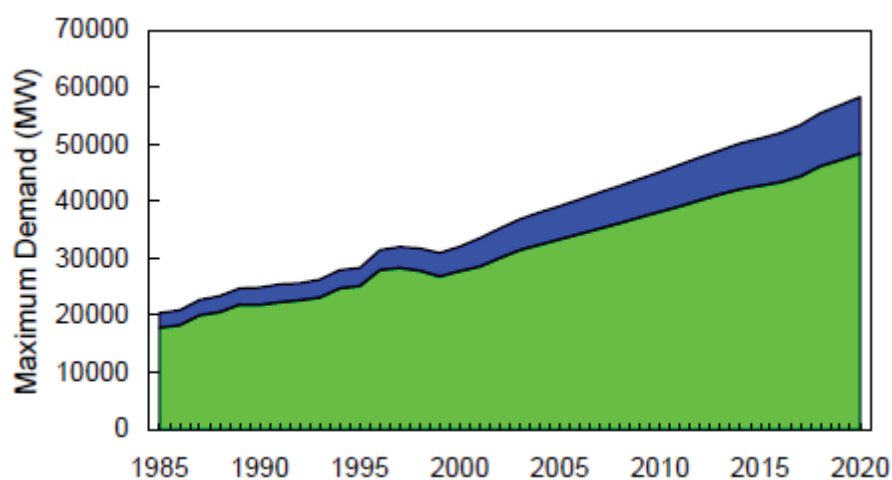


2.1 THE ENERGY GAP IN THE SOUTHERN AFRICAN DEVELOPMENT COMMUNITY REGION

For the entire Southern African Development Community (SADC) region, power consumption has been increasing at a rate of about 3 % per annum, implying an *additional* requirement of 1,200 megawatts (MW) per year (Figure 2.1). The increase in demand may even accelerate, as most SADC countries have set themselves ambitious targets for economic growth – in most cases exceeding 5% per year.

Figure 2.1 Southern Africa Power Forecasts



Source: IWRM, 2008

2.2 ENERGY CONSUMPTION AND PRODUCTION IN ZAMBIA

2.2.1 Energy Consumption (Zambia)

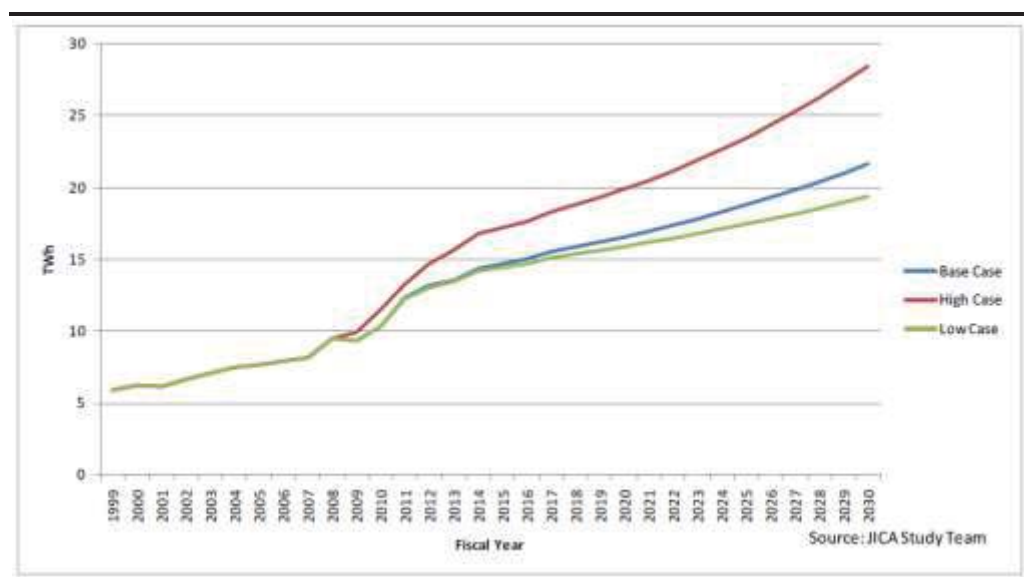
According to the Zambia Development Agency (ZDA; 2014) the country's economy has been growing at an average of 5% per annum over the past 10 years and as a result, the demand for energy has also been rising. This is due to economic activities in the country particularly in the mining, manufacturing and agriculture sectors.

The Japan International Cooperation Agency (2010), in their power system development master plan for Zambia, introduced three power forecast scenarios, based on differences in respect of macro-economic conditions, population growth, and customer increase rate, namely base, high, and low cases (Figure 2.2).

In this study (JICA; 2010), gross domestic product (GDP) growth is assumed to be 6 % p.a. (equivalent to the actual growth rate from the mid- 2000s) in the

base-case scenario, 7 % p.a. (the target figure in the government’s economic development plan) for the high-case scenario, and 5 % p.a. rate in the low-case scenario (as reported above by the ZDA (2014)). Population growth is forecast at 2.3 % p.a. following the historical trend. The electrification rate is forecast to increase at the rate of 4 % p.a., equivalent to the increase in the number of customers in the residential and commercial sector for the past five years, in the base-case scenario, 6 % p.a. in the high-case scenario, and 3.5 % p.a. in the low-case scenario.

Figure 2.2 *Comparison of Demand under Three Demand Forecast Scenarios*



Source: JICA (2010)

As of December 2012, total energy demand exceeded internal generation capacity ⁽¹⁾. This was as a result of the expansions in the mining and manufacturing sectors as well as overall expansions in the economy and population.

The current power deficit has resulted in prolonged load shedding and power cuts, which have occasionally affected trade and production.

2.2.2 *Energy Production (Zambia)*

ZESCO Limited

The Zambian electricity power system is operated as part of an interconnected power system linking South Africa, Zimbabwe, and Democratic Republic of Congo (DRC). Currently there are three major electricity suppliers including: ZESCO Limited, which generates, transmits, distributes and supplies electricity throughout Zambia; Copperbelt Energy Corporation (CEC) in Kitwe which is a net transmitter of electricity purchased from ZESCO at high voltage and distributed to the mining industry based on the Copperbelt; and

(1) Policy Monitoring and Research Centre (PMRC), 2013. *The State of the Energy Sector in Zambia: Implications for Industrial Development, Jobs and Poverty Reduction Background Note*

Lunsemfwa Hydro Power Company (LHPC) based in Kabwe which is an independent power producer generating 48 MW of power that it sells to ZESCO Limited under a Power Purchase Agreement.

There is also the Rural Electrification Authority (REA) which deals with the cause for increasing access to electricity in the rural areas and the Energy Regulation Board which is the regulator of the energy sector in Zambia. Other participants in the industry include small-scale generators and solar based energy services companies supplying power to some rural areas.

Sources of Energy

The main sources of energy in Zambia include biomass, electricity, petroleum, coal and renewables, specifically solar, wind and hydropower.

Biomass

According to ZESCO Limited (2009) ⁽¹⁾ the degree of electrification in Zambia is very low. 22% of the population have direct access to grid electricity, 0.028% of the population have direct access to isolated electric systems, and 77.972% of the population have no access to electricity at all. This proportion of the population in Zambia therefore relies on biomass as the main source of energy.

Hydropower

The three major Zambian hydropower plants, namely; Kariba North Bank, Kafue Gorge, and Victoria Falls are owned and operated by ZESCO. These generated enough power during the 2004/05 financial year to almost match electricity consumption in Zambia (Rural Electrification Master Plan Study, 2007). Furthermore, ZESCO owns and operates four Mini Hydropower Plants. These mini plants include: Lusiwasi, Musonda Falls, Chishimba Falls and Lunzua River. A plant at Chishimba is also being proposed. These plants were initially developed as power sources for independent power networks in rural areas of Zambia. They are currently being upgraded in order to allow greater energy generation as highlighted in *Table 2.1*.

Table 2.1 *Status of ZESCO's Mini Hydropower Plants*

Project	New Capacity (MW)	Status
Lusiwasi Lower	86	Tendering
Lusiwasi Upper	15	Contract awarded
Lunzua	14.8	Construction
Musonda Falls	10	Construction
Chishimba	14.8	Tender documents

(Source: ZRA, 2014)

Major hydropower plants contributed 1,668 MW of the total generation capacity (98% of total national energy production) and small hydropower

(1) ZESCO Ltd, 2009, Business Development Department, General Description Of The Electricity System

plants contributed 24 MW (1.4% of total national energy production), in the year 2006.

The Zambia Development Agency (ZDA, 2014) ⁽¹⁾ states that hydro-power is the most important energy source in the country, after wood fuel. It further states that there has not been any major addition to the country's generation capacity in the last 20-30 years, despite the huge potential in hydro resources. ZDA estimates that even though Zambia possesses 40% of the water resources in the Southern African Development Community (SADC), the Country has about 6,000 MW of unexploited hydro power potential; currently less than 2,259 MW has been developed, as indicated in *Table 2.2*.

Table 2.2 *Installed Generation Capacity in Zambia*

No	Power Station	Installed Capacity (MW)	Type of Generation	Operator
1	Kafue Gorge	990	Hydro	ZESCO
2	Kariba North Bank	1,080	Hydro	ZESCO
3	Victoria Falls	108	Hydro	ZESCO
4	Lusemfwa and Mulungushi	56	Hydro	Lusemfwa Hydro Corp
5	Small Hydros (combined)	25	Hydro	ZESCO
6	Isolated Generation	8	Diesel	ZESCO
7	Gas Turbine (stand by only)	80	Diesel	Copperbelt Energy Corp
	Total Installed Capacity	2,347		

Source: ZDA, 2014. Zambia Energy Sector Profile

Coal Fired Power Stations

Coal accounts for 5% of national energy requirements: the largest consumer is the mining industry, followed by the manufacturing sector (United Nations Development Programme, 2011). Maamba Collieries Limited is Zambia's largest coal supplier, followed by Collum Coal Mines. Currently Maamba Collieries mine two open cast mines in the Kanzize and Izuma Basins in the Southern Province. However, due to the paralysis of mine operations, the Zambian government transferred its 100% stake in the company to ZCCM Investment Holdings Plc (ZCCM-IH). ZCCM is expected to revamp operations at the coal mine and transform it into a viable business entity, thus improving coal supply for enhanced industrial production (ERB, 2008).

Diesel Generators

According to the ERB (2008), Diesel Power Plants contributed 8MW (0.5% of total national energy production) in 2006. The following are Diesel Power Stations owned and operated by ZESCO:

- Mwinilunga;
- Kabompo ;

(1) Zambia Development Agency (2014) *Zambia Energy Sector Profile*

- Zambezi;
- Mufumbwe;
- Kaoma (abandoned due to the area being linked with the National Grid);
- Luangwa;
- Lukulu;
- Chama; and
- Kaputa.

Electricity Imports/Exports

Due to the power deficit that is currently being experienced in the country, ZESCO currently only exports excess off-peak and low voltage power. High power off peak exports during the year 2007 was exported to the Zimbabwe Electricity Transmission and Distribution Company (ZETDC) and Eskom of South Africa. Zambia exported power in small quantities at low voltage to Botswana, the Democratic Republic of Congo, Namibia, Tanzania, and Zimbabwe. ZESCO exports were 337,678 MWh in 2007 compared to 287,772 MWh in 2006 representing an increase of about 17.3%.

Energy imports on the other hand were 232,953 MWh and 54,409 MWh in 2007 and 2006 respectively, representing an increase of 328 percent in one year (ERB, 2008).

2.2.3 *Electrification (Zambia)*

In Zambia, despite some, albeit small levels of energy exports, the household electrification rate remains at approximately 20 % countrywide and only 2 % to 3 % in rural areas. The Poverty Reduction Strategy Paper published in 2002 set a mid-term target to achieve a household electrification rate of 25 % by 2010; 50 % for urban areas and 15 % for rural areas (JICA 2008).

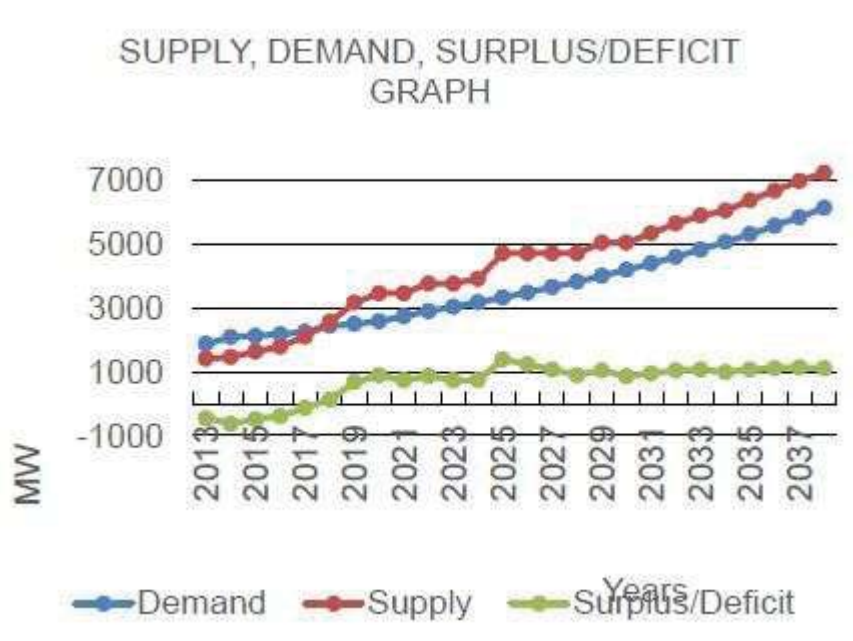
2.3 *ENERGY PRODUCTION AND CONSUMPTION IN ZIMBABWE*

2.3.1 *Energy Consumption (Zimbabwe)*

According to the Ministry of Energy and Power Development's National Energy Policy of 2012, there is a net deficit in the supply of electrical power in Zimbabwe. The country requires nearly 2,200 megawatts (MW) in winter at peak, but generation locally can't meet the demand as on average 1,400 MW are being produced; energy imports and load shedding is used to cover for the deficit, with extensive dependency on load shedding ⁽¹⁾.

(1) http://www.zimbabwesituation.com/news/zimsit_government-lethargy-on-power-investment-costly/

Figure 2.3 2010 - 2030 Supply: Deficit graph for Zimbabwe



Source: ZETDC

2.3.2 Energy Production (Zimbabwe)

Zimbabwe Electricity Supply Authority (ZESA)

The Ministry of Energy and Power Development has overall responsibility for the energy sector in Zimbabwe. The Ministry supervises and oversees the performance of state-owned enterprises such as Zimbabwe Electricity Supply Authority (ZESA). ZESA is a state-owned company whose task is to generate, transmit, and distribute electricity in Zimbabwe. ZESA however delegates this responsibility to its subsidiaries, the energy generating company Zimbabwe Power Company (ZPC) and the Zimbabwe Electricity Transmission and Distribution Company (ZETDC).

ZPC incorporates all the power generation plants of Hwange, Kariba and various small thermal power stations (Harare Power Station, Bulawayo and Munyati Power Stations). ZETDC, on the other hand, develops the Transmission and Distribution Network, and transmits, distributes and supplies electricity to consumers.

ZESA therefore represents Zimbabwe in the Southern African Power Pool and is the only electricity generator and supplier for the Country's public grid.

There is also the Rural Electrification Authority (REA) and the rural electrification programme has seen more than 5,000 rural institutions, farms, villages, borehole, dam points and irrigation schemes electrified to date ⁽¹⁾.

(1) Zimbabwe Ministry of Energy and Power Development (2014), Rural Electrification Programme <http://www.energy.gov.zw/index.php/power-development/rural-electrification-programme>

Sources of Energy

The main sources of energy used in Zimbabwe comprise wood fuel which provides the bulk of the total energy supply (61%) ⁽¹⁾. Most rural areas are facing fuel-wood shortages as a result of agricultural land use and unsustainable harvesting. Demand for wood fuel already exceeds supply in Manicaland, Mashonaland East, the Midlands and Masvingo provinces, which are heavily populated. Mashonaland Central and Matabeleland North are fast reaching the same situation.

Generation capacity is currently provided mainly by hydropower and coal.

Hydropower

The Kariba South hydropower plant has a total installed capacity of 750MW. The Kariba South Power Station has an operational efficiency of above 90 %. Depending on inflows into the lake, the station can generate a maximum of 5000 GW/hrs with a load factor of 80 %. Expansion works which commenced at Kariba South in 2013, are expected to be completed in 2017, adding 300 MW to the national grid ⁽²⁾.

The Ministry of Energy and Power Development (2012) states that the development of large-scale and small-scale hydropower must be prioritised as a strategy for increasing the share of renewable energy as required by the Energy Regulatory Authority (ERA) Act [Chapter 13:23] and international obligations for environmentally sustainable energy services.

Large-scale hydropower on the Zambezi and small-scale hydropower on internal dams and perennial rivers represent a significant renewable energy resource for meeting local and regional electricity demand. Existing in-land dams have an estimated 20 MW potential, and run-of-river schemes could generate 150 MW. Proposed dams have a potential of 260 MW, and the total energy potential is estimated to be between 90 and 120 GWh/a.

Coal

The coal market is dominated by Makomo Resources and the Hwange Colliery Company. An independent power producer (IPP) who is at an advanced stage of project planning, with most agreements signed, and moving to the construction phase of a 660 MW power plant at Gwayi (100 km from Hwange), is looking to exploit coal resources that are deep underground through inclined shaft mining (as opposed to open cast mining that is employed by both Makomo Resources and Hwange Colliery), as a way of ensuring coal supply security and stability for their 660 MW power plant and the market.

(1) Zimbabwe Ministry of Energy and Power Development (2012) National Energy Policy

(2) <https://www.newsday.co.zw/2013/06/18/zimbabwe-energy-crisis-to-ease-in-2017/>

A 1,000 MW Coal Ash power station is also currently being proposed by an IPP to exploit millions of tonnes of coal ash that has accumulated since the initial commissioning of the Hwange Power Station in 1983. This technology will utilise waste coal ash from Hwange Power station, thereby helping to clean up the environment and reduce the subsequent environmental damage due to current rates of coal ash deposition.

The Hwange Power Station is the largest coal-fired power station in Zimbabwe with 920 MW installed capacity, but a current operational capacity of 705 MW. This power station is the 14th largest thermal station in the Southern African region. The station was built in two stages. The 4 x 120 MW units were commissioned between 1983 and 1986 and the 2 x 220 MW were commissioned in 1986 and 1987. The station's design largely represents technologies of the late 1960s. All six units are available and the station currently generates about 40 % of the country's electricity needs. The Hwange Power station operates as a base load station, with its availability averaging 80% ⁽¹⁾.

Zimbabwe's electricity generation capacity and energy exported is expected to improve significantly in 2018 after the completion of a number of new energy developments, as highlighted in *Table 2.3*.

Table 2.3 *Planned Energy Projects in Zimbabwe*

Name of Plant	Technology	Commissioning	Capacity (MW)
CASECO	Coal / thermal	Dec 2017	600
Kariba South expansion	Hydro	Dec 2017	300
ZPC Solar	Solar	Dec 2017	300
Mutare Power Plant	Diesel	Dec 2015	120
Total			1,320

Source: ZRA 2014

In addition, brownfield projects (rehabilitation and expansion projects) are also being developed at the Bulawayo, Munyati (both December 2017) and Harare Thermal Power Stations (December 2015), as well as rehabilitation and expansion works at Hwange Thermal Power Station (December 2017). These power stations are all currently operating at reduced capacity: Hwange Thermal Power Station has an installed capacity of 920 MW but a dependable capacity of 705 MW; Harare Thermal Power Station has an installed capacity of 120 MW and a dependable capacity of 30 MW; Bulawayo Thermal Power Station has an installed capacity of 120 MW and a dependable capacity of 20 MW; and Munyati Thermal Power Station has an installed capacity of 100 MW and a dependable capacity of 20 MW. All of the major power stations in Zimbabwe are old with the small thermal plants commissioned between 1942 and 1957, Kariba in 1959-1962 and Hwange in 1983-1987. The small thermal power stations are undergoing rehabilitation in partnership with ESSAR of India, resulting in a progressive increase in their dependable capacity. The mismatch between the installed capacity and dependable capacity is mainly a

(1) <http://www.zpc.co.zw/powerstations/1/hwange-power-station>

result of age induced down rating of machines and inadequate resources to provide timely maintenance and rehabilitation for full design capacity to be realised (ZPC, 2014).

Renewable Energy

Zimbabwe has the following main forms of renewable energy:

1. Hydro power
2. Solar
3. Ethanol
4. Bagasse
5. Biomass
6. Geothermal
7. Wind

The countries solar energy potential of 16–20 MJ/m²/day is greatly underexploited. There is an enormous potential for use of solar PV and solar water heaters that has not yet been exploited. Zimbabwe Energy Regulatory Authority (ZERA) and ZETDC have registered an increasing interest from IPPs to invest in solar power. As part of the Zimbabwe Agenda for Sustainable Socio-Economic Transformation (Zim Asset) government program, ZPC is implementing three solar projects with a total capacity of 300 MW that are targeted to be commissioned by December 2017. The penetration of solar power in the electricity sector is increasingly becoming viable with advances in solar technology and increasing affordability.

Geothermal potential of about 50 MW is estimated. Currently not much else is known about the potential of geothermal. Due to Zimbabwe’s proximity to the Rift Valley region, it is reasonable to assume that geothermal power generation can be applied ⁽¹⁾.

Currently Available Import Contracts

As can be seen in *Table 2.4* there is currently not a significant amount of dependable power for import within the SAPP utilities.

Table 2.4 *Zimbabwe Import Contracts*

Source	Status of Contract	Contract Capacity (MW) and Nature of Capacity
HCB	-Firm and Non-Firm	- 50MW firm
	-Expires	- non-firm - varies on availability
SNEL	-Firm	-0MW
	-Expired 28 February 2013	
ESKOM	-Non-firm	- Non Firm – varies from 0 to 450MW depending on availability
	-PPA valid up to march 2015	
ZESCO	Non-firm	- Non Firm - varies from 0 to 300MW depending on availability

(1) https://energypedia.info/wiki/Zimbabwe_Energy_Situation

Source	Status of Contract	Contract Capacity (MW) and Nature of Capacity
NamPower Exports	-150MW	-150MW
Total Firm		50

Source: ZRA 2014

Energy Efficiency and Demand Side Management (DSM)

Significant annual power consumption savings could be achieved if concerted efforts could be made to promote energy efficiency and demand side management. *Table 2.5* shows the projected decrease in energy intensities due to technological advancement and adoption of more efficient energy consumption practices.

Table 2.5 *Energy Intensities of Electricity per Specific Use*

Item	Unit	2015	2020	2025	2030	2035	2038
Agriculture	[kWh/US\$]	2.02	1.81	1.61	1.40	1.19	0.98
Mining	[kWh/US\$]	5.34	4.97	4.61	4.24	3.87	3.50
Manufacturing	[kWh/US\$]	4.90	4.68	4.46	4.24	4.02	3.80
-Basic mat.	[kWh/US\$]	7.81	7.25	6.69	6.12	5.56	5.00
-Machinery and Equipment	[kWh/US\$]	4.79	4.53	4.27	4.02	3.76	3.50
-Non-durable Goods	[kWh/US\$]	3.17	3.02	2.86	2.71	2.55	2.40

ZETDC DTM and Energy Efficiency Initiatives

ZETDC is currently engaged in DSM activities that are expected to realise substantial energy savings that would go a long way in alleviating the current energy deficit. Activities being carried out to influence energy consumption patterns are summarised in *Table 2.6*.

Table 2.6 *DSM and Energy Efficiency Initiatives Summary*

Initiative	2015 MW	2016 MW	2017 MW	2018 MW	Total MW
LED lighting	110	110			220
LED Commercial lighting	30	30			60
Solar water heaters	10	10	10		30
Potential savings (MW)	171	170	30	15	386

2.3.3 *Electrification (Zimbabwe)*

37 % of households in Zimbabwe have access to electricity that is connected via power lines and in urban areas 83 % of households have electricity, compared with 13 % in rural areas (Ministry of Energy and Power Development; 2012). It is estimated that rural communities meet 94 % of their cooking energy requirements from traditional fuels (mainly firewood) and 20 % of urban households use wood as the main cooking fuel. The majority of urban households use electricity for cooking (73 %), while only 6 % of rural households use electricity (Ministry of Energy and Power Development; 2012).

Water is released from the reservoir through six sluice gates located approximately 80 m above the river level downstream of the dam (*Figure 2.4*). In the first 20 years after the dam was constructed there were sustained heavy spillage episodes resulting in erosion of the bedrock to 80 m below the normal water level. This area is known as the 'Plunge Pool'. The plunge pool represents a risk to the stability of the dam wall and therefore risk of a flood event and reduced operating capacity of the dam. *Figure 2.6* below shows the results of a three dimensional (3-D) Multi-beam Bathymetric Survey undertaken in order to map the plunge pool.

Figure 2.4 All Six Sluice Gates Open during a Test Spillage (1966)



Source: ZRA, 2014.

Figure 2.5 Present Plunge Pool

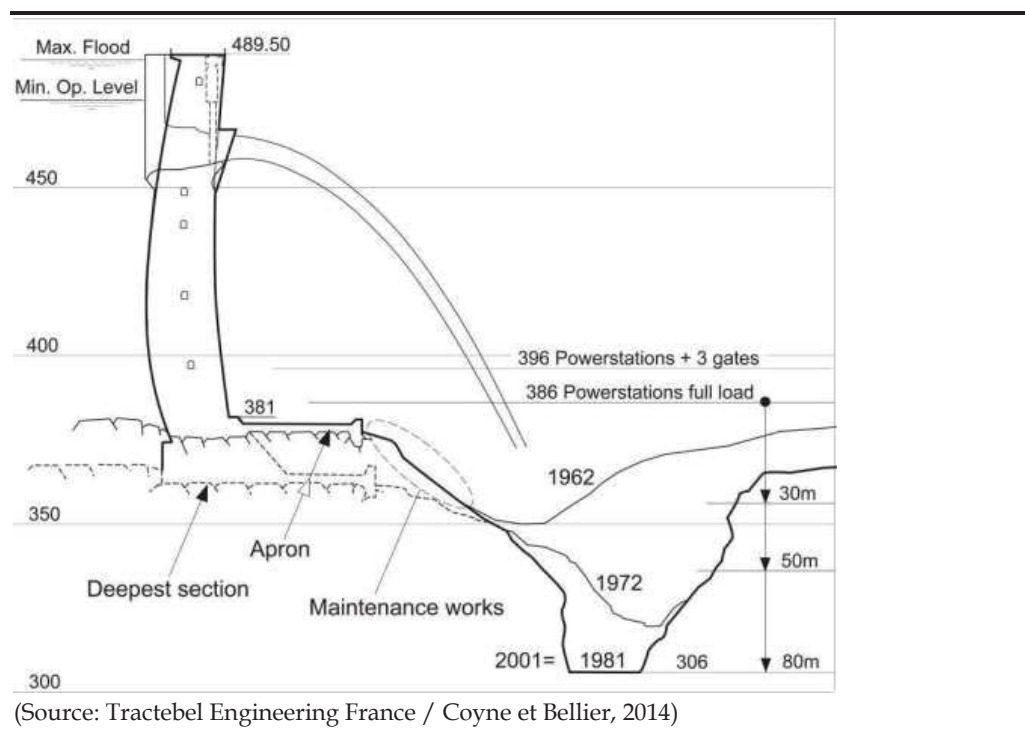
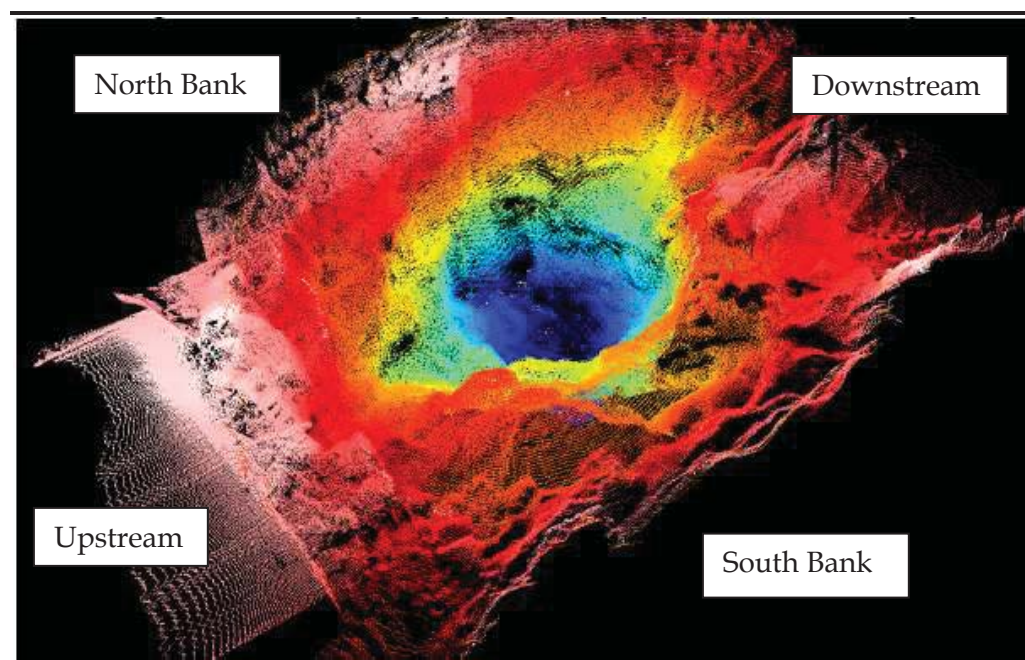


Figure 2.6 3-D Multi-beam Bathymetric Survey of the Plunge Pool



Source: Tractebel Engineering France / Coyne et Bellier, 2014

Failure to implement remedial measures to the plunge pool will result in the failure to operate the reservoir as expected (i.e. at a reduced capacity) or required under extreme flood events, and an increase in the risk of dam wall failure. A scenario where the dam wall fails will release a flood event of a total 273 km³ resulting in:

- Major loss of life as the flood plain is home to approximately three million people;
- Loss of livelihoods (socio-economic activities);
- Environmental degradation; and
- A loss of main source of power to the SADC region.

Catastrophic dam failure of the Kariba Dam would result in significant downstream environmental damage, as a result of the flood waters that would flow downstream, reaching into the Mozambique delta. However, arguably the most important motivating factor of the proposed Kariba Dam Rehabilitation Works is the potential resultant human fatality risks from a catastrophic dam failure event. There are an estimated three million people who live downstream of the Kariba Dam that may die should there be a catastrophic dam failure event. Therefore, it is imperative that the Kariba Dam is maintained in safe working condition.

Moreover, and as has been described above, the Kariba Dam Hydro-Electric Scheme significantly contributes to the security of energy supply to the SADC region and specifically to Zambia and Zimbabwe over the last 50 years. Furthermore, as described above, this region has an increasing demand for energy supply, placing even greater significance to the existing energy supply by the Kariba Dam Hydro-Electric Scheme. Loss of this energy supply would significantly adversely impact the socio-economic status of the region.

Therefore, timely rehabilitation is required in order to prevent further degradation of dam safety features, and to uphold Kariba Dam's status of functioning to meet international standards. Studies conducted by Tractebel Engineering (2014) show that the best solution to avoid dam toe weakening and control future development of the plunge pool would be to enlarge it downstream as well as on both banks sides. This reshaping will enable the evacuation of spillage flows downstream as well as avoid turbulence in a restricted and confined area.