Republic of Botswana

Integrated Resource Plan for Electricity for Botswana

October 2020

BACKGROUND

Botswana power supply had over the year's dependent on the imports from neighboring countries mainly Republic of South Africa. Reliance on this imports was negated in 2007 when the electricity demand in the SADC region started surpassing the supply. By then Botswana had planned to build a 600 MW Morupule B coal Power plant to support the existing aged 132MW Morupule A Coal Power plant. The two plants were adequate to meet the national demand.

As the SADC region was experiencing power shortage, private sector showed interest in investing on power generation. In 2007, legislation in Botswana was then liberalized to accommodate participation of private sector. Poverty and air pollutions also became imperative for Botswana to be considerate in her power supply development. This lead to policy shift for which Botswana reaction was to develop and adhere to the universal access to modern energy services and reduction of greenhouse gases.

Integrated Energy Planning and developing an Integrated Resource Plan (IRP) are an integral part of the energy planning process in Botswana as guided by its 11th National Development Plans (NDP 11) and other sector policies and ambitions.

In the energy sector, the NDP 11 focuses on increasing self-reliance on the country's energy resources. Hence, Botswana is looking to diversify and support the development of the economy by securing competitive, cost-reflective and sustainable electricity prices for industry, services and households. Being part of the Southern African Power Pool (SAPP) and due to its geographical position, interconnections (existing and planned) offer opportunity for electricity export and imports to/from the region.

In line with these development path, the IRP outlines the least cost development plan for a period of 20 years (year 2020 to 2040). It considers various scenarios of energy demand and supply strategies and identify the least-cost development paths by simultaneously looking at (1) demand-side measures, (2) energy efficiency improvements and (3) electricity supply options from domestic and regional sources.

The optimal capacity expansion path proposed in the IRP maintains prescribed standards of reliable electricity generation systems, high level of social equity and considers environmental protection. The main approach in the IRP compilation is based on a detailed techno-economic analysis of potential demand and supply strategies through various scenarios. Therefore, the IRP is organized around two main activities; being demand analysis and supply analysis:

1) **ENERGY DEMAND ANALYSIS FOR THE NEXT 20 YEARS**

   The Energy Demand analysis all energy commodities in all sectors based on use of electricity, economic projections, demography, demand projections, and identification of energy efficiency and demand side management measures.

Three basic energy demand scenarios were used to determine different options of projected energy demand for the entire planning period. In all scenarios, the same population growth is projected, from 2.1 million in 2016 to 2.9 million in 2040, an overall increase of 38% over this period.

The proposed scenarios are;

i. Business as Usual (BAU) – an optimistic scenario where rapid GDP growth is projected up to year 2040 (refer to Table 1).
ii. Alternative Scenario (ALT) – a slower growth rates are assumed in the ALT scenario (refer to Figure 1) is used. One of the reasons for the slowdown in economic growth in this scenario is the assumed reduction of the role of diamond mining. Assuming a halving of diamond production and an associated halving of the related energy consumption.
iii. Energy Demand Management Measures (EDM) - same economic growth as the BAU scenario is sustained, but technological progress and energy efficiency measures are applied.

The following Table 1 shows modelled scenarios, while highlighting quantitative key parameters and their differences.

Table 1. Energy Demand Scenarios

	BAU	EDM	ALT
Demography	Projection of population in Botswana from 2016 to 2040 was agreed as follows: 2016 - 2,114,269 2040 - 2,926,000		
Household size (persons per household)	2016: 3.5 2040: 3.0		2016: 3.5 2040: 3.2
Urban / Rural	2016: 65% / 35% 2040: 81% / 19%		2016: 65% / 35% 2040: 74% / 26%
GDP	GDP growth rate from 2016 to 2040: 3.33%		GDP growth rate from 2016 to 2040: 2.36%
Mining	Mining share in GDP 2016: 22.2% 2040: 12.2%		Mining share in GDP 2016: 22.2% 2040: 7.3%
Manufacturing	Manufacturing share in GDP 2016: 5.7% 2040: 12.8%		Manufacturing share in GDP 2016: 5.7% 2040: 14%
Car ownership (persons/car)	2016: 5.1 2040: 3.2		2016: 5.1 2040: 4
Urban HH solar collectors in 2040	15%	50%	9%
Heat losses urban HH (kJ/m2/C/h)	2016: 12.9 2040: 10	2016: 12.9 2040: 7.5	2016: 12.9 2040: 11.4
Service sector area per capita (m2/person)	2016: 5.7 2040: 9.3		2016: 5.7 2040: 7.7
Electrification rate	2016: 64% 2040: 86.5%		2016: 64% 2040: 79%
Urban HH air conditioner penetration in 2040	50%		25%
Measures	No measures	Measures according to NEES have been implemented and further described in chapter 5 and 6	No measures

1.1 Results Of Energy Demand Analysis

Table 2 below indicates the results of all the three scenarios. It is projected that BAU will have electricity consumption of around 8.5 TWh, followed by EDM with 7.7 TWh and lastly, Alt with 6.0 TWh.

Table 2. Electricity projection for different Demands

		2016	2020	2025	2030	2035	2040
BAU	TWh	3.477	4.089	5.065	6.090	7.256	8.478
EDM	TWh	3.477	4.038	4.930	5.901	6.836	7.738
ALT	TWh	3.477	3.860	4.402	4.939	5.455	6.010

The EDM scenario was chosen as the most ideal scenario as it was developed in accordance with existing blue print documents being the National Energy Efficiency Strategy (NEES) and SE4ALL Action Agenda. In this scenario the final electricity consumption increases from 3.477 TWh in 2016 to 7.738 TWh in 2040.

2) ELECTRICITY SUPPLY ANALYSIS FOR THE NEXT 20 YEARS

Electricity supply analysis evaluates through optimization and simulation of supply strategies and identify the least cost expansion plan

Relevant national plans and documents used to inform the supply side analysis included the Renewable Energy Strategy (RES) for Botswana and the Sustainable Energy for All (SE4ALL) Action Agenda, as well as inputs from stakeholders.

Based on these documents and inputs from the stakeholders, the main supply side strategic objectives of the IRP were identified as follows:

i. **Diversification** of sources of electricity generation
ii. **Competitiveness** in electricity sector
iii. **Security of electricity supply**
iv. **Self-sufficiency** in electricity generation and becoming a **net electricity exporter**
v. Mitigation of environmental impact, through various methods such as using **low carbon technologies**[1] in coal.

These strategic objectives were assessed through developing and analysing energy supply scenarios, considering the available resources for power generation, existing generating facilities, power generation candidates, and development of supply scenarios.

[1] Technologies referred to as low carbon technologies in this context are coal with carbon capture and storage (CCS) and coalbed methane with carbon sequestration.

2.1 Available Resources For Power Generation

Currently, in Botswana electricity is primarily generated from domestic coal resources. Apart from coal-bed methane, there are no proven reserves of other possible fossil fuel resources for energy generation like natural gas or oil. Botswana has large coal reserves, estimated to be in excess of 200 billion tons. Coal exists in 12 coalfields, but currently only Morupule Coal Mine (MCM) and Medie Coal Mine are in operation.

Botswana also has a significant solar potential, receiving over 3,200 hours of sunshine per year with an average insolation on a flat surface of 21 MJ/m. This rate of irradiation is among the highest in the world. There is also wind potential. Regions with the highest wind potential are located in the South-West and Eastern parts of Botswana, with average wind speeds above 7 m/s, and a wind power density above 200 W/m^2.

Other energy resources include biogas and fuel wood. Petroleum products are imported. There is no hydro power potential in Botswana.

2.2 Existing and Committed Projects

The existing power generation system of Botswana is based on fossil fuels and consists of two coal-fired power plants and two diesel generators. The bulk of electricity produced locally comes from the coal-fired plant Morupule B, with the other coal-fired power plant being Morupule A. Besides the two coal-fired power plants, currently there are two other significant diesel-fuelled power plants in operation. The first is Orapa with a capacity of 90 MW. The second is Matshelagabedi, a diesel power plant with an installed capacity of 72.54 MW.

In line with Botswana's NDP 11 two new renewable energy projects were identified. One is a 100 MW (2x50 MW) solar PV power plant which is currently in the procurement phase and the 35MW grid connected PV power plants. The 100MW project is expected to feed electricity into the system by the year 2021.

Further, there are government efforts in developing Coal Bed Methane (CBM). The CBM generation initiative targets a 10 MW project, which is currently in the negotiation stage and expected to generate electricity for the national grid by 2025.

3. Main Scenario Assumptions

The elements of the existing power system are the same in all scenarios, as well as the list of expansion project candidates and their technical and cost characteristics. This includes generating and cross-border transmission capacities and all the associated costs (built cost, fuel cost, fixed and variable O&M costs, etc.).

The planning horizon is the same in all scenarios, 2020-2040. The chosen base year is 2016. Total system costs include investments costs in new generation capacities, fuel and operation costs of the domestic power plants.

A discount rate of 8% is assumed in all scenarios. All future costs and revenues are discounted with this rate to calculate the net present value of total system costs.

Three supply side scenario models (Minimum Constraints, Self-Sufficiency and Clean Electricity) were developed and are described below as follows;

i. Minimum Constraints

In this scenario only two constraints are set: the first one is to require the minimum reserve margin to be equal to peak load; and the second one is to limit the net import of electricity to 30% of the demand by the year 2030, and in all of the following years. There are no constraints on neither energy mix nor environment, except meeting demand through local resources.

ii. Self Sufficiency

The Self-sufficiency (SS) scenario assumes that Botswana will become self-sufficient in electricity production, covering domestic needs and exporting electricity by the year 2035. The projected demand must be met with local resources in the SS scenario. The energy mix is a constraint set up on each type of technology (coal, gas, solar PV, solar CSP and wind) not to exceed 40% of the total demand, i.e. generation + net imports. For this purpose, five constraints were modelled, one for each type of technology. For coal, the 40% constraint was implemented through a linear decrease in coal generation from 80% in 2030 to 40% in 2040.

iii. Clean Electricity

The main assumption of the Clean Electricity (CE) scenario is to allow building only low carbon coal options. These include coal technologies with CCS and enhanced Coal Bed Methane, but not conventional coal power plants.

Table 3. Electricity Supply Scenarios

Assumptions	**Minimum constraints (MC)**	**Self-sufficiency (SS)**	**Clean electricity (CE)**
Meeting the projected demand	Local resources & electricity import	Local resources	Local resources & electricity import
Reserve margin	≥0%	≥20% from 2030	≥10%
Net import/export of electricity	Net import limited to 30% from 2030	Net import 20% of total demand from 2030, linearly decreasing to net exporter at least 10% by 2035	Net import limited to 20% from 2030
Constraints on the energy mix	None	Max 80% generation by single technology until 2029, then -4%/year to 2040; 100 MW CBM committed in EDM SS	Max 40% by a single technology in 2030 RE 20% of demand from 2030, 35% by 2040
Environmental constraints	None	135 MW PV committed in EDM SS	Only low carbon coal technologies 135 MW PV committed

4. RESULTS - PREFERRED SCENARIO

Figure 3 below captures results of the preferred scenario which is Energy Demand Measures - Self Sufficiency (EDM SS).

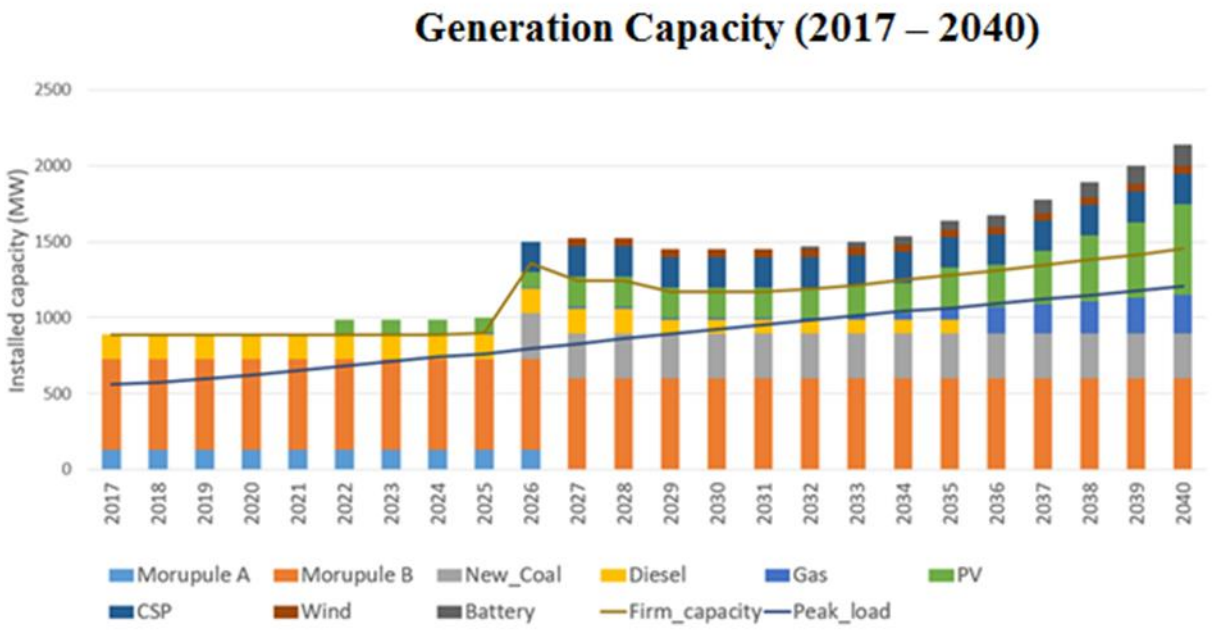

Figure 3: Modeling Results - Installed Capacity (2017 – 2040)

The above mentioned preferred scenario (EDM –SS) was chosen on the basis that it meets all the IRP supply side strategic objectives set as follows;

i) **Diversification** – The current electricity generation is dominated by coal plants which are backed up by minute diesel peaking plants. During the planning period there will be significant increase of gas generation as opposed to the beginning of the planning period. Also, an increase in generation from renewables will be realized. Contribution from the newly introduced technology will reduce coal contribution from the current 99% to 61% by the end of the planning period. Figure 3 indicates the envisaged share of electricity generating technologies.

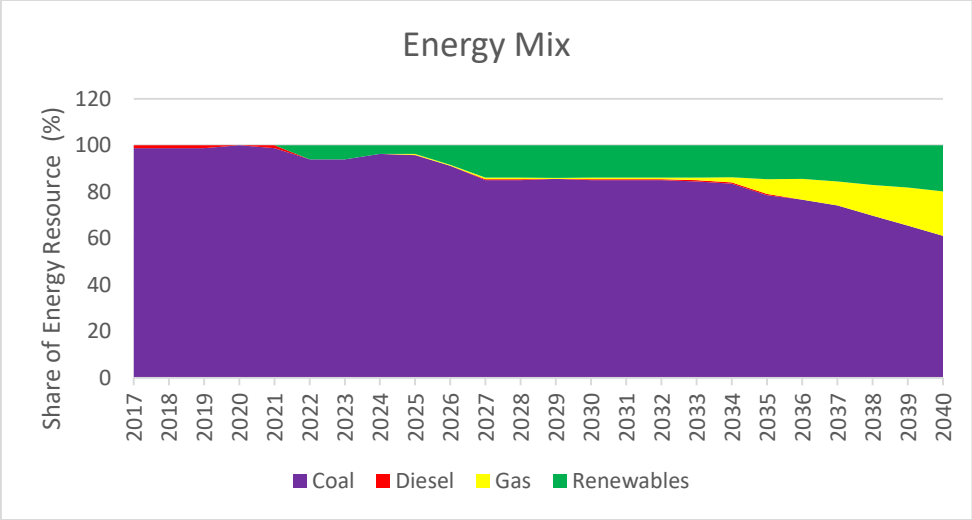

Figure 1. Energy Supply Mix

ii) Net Electricity Exporter

From the beginning of the planning period, Botswana is relying on electricity imports. Due to the expected increase in local generation from year 2024, the electricity imports will be significantly reduced. From year 2026, Botswana will be net exporter for the entire planning period, but with some significant imports though.

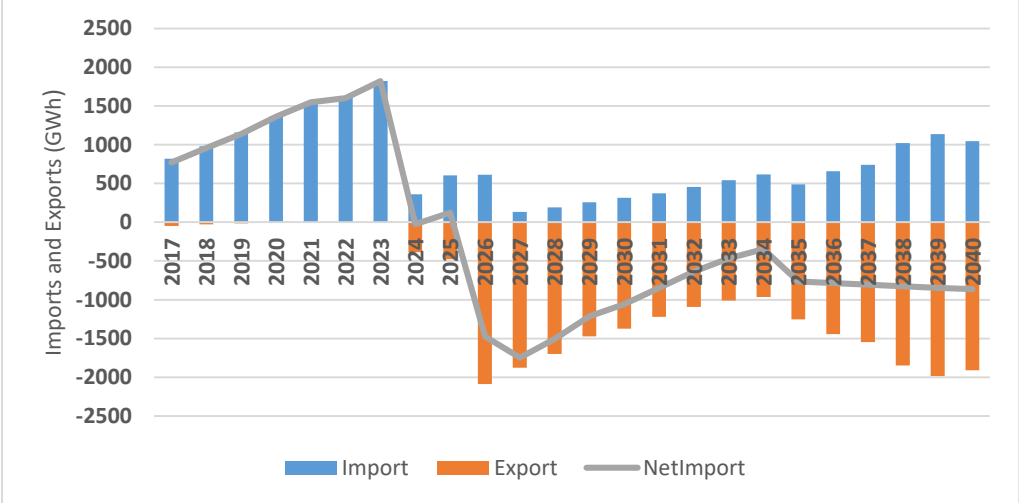

Figure 2. Electricity Import/Export

iii) Mitigating Environmental Impact

During the planning period, introduction of new generation, Photovoltaic, starts in the year 2022. With the exception of PV generation other technologies are emitting CO2, hence the exponential growth in CO2 from year 2023 to 2027. The emissions plateaus at around 6500Kt of CO2 from year 2027 until end of the planning period. The flattening of the curve is mainly due to the introduction of no/low CO2 emitting technologies.

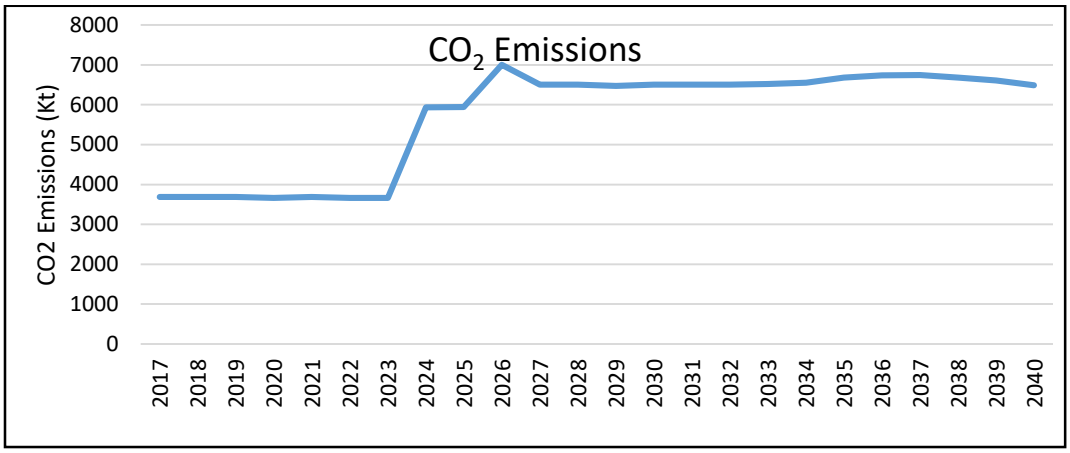

Figure 3. CO_2 Emission projections

iv) **Security of Supply**

Apart from the existing coal power plants, the model recommends additional coal power plant with the capacity of 300MW from year 2026 up to the end of the planning period. A 10MW CBM project is proposed from year 2025 which will be up scaled from year 2033 to a maximum of 250MW in year 2040. A 100MW PV technology is proposed from year 2022, which then is increased to 200MW from year 2027 to a maximum of 600MW for the duration of the planning period. The model proposes a 200MW CSP technology from year 2026 up to the end of the planning period. The model proposes a 50MW Wind technology from year 2027 up to the end of the planning period. An 18MW battery technology is proposed from year 2032, which is increased to 140 by year 2040. This additional generation capacity is also captured on Figure 3 below.

Table 4. Results of the projected Power Build Programme

YEAR	New Coal	CBM	PV	CSP	Wind	Battery
2017	0	0	0	0	0	0
2018	0	0	0	0	0	0
2019	0	0	0	0	0	0
2020	0	0	0	0	0	0
2021	0	0	0	0	0	0
2022	0	0	100	0	0	0

2023	0	0	100	0	0	0
2024	0	0	100	0	0	0
2025	0	10	100	0	0	0
2026	300	10	100	200	0	0
2027	300	10	200	200	50	0
2028	300	10	200	200	50	0
2029	300	10	200	200	50	0
2030	300	10	200	200	50	0
2031	300	10	200	200	50	0
2032	300	10	200	200	50	18
2033	300	20	201.96	200	50	38
2034	300	40	201.96	200	50	54
2035	300	70	271.96	200	50	56
2036	300	170	280	200	50	76
2037	300	190	350	200	50	90
2038	300	210	430	200	50	106
2039	300	230	500	200	50	120
2040	300	250	600	200	50	140

5. Approved IRP Projects

In line with the IRP model results, Government of Botswana has approved and is implementing energy projects with a total installed capacity of 795MW (see Table 5) required to meet the growing energy demand at least cost whilst also reducing the country's carbon foot print. These will be implemented during the first seven (7) years of the IRP as follows:

a) 100MW Solar Photovoltaic and total of 35 MV grid tied Solar Photovoltaic by 2022 (currently under procurement). These projects will be implemented through Independent Power Producers (IPPs);

b) 10 - 100MW CBM by the year 2025 (currently under procurement);

c) 200MW Concentrated Solar Plant (CSP) by the year 2026 (procurement to start during 2021);

d) 300MW Coal by the year 2026 (procurement should to start immediately during 2020);

e) 50MW Wind by the year 2027 (procurement to start in 2024 after wind resource mapping is complete); and

f) 100MW Solar Photovoltaic by the year 2027 (procurement to start in 2025). The projects will be developed through private sector investment as Independent Power Producers (IPP) or government joint venture investments.

Table 5: Approved IRP Projects

Generation Capacity	Technology	Commercial Operation Date	Status
100MW	Solar PV	2022	Under Procurement
35MW	Solar PV	2022	Under Procurement
10MW	CBM	2025	Under Procurement
200MW	CSP	2026	Procurement to start during 2021
300MW	Coal	2026	Procurement to start in 2021
50MW	Wind	2027	Procurement to start in 2024 after wind resource mapping is complete
100MW	Solar PV	2027	Procurement to start in 2025