high initial costs, lack of skilled manpower, and high maintenance costs, which made it difficult for low income households to acquire them. Solar systems were therefore limited to micro-systems for basic lighting, radio and charging of cell-phones and batteries. The use of off-grid systems, including standalone electricity generators, individual solar photovoltaic systems and mini-grids complemented national grid systems in enhancing access to energy in rural and remote settlements.

Apart from hydropower, the place for renewable energy technologies in the global electricity generation, especially in the 1980s and 1990s, has been limited. For instance, in 2013 the share of renewable energy sources (other than hydro) in the global energy mix was less than five percent (as indicated in Section

1), and it is estimated that the share of renewable energy sources in the global electricity generation will increase to 26% by 2020, the bulk of which will come from renewable sources other than hydro-electric power (Renewable Energy Policy Network for the 21st Century [REN21], 2015). In Botswana, and the rest of the developing world, renewable energy has in the past been restricted to use in the rural and remote settlements where electric energy supply through the national grid is viewed as almost impossible. Due to technological advances in the manufacturing of solar systems and the growing private sector involvement in renewable energy technologies around the world, there has been a general decline in the price of solar energy systems (REN21, 2014). For instance, the price of solar photovoltaic modules decreased from US$30/Wpeak in 1980 to US$0.90/Wpeak in 2013 (REN21, 2014). Coupled with the general increase in the price of petroleum products and growing pressure to reduce their use due to global warming and climate concerns, there is hope that transition to renewable energy technologies will be faster than in the past.

Conclusion and policy implications

This study has highlighted the following main challenges of improving access to grid electricity in rural settlements in Botswana and the Okavango Delta a) low adoption due to low incomes and general poverty, b) frequent power outages and load shedding, c) poor project preparation, d) high cost of expanding the grid to remote and sparsely populated settlements, and e) inaccessibility due to flooding in the Okavango Delta. Low adoption due to low income and poverty is an indication that access to energy in whatever form, including renewable energy, is a part of the broad human wellfare problem and as such cannot be treated in isolation. There is need for targeted programmes towards reducing poverty and improving rural livelihoods, and current social welfare programmes have so far been ineffective in achieving this in Botswana.

Frequent power outages and load shedding have been common not only in Botswana, but in the SADC region as a whole. To some extent these are indicators of inadequate supply and, to a large extent, an increase in demand for electricity for various purposes. Cases in point have been provided in this study where households adapted to frequent power outages by purchasing and using solar lanterns and installing solar photovoltaic systems in their houses. There is a need to invest in alternative energy sources, and renewable energy technologies present an opportunity to augment power supply and reduce environmental costs associated with fossil fuel-based electricity generation. In environmentally-sensitive areas such as the Okavango Delta, renewable energy technologies that have minimal impact on the environment should continue to be promoted. The paper suggests that the tourism sector could pioneer the use of renewable energy in remote areas. As an environment-dependent sector, particularly in the ecologically bio-diverse wetlands such as the Okavango Delta, the tourism sector tourism can lead in the development of environmentally-friendly energy sources and the general reduction of the carbon foot-print in economic development.

Poor project preparation due to lack of integrity in the energy sector is a major challenge as it may deprive nations and citizens the right to access affordable clean energy. In 2015, Botswana was rated by Transparency International (2016) as one of the least corrupt countries in Africa and the world, being ranked 28 out of 168 countries with a corruption perception index of 63 (0=highly corrupt, 100=clean). However, this study has indicated that lack of integrity resulted in major losses at

Morupule-B Power Station, leading to widespread power shortages in the country. Lack of integrity in the energy sector can adversely impact access to energy and lead to disruptions in other sectors; it requires political will to support and strengthen institutions meant to prevent, detect and curtail corruption and related malpractices to ensure efficient use of limited resources.

The high cost of expanding the national grid to remote and sparsely populated settlements and the Government's decision to halt the expansion of the grid to these settlements are indicators that access to clean and affordable energy cannot be achieved exclusively through connection to the national grid. The implementation of the Rural Electrification Programme through the expansion of the internal grid in electrified villages, coupled with subsidies partially financed through the National Electrification Fund is a positive step for promoting access to grid electricity. However, the phasing out of solar photovoltaic systems when grid electricity is extended to rural settlements is worrying. Solar energy remains the most readily available energy source in Botswana, given that the country has one of the highest levels of solar energy resources in the world, estimated at 320 days of sunshine per year, and a global insolation of 21 MJ/m^2 per day (Nijegorodov et al., 2005; Adringa, 1989). It may help to allow for its continued use to supplement grid-electricity wherever the latter is in short supply.

There is need for increased investment in off-grid systems, particularly those based on renewable energy sources, as well as the introduction of subsidies to promote the adoption of renewable energy, which can serve as alternative energy source. Financial resources obtained from the National Electrification Fund may be used to promote the adoption of renewable energy, particularly solar photovoltaic systems. Feed-in supplementary connections to grid systems from independent solar photovoltaic electricity installations should be promoted and the provision of feed-in tariffs and tax rebates should be used as incentives for the installation of solar systems in residential and commercial settings. In the Okavango Delta, increased support and incentives for the use of renewable energy is required to push for a total transition from fossil fuel-generated electricity to solar photovoltaic systems for the tourism sector to pioneer a secure and sustainable path for the energy sector in Botswana and beyond.

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