

# BIDPA Working Paper 39

July 2014

## **Towards a Diversified Economy: A Preliminary Assessment of the Potential, Prospects and Challenges for Electricity Exports from Botswana**

**Margaret Sengwaketse**

**BOTSWANA INSTITUTE FOR DEVELOPMENT POLICY ANALYSIS**





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## **BIDPA**

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## 1. Introduction

There are several factors that make the study of the energy sector in general, and electricity sector in particular, relevant than it has ever been. In recent years, the energy sector has been in the liberalization agenda in the Southern African Development Community (SADC). In Botswana, estimates suggest that Botswana has very large inferred coal bed methane (CBM) resources. If exploited CBM presents prospects to generate electricity using a low carbon and low to medium cost source of power. Botswana also has one of Africa's largest coal resources estimated at 212 billion tonnes. In recent years, uranium deposits have been discovered in Northern Botswana. If these resources are developed for the purposes of electricity generation, Botswana may generate enough electricity for domestic requirements and possibly, for exports. While the resources that could be used to generate electricity are significant and varied, the study will focus on prospects of thermal power generation for export.

The focus on coal for electricity generation and export is motivated by the following factors. As discussed earlier, estimates suggest that, Botswana has significant reserves of coal. Secondly, Botswana already produces power, albeit at very low levels, for domestic power consumption and there are plans by the private sector to produce more power for domestic consumption. Third, production of thermal electricity is already in the Government of Botswana's diversification agenda through the coal roadmap. Further, while CBM provides an option of low carbon and low to medium cost source of energy and therefore merits studying, the commercial viability of CBM still remains uncertain despite the accelerated development in the United States of America (USA). While uranium is a relatively cheap source of energy, and likely to be a viable option of electricity generation for domestic consumption and export, public perceptions of the health and safety risks associated with nuclear following the Fukushima (Japan) nuclear accident means it presents a longer term prospect for electricity generation subject to increased consumer confidence.

The objective of the study is to assess prospects and challenges of coal-fired power exports in Botswana. Specifically, the study reviews supply and demand factors that are likely to affect electricity trade, environmental concerns, infrastructure and technology issues that are likely to have an impact on the production of thermal power for export.

## 2. Supply Factors

Ebinger et al. (2012) in their evaluation of the liquefied natural gas exports in the United States analysed the supply situation of natural gas based on three aspects; resource availability and production sustainability; policy, regulatory, and environmental issues; and, capacity and infrastructural considerations. This study adopts the same approach to assess supply side factors on prospects of coal-fired electricity exports in Botswana.

### 2.1 *A Review of the Resource Base*

The potential to export coal-fired power depends on whether there are adequate coal reserves to support power generation. Some studies and government reports have estimated the amount of coal resources in Botswana. According to the National Development Plan



The author indicates that the higher the energy content, the higher the value of coal per unit of mass; and, the lower the moisture and content of the coal, the better the quality of the coal. The author further explains that the higher the fixed carbon, the higher the energy content; whereas a high sulphur content in coal is not good for the environment as sulphur is converted to sulphur dioxide during combustion. Table 2 shows a comparison of Botswana coal with that of popular reference brands. It is evident in table 2 that in terms of energy content, Botswana coal is of relatively lower quality than the reference brands. However, with regard to high quality coal in Botswana, the difference with the other brands is not very large. In terms of ash and sulphur content, high quality coal in Botswana compared favourably with the other brands.

**Table 2: A Comparison of the Quality of Botswana Coal and Other Brands**

	<b>Botswana (High)</b>	<b>Botswana (Low)</b>	<b>New Castle Benchmark</b>	<b>Richard's Bay Benchmark</b>
Energy kcal/kg	6,000	5,400	6,322	6,300
Total moisture % (ar)	8	10	15 (max)	15 (max)
Inherent moisture % (ad)	4	5		
Ash % (ad)	13	20	14 (max)	16 (max)
Fixed carbon (ad)	58	50		
Total sulphur % (ad)	0.45	0.8	<0.75	<1.0

**Source:** Ministry of Minerals and Water Resources, 2011

Despite the large coal resources that exist in Botswana, a significant proportion of these resources are unexploited. Currently, Morupule Colliery is the only coal producer in Botswana. NDP 10 estimates indicated that Morupule Colliery has the capacity to produce about a million tonnes of coal per year. According to the NDP, one of the main reasons why Morupule Colliery is unable to produce at full capacity is depressed demand. Others suggest there are other reasons beside demand factors as to why Morupule Colliery is unable to produce at full capacity. For example, Mackenzie (2011) indicates that the mining methods being used limit resource recovery at Morupule Colliery.

The capacity of Morupule Colliery is being expanded to 3.2 million tonnes per annum (mtpa) to meet requirements for Morupule B thermal power station. Botswana Power Corporation (BPC) uses coal from Morupule Colliery to operate a power plant at Morupule. Before the expansion of the power station at Morupule (i.e. Morupule B), Morupule Power station (Morupule A) contributed about 24 per cent (120 MW) of the national power consumption of about 500 MW. Prior to the power shortages in South Africa in 2008, the balance of Botswana's electricity requirements were met by imports from Eskom in South Africa. Imports of electricity from South Africa have fallen significantly following the decision by Eskom to stop exporting power to Botswana from 2013.

The reduced electricity imports have prompted BPC to expand local power production to



financial resources are likely to be an important consideration for the production of electricity. The availability of other inputs and skills to sustain production are also going to be very important of whether Botswana can take advantage of its large coal reserves to export electricity.

## **2.2 Environmental and Regulatory Considerations**

### *2.2.1 Environmental Issues*

GHG emissions are a major concern for coal-fired power generation. The higher carbon content of coal compared to, for example, natural gas implies that coal-fired power plants have higher GHG emissions than natural gas. The Canadian Energy Board (2008) estimates that depending on the plant technology, gas-fired power generation produces 40-50 per cent fewer emissions than a coal-fired plant to produce the same amount of electricity. Barnett and Reback (2012) estimate that conventional power plants emit, on average, just below 2000 pounds of CO<sub>2</sub> per Mega Watt hour (MWh) compared with just below 800 pounds of CO<sub>2</sub> per MWh (60 per cent below coal) for a natural gas combined-cycle power plant.

The debate on the need for countries to reduce carbon emissions has increased in recent years. In the United States, for example, the Environmental Protection Agency has tabled a Clean Power Plan Proposed Rule in June 2014. In view of the fact that power plants are the largest source of carbon dioxide emissions in the United States and constitutes a third of all the domestic greenhouse gas emissions (EPA, 2014), power plants are one of the main targets of the Clean Power Plan. A total of 1,000 fossil fuel fired power plants are covered by the proposed rule (EPA, 2014). Under the Plan, the EPA proposes a 30 per cent cut in carbon pollution from the power sector by 2030.

The debate and concerns on emission of green-house gases have not been limited to the developed countries. In 2005, South Africa for example, contributed 1.1 per cent of global green-house gas emissions and about 40 per cent of emissions in Sub-Saharan Africa (SSA) (Pegels, 2009). In response to these significant emissions, South Africa produced two Long-Term Mitigation Scenarios in 2007. The mitigation scenarios outline different strategies of reducing green-house emissions in South Africa. The Government of Botswana has also acknowledged that climate change is a concern for development. For example, the NDP 10 mid-term review in 2011 indicated that emphasis of the remaining years of the national development plan would be on the development of a National Climate Change Policy and a Comprehensive Climate Change Strategy and Action Plan. These initiatives are aimed at creating an enabling environment for the effective implementation of measures to adapt and mitigate the effects of climate change in the Botswana economy.

It is evident from the examples above that the debate on climate change is no longer about what needs to be done in the future but is rapidly transforming into tangible responses by developed and developing countries alike to reduce the effects of emissions on the environment. As initiatives to regulate GHGs may be in place in some parts of the world in the next five years, it implies that as the debate on climate change intensifies and the legal environment around the world changes accordingly to take into account mitigation measures, prospects for development of coal-fired electricity exports in Botswana should take into



**Table 3: Estimates of Total Plant and Levelised Electricity Costs for New Coal-Fired Power Plants With and Without CCS Technology (in 2010 dollars)**

	Supercritical Pulverised Coal Plants	Supercritical Pulverised Coal Plants	Supercritical Pulverised Coal Plants	Supercritical Pulverised Coal Plants
<b>Carnegie Mellon University</b>				
Without CCS	1,788	1,710	55.9	56.0
With CCS	3,237	3,234	97.3	100.8
Premium for CCS (%)	81	89	74	80
<b>Electric Power Research Institute</b>				
Without CCS	1,888	n/a	65.5	n/a
With CCS	3,138	n/a	111.5	n/a
Premium for CCS (%)	66	n/a	70	n/a
<b>Global Carbon Capture and Storage Institute</b>				
Without CCS	1,919	n/a	57.4	n/a
With CCS	3,464	n/a	101.8	n/a
Premium for CCS (%)	81	n/a	77	n/a
<b>Massachusetts Institute of Technology</b>				
Without CCS	1,734	1,669	53.1	54.6
With CCS	2,790	2,907	95.4	103.3
Premium for CCS (%)	61	74	79	89
<b>National Energy Technology</b>				
Without CCS	1,637	1,612	63.2	64.0
With CCS	2,895	2,924	107.7	111.3
Premium for CCS (%)	77	81	71	74

**Source:** Congress of the United States Budget Office, 2012

The discussion above indicates that CCS technology in coal-fired power plants demands significant technical capability. Skills shortage is a major challenge in Botswana (BIDPA and World Bank, 2006). The high technical demands of the CCS technology are likely to undermine Botswana's efforts to take advantage of the new environmentally friendly technology in the development of new coal plants. Combined with the relatively higher costs associated with constructing power plants with CCS, the technical skills requirements associated with CCS



and are likely to play a significant role in the viability of electricity generation for export.

### *2.2.2.1 Local Regulatory Framework and Institutions for Electricity Generation*

The Ministry of Minerals, Energy and Water Resources, through the Energy Affairs Division performs the function of formulation, direction and coordination of national energy policy. BPC, a parastatal under the Ministry of Minerals, Energy and Water Resources is responsible for electricity generation and supply. BPC performs its electricity generation and supply role in accordance with the BPC Act. The Electricity Supply Act supports Botswana Government's commitment to have the private sector or independent power producers (IPPs) involved in the development of power stations in the country.

It appears that the private sector is already responding to the role of being producers of power. For example, African Energy Resources are, through the Sese Integrated Power Project, intending to take advantage of the fact that given the availability of coal, as a source of relatively cheap feedstock for electricity generation; their proximity to the transmission network that forms the backbone of the Southern African Power Pool (SAPP); and that shortage of electricity is likely to continue being a problem into the foreseeable future in Southern Africa and produce power (African Energy, 2013). Sese Integrated Power Project includes the design of an initial 300 MW power station and estimates suggest a portion of the project has enough coal to generate 2,400 MW of electricity for over 30 years (African Energy, 2013). Given their proximity to South Africa, it is likely that should Eskom allow international IPPs to feed into the South African electricity grid in 2019 as planned, Sese Integrated Power could be in a position to expand production to produce power for export in the region.

Other regulations that affect the energy sector in general include the Environmental Assessment Act of 2011 and Mines and Minerals Act of 1999. Prior to its review, the Environmental Assessment Act was referred to as the Environmental Impact Assessment. To facilitate its implementation the Environmental Assessment Regulations of 2012 have been developed. Since coal-fired power stations use coal as an input to electricity generation and coal is mined, the Mines and Minerals Act has provisions that affect the production of electricity. One of the provisions of the Mines and Minerals Act of 1999 stipulates that the validity of a mining licence is up to 25 years. This duration is subject to renewal through an application for renewal to the Minister. The Mines and Minerals Act also stipulates obligations regarding the environment. The provision indicates that the mineral concessions shall operate in a manner consistent with regulations and good mining practices that take into account the preservation of the environment, minimize and control waste or undue loss or damage to national and biological resources. According to the Mines and Minerals Act, it is a requirement for applicants for new mining licences or renewals of existing licences to prepare and submit a comprehensive environmental impact assessment as part of the project feasibility study report.

The NDP 10 midterm review indicates that there is no national climate change policy and strategy and that research capacity on climate change issues is limited. To rectify this, the review proposes that during the remainder of NDP 10, a National Climate Change Policy and a Comprehensive National Climate Change Strategy and Action Plan should be developed



international capital markets; international financial institutions and the private sector. However to complement these external sources of funds, there has to be some contribution from local sources. The power utilities in the Southern African region have operated at a loss and are not likely to be a local source of funds (Mbirimi, 2010). Further, capital markets in developing countries in general, and Southern Africa in particular, are not developed. That leaves one possible source of local funds, which is the national treasury. According to Mbirimi (2010), estimates by Africa Infrastructure Country Diagnostic (AICD) indicate that the financial resources required for investment in new generation capacity in countries such as Zimbabwe and the DRC might be up to six percent of Gross Domestic Product (GDP). These financial requirements are significant and might put considerable pressure on countries to balance the need for new generation capacity and other competing development needs in the economy. The second problem is with regard to distances involved between the source of power; for example, hydro power in Congo and the main market, South Africa. The distance between the source of power and the main markets presents problems regarding security and reliability of power transportation and the costs of constructing and extending transmission network. Again, given the limited capabilities of most countries in Southern Africa to mobilize domestic resources to generate and transmit electricity, these costs tend to be prohibitive.

One other challenge the SAPP faces is the need to reduce greenhouse emissions. This is not a very easy task due to the fact that 70 per cent of the electricity in the pool is produced from coal, a major polluter through the emission of greenhouse gases. Secondly, SAPP recognizes the need to increase renewable energy projects to reduce the problem of greenhouse gas emissions. However, these renewable technologies are relatively new and their costs are still very high, and given the fact that electricity tariffs in the pool generally do not reflect costs of producing electricity, power producers cannot recover the high costs of renewable technologies. Finally, different countries in the power pool are at different levels with regard to the implementation of environmental protection legislation, and this creates problems in adopting a common standard on measures to reduce greenhouse gases.

### **SADC Protocol on Energy**

The SADC Protocol on Energy was signed in August 1996 with the objective of ensuring that sectoral and regional energy policies and programmes are harmonized with SADC-wide policies and programmes, and sector specific strategies in SADC. Guidelines on regional integration and cooperation in the electricity sector include; promotion of electricity trade through power pooling; promotion of integrated resource planning in the electricity sector through economies of scale, and optimal investment and sharing of benefits in an equitable manner; promotion of the development of common regional standards, rules and procedures governing generation, transmission and distribution of electricity.

### **Regulatory Framework of STEM and DAM**

The short-term energy market is governed by a legal agreement and a set of trading and financial rules and participation in this market is open to all members of the SAPP and IPPs. The Day Ahead Market (DAM) offers a secure, effective and non-discriminatory trade in electricity and provides a neutral reference price. The objective of these SAPP markets is



indicates that operation and maintenance costs of thermal power plants constitute 15 per cent of total costs and fuel costs, 35 per cent. The costs estimates discussed above indicate that in addition to construction costs, costs associated with the importation of equipment, human capacity gaps as well as maintenance and operation are significant and therefore, these additional costs will be an important factor in the feasibility of the development of thermal power exports in Botswana.

Although generation, transmission and distribution costs estimates discussed above vary, it is clear from the discussion above that cost for producing coal-fired electricity are significant. The implication is that the availability of funds to generate and transmit electricity will be an important determinant of Botswana's ability to exploit coal to produce electricity for export. Mbirimi (2010) identifies three possible sources of funding for energy projects; external donor funds, domestic and international capital markets, and, financial resources generated by power utilities. According to Eberhard, et al., (2008) power utilities in Africa have contributed very little or nothing at all to capital costs of power generation and have not even been able to generate adequate financial resources to finance their operating costs and have depended, to a large extent, on subsidies from their governments or donors. The report further indicates that although official development assistance has contributed to investment in the power sector in Africa, investment was much lower than what was needed to keep pace with development and increase access to electricity. Private investment in the power sector in SSA has been, on average, US\$300 million per year over the last decade (Eberhard, et al., 2008). Further, the authors indicate that during the last decade, external flows i.e. aid and private investment to the power sector were about 0.1 per cent of GDP.

Unless the situation on external investment flows into the power sector changes, it might be difficult for Botswana to mobilize resources from external sources to develop thermal power exports. During the 2014/2015 financial year, the Ministry of Minerals, Energy and Water Resources received the largest share P3.55 billion representing 29 per cent of the development budget. Major projects included the construction of the North-West transmission line, Morupule A and B power generation projects and the Zimbabwe, Zambia, Botswana and Namibia transmission project. The significant financial resources committed to the energy sector are mainly for the generation and transmission of power for domestic needs. Given the competing domestic needs, it might be a major challenge to use the government budget to finance power generation, transmission and distribution projects to facilitate exports of coal-fired power.

Despite the high costs of power generation, some recent developments suggest the development of power exports in Botswana might be feasible. The first is that, the Zimbabwe, Zambia, Botswana and Namibia (ZIZABONA) interconnection transmission project has been identified as a priority project and endorsed by SAPP. ZIZABONA is trans-boundary infrastructure development and regional integration project that is aimed to alleviate transmission congestion through the construction and operation of new high-voltage transmission facilities that will connect power utilities in Zambia, Zimbabwe, Botswana and Namibia. The project will also serve as a western transmission corridor in Southern Africa and will facilitate electricity trade between the utilities. SADC Energy ministers have approved priority projects. Development Bank South Africa (DBSA) has



mines and facilities that are likely to start production in 2019 was 260GWh. The estimates were based on five mining sites.

Projections on Botswana's energy demand suggest that in the absence of alternative sources of power generation, domestic demand for thermal power is expected to increase as generation capacity expands to meet increasing domestic energy demand. Efforts to increase domestic supply of coal fired electricity are already evident as the construction of Morupule B 600 MW coal plant is nearing completion and there are plans to build a further 600 MW power plant during phase two of power expansion at Morupule. The expansion of generation capacity for domestic energy needs would increase coal demand for power generation. Projections by Mackenzie (2011) indicate that coal demand for domestic power generation could reach up to three metric tonnes per annum (Mtpa).

In addition to domestic demand for coal for electricity production, another important possible consumer of coal is the industrial sector. Coal is a primary input in the production of cement and conversion of coal to liquids. While these two uses of coal are likely to compete with electricity generation, Mackenzie (2011) advances two reasons why these are not likely to be a major threat to coal power generation. The first reason is that despite growth in demand for cement in Africa, transport costs for cement over long distances are very high. Although transport costs are a major factor in cement trade, some trade between countries is still possible over relatively shorter distances and efficient logistics systems. For example, Botswana still meets some of its demand for cement through imports, specifically from South Africa. As cement is a low value product, the prohibitive transportation costs for cement are likely to act as a disincentive for Botswana to produce cement for export. As a result, cement produced in Botswana is likely to be consumed locally. Mackenzie (2011) estimates that domestic demand for coal for cement production would be about 50 kilo tonnes per annum. Given these estimates, the demand for coal for cement production is too small to pose any serious threat to the production of thermal power for export.

The second reason is that while South Africa is a major consumer of oil products and demand for liquid fuels is growing in Botswana, a technology used to produce diesel from coal namely the Fischer Tropsch process, also produces naphtha, a product with no demand in Southern Africa. Further, the Fischer Tropsch and MTG, a gasoline producing technology are both capital intensive and conversion of coal to liquids is only possible at very large scale. Estimates suggest that prospects for increased coal use in the production of cement and conversion of coal to fuel are small. Based on these reasons, it is unlikely that the production of cement from coal and the conversion of coal to liquids will be significant competitors of the use of coal for production of electricity for export.

#### *2.4.2 External Demand Factors*

As discussed above, estimates indicate that Botswana has significant coal resources and that once rail infrastructure to the coast is built, Botswana could become a participant in the global coal markets. While the export of coal is one of the most important aspects of the development of the coal industry in Botswana, and is associated with significant expected economic benefits, an assessment of demand factors for coal is beyond the scope of this paper. The discussion on demand factors in this section is limited to an assessment

of demand factors for thermal electricity exports. As electricity generation and transmission costs can be significant, it is reasonable to expect Botswana's prospects for export electricity would be biased towards a regional market.

Mbirimi (2010) identifies three determinants of demand for power in the SADC region. These include, market demand due to economic and population growth and urbanization; suppressed demand, evident in power cuts and rationing; and, social demand for power to meet the goal of widening access to electricity. Economic and population growth are some of the drivers for energy demand growth, and have been increasing in the SADC region. Estimates by DB (2010) and IMF (2010) (cited in IRENA, 2012) suggest annual GDP growth rates of four per cent between 2008 and 2015; 3.5 per cent between 2015 and 2030; and, three per cent between 2030 and 2050 in Southern Africa. Population growth is one of the key drivers of electricity consumption. Electricity demand in Africa is estimated to grow at an average four to six per cent per annum between 2008 and 2030. According to IRENA (2012), electricity demand in developing countries tends to grow as fast as GDP growth, estimates suggest that in Southern Africa, electricity demand growth will match GDP growth at three to four per cent per year between now and 2050 (DB, 2010 and IMF, 2010 cited in IRENA, 2012).

Urbanisation is one of the major determinants of electricity demand. Projections indicate that by 2050, urbanization rates in Africa will increase by 20 per cent. In Southern Africa, United Nations estimates (cited in IRENA, 2012) indicate that the share of urban population in total population in 2008 was 44 per cent; and would increase to 47 per cent in 2015; 55 per cent in 2030; and, reach 66 per cent in 2050. The rising urbanization rates in Southern Africa suggest that demand for electricity in the region will increase and that presents an opportunity for Botswana to produce electricity for export in the region.

Mbirimi (2010) suggests that the growth in the demand for power in the region presents both opportunities and risks. The author posits that the opportunity exists because the growth in demand for power in SADC region facilitates a regional approach to the expansion of generating capacity and energy supply. According to Mbirimi (2010), risks associated with the demand for power exist because, as domestic demand for electricity increases, individual economies can respond to a growth in electricity demand by adopting a relatively cheaper and quicker option, which is expanding domestic generation capacity. In South Africa, for example, estimates suggest that energy demand will double in the next 15 years (Pegels, 2009). This immense demand pressure might prompt the South African economy to increase domestic demand supply capacity. Mbirimi (2010) posits that the construction of Kusile and Medupe coal-fired power plants in South Africa could be a possible manifestation of expansion of domestic power generation capacity in response to domestic power demand pressures. As growth in electricity demand has created opportunities for the development of regional power trade, Mbirimi (2010) suggests that the response to this opportunity should be prompt and firm.

The discussion on regional demand factors above suggests that given the growth in demand for electricity in SADC and increasing urbanization rates in Southern Africa, opportunities for the development of electricity exports in Botswana exist. However, challenges and uncertainties on the demand side remain. The expansion of domestic power generation

in South Africa, the largest potential export market for Botswana's electricity exports, may dampen demand for electricity imports from the region in general and Botswana in particular. Botswana's success in the development of electricity exports would depend, at least to some extent, on the speed with which the country can grasp the potential created by regional approach to power generation capacity.

#### *2.4.3 Other Demand Factors: Alternative Sources of Electricity Generation*

In addition to domestic demand and regional demand factors discussed above, the development of coal-fired power exports in Botswana is likely to compete with other sources of electricity. These alternative sources of electricity generation include in particular, renewable sources of energy such as hydro power, solar and wind power. The threat to coal-fired power generation emerges from two fronts. The first is that concerns about climate change have intensified the debate on the emission of greenhouse gasses and stimulated the development of renewable energy technologies and the possibility of legislation in future to curb greenhouse gas emissions. Two developments suggest that efforts to tackle concerns on climate change are already taking place in Southern Africa. The first is that, as part of the Copenhagen Accord of 2009, South Africa committed to taking mitigation action that would enable it reduce emissions by 34 per cent and 42 per cent, using the Business as Usual growth in emissions path by 2020 and 2025 respectively (Peršut et al., 2011). According to Peršut et al (2011), the commitments South Africa made on emission mitigation action include emission reduction targets from the power sector. South Africa's Integrated Resource Plan of 2010 which was approved by the South African Cabinet in 2011 intends to reduce carbon dioxide emissions from 912 g/kWh to 600g/kWh by 2030 (Haffejee, 2013). In addition, probably as part of the emission mitigation plan, South Africa's Integrated Resource Plan has committed to diversifying the electricity generation mix and according to KPMG (2012) forecasts an increase in the share of renewable energy in South Africa's generation mix to 17 per cent by 2030.

The second threat to coal-fired power generation is that capital costs of levelised cost of electricity for renewable energy have come down over time and would continue to decline in future due to learning effects (IRENA, 2012). Table 4 presents capital cost projections of renewable energy options by technology. The cost estimates below, do not include equipment transportation costs and import tariffs. If transportation costs for equipment are considered, the costs for renewable energy technologies in locations such as landlocked countries, where transport costs are significant, might be higher than indicated in table 4. It is evident from table 4 that with the exception of biomass combustion, the decline in the capital cost of renewable energy sources is significant. If the costs of renewable energy sources continue to decline as suggested by the estimates below, the development of coal-fired power stations could face increasing competition from renewable sources of energy.

**Table 4: Renewable Capital Cost Projections by Technology, 2010 to 2050**

<b>(USD/kWh)</b>	<b>2010</b>	<b>2015</b>	<b>2030</b>	<b>2050</b>
<b>Solar PV (utility-scale)</b>	3,000-4,000	2,850-3,000	2,200-2,450	1,800-2,100
<b>Solar PV (Home System)</b>	5,000-6,000	4,500-5,700	3,600-4,100	2,200-3,500
<b>Solar CSP (with 8 hour storage)</b>	8,500	6,000-6,500	4,200-5,100	3,000-4,400
<b>Wind (2 MW turbine)</b>	1,750	1,700-1,800	1,400-1,700	1,100-1,300
<b>Biogas engine (including digestion)</b>	2,000	1,800	1,500-1,700	1,200-1,500
<b>Biomass gasification</b>	2,000	1,800	1,500-1,700	1,200-1,500
<b>Biomass combustion</b>	1,250	1,250	1,250	1,250
<b>Hydro</b>	3,000	2,700-2,900	2,300-2,800	2,000-2,700
<b>Geothermal</b>	4,000	3,600-3,900	3,000-3,250	2,400-3,000

Source: IRENA, 2012

It seems competition from renewable power generation technologies is steadily increasing. Estimates by GWEC (2011) and Sun and Wind Energy (2011) (cited in IRENA, 2012), indicate that hydropower generation constitutes the largest proportion in terms of existing power generation capacity, new capacity and forecast suggest that the generation capacity of wind and solar energy will be significant in the future. Platts (2011) (cited in IRENA, 2012) indicates that total hydropower capacity in Africa was about 26 GW. Part of this untapped hydropower potential is in Southern Africa namely the Grand Inga in the Democratic Republic of Congo.

IRENA (2012) highlights the following facts about the Grand Inga hydropower project. The first is that, it is estimated that the Grand Inga project has the potential to generate 44 gigawatts of hydropower and currently has installed capacity of 1,775 MW. Secondly, the project is divided into three phases. Phase 1, has a total installed capacity of 351 MW and phase II, 1,424 MW. The operating capacity of both phase I and II currently stands at 875 MW due to inadequate maintenance in existing plants. Third, a new project, Inga III dam, has a proposed capacity of between 3.5 to 5 GW and is at design stage. Estimates indicate that the cost of Inga III dam would range between US\$8 billion and US\$10 billion, i.e. US\$1,300 to US\$2,000/KW. The project includes the construction of high voltage transmission lines to supply power to Zambia, Zimbabwe, South Africa and the Republic of Congo (Brazzaville). If completed, Inga III would be the largest hydropower project in Africa and the fifth largest in the world. In addition to the Grand Inga project, hydropower potential exists in other parts of Southern Africa. For example, Angola has hydropower potential of 18 GW and Mozambique, 12 GW (IRENA, 2012).

Hydropower is not the only possible threat to thermal power generation. The potential for solar photovoltaic (PV) in Africa is very large and has prospects for growth since it offers an excellent option for off-grid electricity generation (IRENA, 2012). With the PV technology, panels use silicone to convert solar radiation into electricity. The other technology for producing electricity from solar radiation is the concentrating solar power (CSP). CSP technology uses mirrors to concentrate solar energy for heating fluids. The energy from the heat produces steam which in turn produces energy using turbines. According to Pegels (2009), solar energy is the renewable energy with the greatest potential in South Africa and 1.25 per cent of the 194,000 km<sup>2</sup> of total area with high radiation in South Africa can produce 80 GW of electricity, enough to meet the projected demand of South Africa in 2025. IRENA (2012) makes the following observations regarding wind energy. The first observation is that despite a very small installed capacity of wind power in Africa in general, South Africa is poised to be a significant producer of wind energy due to the introduction

of a bidding system. Second, the Integrated Resource Plan estimates to have installed 8.4 gigawatts of wind power capacity by 2030 and as part of the initiatives to reach that target, has already approved bids including 634 MW of wind energy in 2011 and based on bids held by the Government, plans to produce an additional 2,209 MW of renewable energy including wind power in the next two years.

While the discussion above is specific in terms of South African initiatives on renewable energy, the South African energy policy tends to encourage the participation of IPPs and the development of renewable energy sources. The commitment to these two aspects is demonstrated in the following policy decisions outlined in Haffejee (2013). The first is that the Government produced a White Paper on Energy in 1998. One of the proposals of the White Paper was the liberalization of the power sector. As a result, in 2001, cabinet proposed a 70/30 split between power generated by Eskom and IPPs. Secondly, a White Paper on Renewables was developed in 2004 and proposed renewable energy targets. In addition, the Government of South Africa has displayed commitment to a Green Economy that is accompanied by localization and job creation. The third initiative is that ministers in South Africa are determined to produce 3,725 MW of electricity from renewable energy IPPs before 2019. Finally, the Integrated Resource Plan of 2010 has set a 17,800 MW target from renewable sources of energy by 2030.

As part of the national measures to support private sector investment in renewable energy and other clean technologies and discourage investments in fossil fuel technologies, South Africa included a ZAR 0.02/kWh levy on non-renewable electricity in 2009 which formed part of the electricity price increase endorsed by the National Energy Regulator of South Africa (Nersa) (Pegels, 2009). According to the author, proposals of the Long-Term Mitigation Scenario (LMTS) in South Africa included an escalating tax on greenhouse emissions which would increase from ZAR 100 per tonne of carbon dioxide (or ZAR 0.102/kWh) in 2008 to ZAR 750 (ZAR 0.765/kWh) in 2040. The estimates on the levy on greenhouse emissions were based on the assumption that the production of 1MWh of coal-fired electricity emitted just over one tonne of carbon dioxide (Pegels, 2009).

One of the most important determinants of Botswana's export of electricity is strategies that Eskom, South Africa's largest producer of power, adopts in its effort to meet South Africa's demand for electricity. CIC Energy had proposed to develop 1,200 MW coal-fired power plant at Mmamabula. CIC had planned to export 75 per cent of the power it would produce at Mmamabula to South Africa and sell the remainder to BPC. However, Eskom, the main buyer of Mmamabula, based on its revision of demand forecast stated that it would only require additional base-load generation capacity from 2018 under the assumption that this additional power needs would be met by both local and regional IPPs.

Being the most important potential market for Botswana's electricity exports, the rapid growth in renewable energy in the generation mix in South Africa in accordance with the Integrated Resource Plan and other initiatives and policies in the South African energy sector outlined above, these developments pose a serious threat to Botswana's prospects to develop thermal power exports. Electricity demand figures discussed in the previous section suggest that South Africa is an important determinant of the feasibility of the development of electricity exports in Botswana. Although South African energy initiatives encourage the participation of IPPs, its commitment to the development of renewable energy sources suggest that South Africa's demand for electricity from independent producers of power is likely to come from renewable sources. These developments in South Africa's energy policy are likely to weaken Botswana's prospects to produce power for export to South Africa. Further, the discussion



advantage of this opportunity, Botswana needs to consider the availability of technical skills. However, shortage of skills has been a major challenge in Botswana and this might affect prospects for power production. Further, the costs of the technologies are high and other requirements such as inputs to run and manage the power plants are significant.

GHGs are a major global concern and since coal-fired power generation is a major polluter, pressure to build power stations which reduce emissions will increase as the debate on greenhouse gas emissions intensifies. New technologies that use carbon capture and storage technology present a possible solution to environmental concerns but so far have not been used in anything other than demonstration plants. However, carbon capture and storage technology is expensive; has great technical demands, and, the technology is not widely available yet. If the current trend on initiatives that mitigate the effects of greenhouse gas emissions intensify, new power plants might require carbon capture and storage technology, pushing costs of electricity production up. In addition the technology is technically demanding, and is likely to put considerable pressure on skills.

The costs of electricity generation, transmission and distribution are significant. Botswana's success in the development of electricity for export would depend on the availability of, among others, financial resources. Therefore, government should be committed to mobilizing these resources. Trends suggest that aid and private investment in the energy sector in SSA has been limited. There are some positive developments in private sector investment in energy projects such as Jindhal Botswana's plans to construct a new power station. If trends in the flow of investment continue, it might be a major challenge to use external resources to finance the development of energy exports.

Estimates on electricity demand suggest that demand for electricity is growing in the region. These figures suggest that an opportunity exists for Botswana to produce electricity for export in the region. But challenges and uncertainties for power exports remain. For example, the region has significant renewable energy potential but in geo-politically stable environments. In addition, costs of renewable sources of energy are decreasing rapidly. If these trends continue, thermal power exports will face stiff competition from renewable energy sources. Since upfront costs for hydropower projects are high and gestation period long, this presents a window of opportunity to develop thermal power exports. However, the Government of Botswana has to take advantage of the opportunity firmly and in a timely manner.

South Africa plays a key role in the feasibility of Botswana's electricity exports. South Africa has liberalized its electricity market to include the participation of IPPs and at the same time has consistently pursued a policy of increasing the generation of power from renewable energy sources. In addition, Botswana and South Africa signed a Memorandum of Agreement on Cooperation in the Field of Energy. Given the increasing costs of mining coal in South Africa it is possible that South Africa wants to use the Agreement to import coal for domestic production of electricity rather than import electricity from Botswana. Based on this bias towards renewable energy and the possibility that South Africa might, through the Memorandum of Agreement on Energy, be more interested in Botswana's coal rather than electricity exports, it is difficult to envisage South Africa as a potential market for Botswana's thermal power exports. These developments are likely to thwart efforts to develop a viable thermal power exporting sector in Botswana. In addition, should South Africa pursue self-sufficiency in electricity generation as evidenced by the development of Medupe and Kusile projects, prospects for Botswana's electricity exports will be weakened.



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