Energy Security in Africa and Role of Hydro Power in Zambezi River Basin

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Abstract:
Energy security usually is defined as "reliable supplies at a reasonable price". It is an important issue in modern era. Rising oil prices, increasing global energy consumption and concern for the environment has led to a renewed interest in alternative energy sources such as renewable energy. Renewable energy currently constitutes about 17% of the global energy mix with hydropower making about 90% of this. So in this context hydropower becomes a good option for providing energy security. The African Continent is endowed with enormous hydropower potential that needs to be harnessed. Despite this huge potential which is enough to meet all the electricity needs of the continent, only a small fraction has been exploited. This could be due to the major technical, financial and environmental challenges that need to be overcome for the development of this resource base. A total of almost 5,000 MW of hydropower has been developed in the Zambezi River Basin. Zambezi River Basin's hydropower resources have the potential to significantly contribute to solving the region's power problems. The resource is readily available and produces cheaper and cleaner electricity than other traditional resources such as coal and oil.

Keywords: *Clean energy, Energy Security, Hydropower, Zambezi River Basin*

1. Introduction

Energy security usually is defined as "*reliable supplies at a reasonable price*". No state, not even one that is among the strongest ones, is capable of guaranteeing the satisfaction of their own energy needs. The concept of energy security is a multidimensional concept, including external as well as internal action. Economic, political and security measures have to be applied in combination to generate the essential synergies. Rising oil prices, increasing global energy consumption and concern for the environment has led to a renewed interest in alternative energy sources such as renewable energy. Renewable energy currently constitutes about 17% of the global energy mix with hydropower making about 90% of this. Most renewable energy sources are clean and environmentally benign and would contribute towards the mitigation of the effects of greenhouse gas emission and the global warming potentials.

More than any other continent, Africa needs an energy revolution and independence from the international fossil fuel economy; a change to renewable energy and energy autonomy is paramount for survival. Africa depends largely on the import of fossil fuels to meet a significant and growing part of its modern energy needs, which has created perverse effects on the economy and lives of Africans. Renewable energy is the only viable alternative that has the potential, when properly managed, to improve quality of life on a national and continental scale.

2. Hydropower: Need and Relevance

Although Africa is endowed with abundant gas and coal resources, hydropower remains a critical component of the energy mix. The resource uses proven technology and is easily accessible across the region. Some of the key benefits of using hydropower include:

2.1 Availability
Hydro power is readily available in many African countries, for both large and small scale projects. This saves the transportation costs encountered in carrying coal, gas or fossil fuel from the source to the location of the power plant. Moreover, hydro power can be effectively explored for potential distributed generation, which is suitable for industrial power consumers.

2.2 Cheaper Electricity
The life time cost of power from hydro power plants is significantly cheaper than thermal power. It costs approximately US 20 cents to produce one kWh from oil, whilst hydro power plants' lifetime charges are expected to average US 6 cents per kWh. The low cost of hydropower is easily achieved since hydro power plants have very minimal operational costs and little or no cost of feedstock. Low cost electricity is a significant competitive advantage for industrial bulk power consumers, since it results in lower production costs.

2.3 Renewable and Environmentally Friendly
Hydro-electric power is the best-established means of electricity generation from renewable sources. It currently contributes 18 per cent of the world's electricity. Hydropower is climate-friendly and does not result in the conventional air pollutants associated with other fossil fuel generation options. The adoption of hydro power will significantly help Africa to reduce greenhouse gas emissions and benefit industrialists from the sale of carbon credits.

2.4 Flexibility of Supply
Hydropower can also be used for industrial power due to its ability to supply electricity for both peaking and base load. This source of power can be easily 'stopped and started' making it very flexible and adaptable to demand levels.

2.5 Future of Hydropower in Africa
A bright future lies ahead for hydropower in Africa. A majority of utilities in Africa are increasing their efforts to tap into this resource for sustainable power supply. For example, by 2020, hydropower is expected to account for 79 and 52 per cent of East and West Africa's (excluding Nigeria) total new additional generation capacity, respectively. Frost & Sullivan expects sub-Saharan Africa to add at least 20, 000MW of hydropower capacity by 2015. This will be achieved through both refurbishments of existing old plants and construction of new projects. A significant number of international IPPs such as Globeleq and Agha Khan Network are also exploring opportunities to use Africa's hydro resources to generate private power.

3. Energy Security and Hydropower
Hydropower is one of the cleanest and most reliable sources of energy. Environmentally conscious countries such as Canada, New Zealand, Norway and Sweden have chosen hydropower as their main source of electricity generation. Hydropower currently makes about 20% contribution to the global electricity supply, second to fossil fuel. It is anticipated that the global demand for electricity will increase steadily and the growth for hydroelectricity is projected at 2.4% – 3.6% from 1990 – 2020. A large number of hydropower development projects with a total capacity of around 100 000MW are currently on-going globally. The greatest contribution to current hydropower development is coming from Asia (84 000MW). The contributions from the other regions are as follows: South America (14 800MW), Africa (2 403MW), Europe (2 211MW), North & Central America (1 236MW).

The African Continent is endowed with enormous hydropower potential that needs to be harnessed. Despite this huge potential which is enough to meet all the electricity needs of the continent, only a small fraction has been exploited. This could be due to the major technical, financial and environmental challenges that need to be overcome for the development of this resource base.

Energy security and access challenges are the main issues to address in terms of the developmental agenda of Africa for the attainment of the Millennium Development Goals (MDGs). Hydropower has a great role to play in solving Africa's energy security and access issues. New Partnership for Africa's Development (NEPAD) vision for the energy sector has targeted the exploitation of Africa's vast hydropower potential in order to address the socio-economic problems of the continent. The total installed capacity of Africa is about 20.3GW and a total generation of 76000GW/year. A comparison with the Gross theoretical hydropower potential of about 4000000 GWh/year indicates that the current production from hydropower plants in Africa is about 20% of the total potential. The focus over the years in many African countries has been large-scale hydropower schemes. Recent studies have shown that electricity generation through small hydropower (SHP) is gaining owing to its short gestation period, low investment and least environmental impacts. Also, economically viable and proven small scale hydropower technologies have been commercially developed and are available for generating both electrical and mechanical power for rural industrialization and development. This report is an attempt to compile available information on large and small hydropower (SHP) capacities for currently installed, potential, on-going and pipe-line projects in Africa.

4. Zambezi River Basin: An Overview

The Zambezi River basin (ZRB) lies within the fourth-largest basin in Africa after the Congo, Nile, and Niger River basins. Covering 1.37 million km2, the Zambezi River has its source in Zambia, 1,450 meters above sea level. The main stem then flows southwest into Angola, turns south, enters Zambia again, and passes through the Eastern Caprivi Strip in Namibia and northern Botswana. The Zambezi River then flows through Mosi-oa-Tunya (Victoria Falls), shared by Zambia and Zimbabwe, before entering Lake Kariba, which masses behind Kariba Dam, built in 1958. A short distance downstream from Kariba Dam, the Zambezi River is joined by the Kafue River, a major tributary, which rises in northern Zambia. The Kafue River flows through the Copper belt of Zambia into the reservoir behind the Itezhi Tezhi Dam (ITT), built in 1976. From there, the Kafue River enters the Kafue Flats and then flows through a series of steep gorges, the site of the Kafue Gorge Upper (KGU) hydroelectric scheme, commissioned in 1979. Below the Kafue River confluence, the Zambezi River pools behind Cahora Bassa Dam in Mozambique, built in 1974. Some distance downstream, the Zambezi River is joined by the Shire River, which flows out of Lake Malawi/Niassa/Nyasa to the north. Lake Malawi/ Niassa/Nyasa, which covers an area of 28,000 km2, are the third-largest freshwater lake in Africa. From the confluence, the Zambezi River travels some 150 km, part of which is the Zambezi Delta, before entering the Indian Ocean.

The hydrology of the ZRB is not uniform, with generally high rainfall in the north and lower rainfall in the south. In some areas in the Upper Zambezi and around Lake Malawi/Niassa/ Nyasa, rainfall can be as much as 1,400 mm/year, while in the southern part of Zimbabwe it can be as little as 500 mm/year. The mean annual discharge at the outlet of the Zambezi River is 4,134 m^3/s or around 130 km3/year. Due to the rainfall distribution, northern tributaries contribute much more water than southern ones. For example, the northern highlands catchment of the Upper Zambezi sub basin contributes 25 percent, Kafue River nine percent, Luangwa River 13 percent, and Shire River 12 percent—for a total of 60 percent of the Zambezi River discharge.

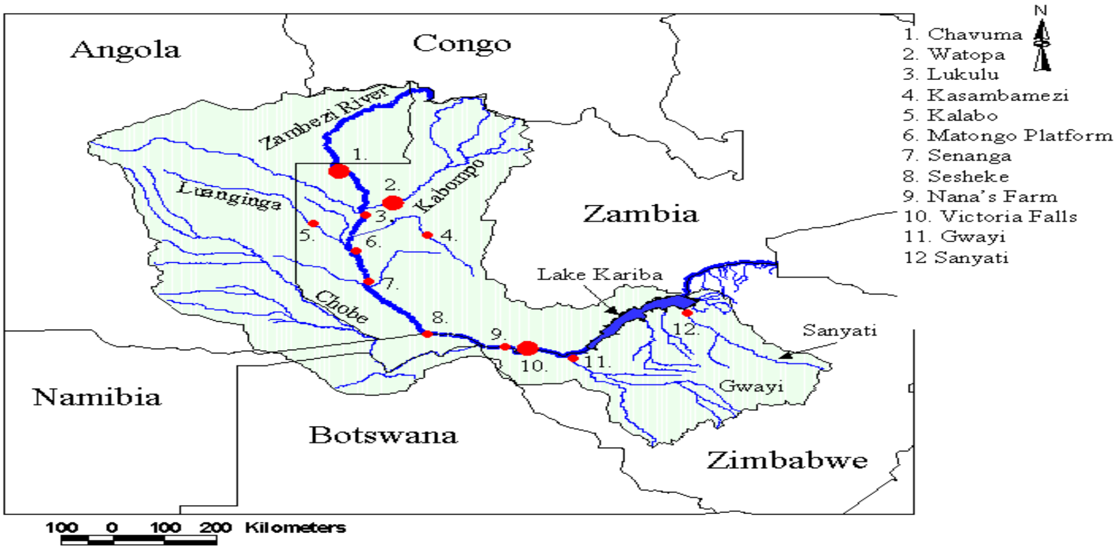

Fig. 1. Zambezi River Basin

5. Existing Hydropower Plants in the ZRB:

A total of almost 5,000 MW of hydropower has been developed in the Basin. The major hydropower plants (HPP) are described below:

5.1 Kariba

The Kariba reservoir provides storage for two power plants: the Kariba South Bank power plant, which has an installed capacity of 750 MW; and the Kariba North Bank power plant, which has an installed capacity of 720 MW. The Kariba reservoir is the second largest man-made lake in Africa after the Lake Volta, with a surface area of 5,577 km2 and a volume of nearly 65 km3 at a full supply level of 488.5 meters. The Kariba South Bank power plant was recently upgraded to 750 MW and the Kariba North Bank to 720 MW. Each powerhouse consists of six identical units. At Kariba North, space was allocated at construction time for housing two future Supplementary units.

5.2 Itezhi Tezhi and Kafue Gorge Upper

Itezhi Tezhi Dam (ITT) and reservoir was completed in 1977 to regulate the Kafue Gorge Upper power It consists of four Pelton turbine units of various capacities, installed between 1924 and 1947 with an effective head of 325 meters and an original capacity of 20 MW, although that has been downsized to 16 MW. A small reservoir with 0.23 km3 capacity, located five kilometers upstream of the powerhouse, provides regulation.

5.3 Victoria Falls

Victoria Falls hydropower consists of three power plants:

• Plant A, commissioned in 1937, has an installed capacity of 8 MW (2 x 1 MW and 3 x 2 MW) but has had its rating lowered to 4.8 MW.

• Plant B, commissioned in 1968, has an installed capacity of 60 MW (6 x 10 MW).

• Plant C, commissioned in 1972, has an installed capacity of 40 MW (4 x 10 MW).

5.4 Cahora Bassa

The Cahora Bassa development is the largest hydropower development in the Basin. It consists of an arch dam, a large reservoir with a surface area of 2,675 km2, a volume of 51.75 km3 at a full supply level of 326 meters, and a powerhouse of five 415 MW Francis units (totaling 2,075 MW).

5.5 Nkula Falls

The Nkula Falls hydropower development, commis- sioned in 1966 and located on the Shire downstream of Liwonde, consists of two powerhouses: Nkula A (three Francis turbines of eight MW, totaling 24 MW) and Nkula B (five Francis turbines of 20 MW, totaling 100 MW). The total capacity at Nkula Falls is 124 MW.

Table 1. Existing Hydropower in Zambezi River Basin

Name	Utility	River	Country	Type	Capacity (MW)
Victoria Falls	ZESCO	Zambezi	Zambia	Run-of-River	108
Kariba	ZESCO/ZESA	Zambezi	Zambia & Zimbabwe	Reservoir	1,470
Itezhi Tezhi	ZESCO	Kafue	Zambia	Reservoir	n/a
Kafue Gorge Upper	ZESCO	Kafue	Zambia	Reservoir	990
Mulungushi	ZESCO	Mulungushi	Zambia	Reservoir	20
Lunsemfwa	ZESCO	Lunsemfwa	Zambia	Reservoir	18
Lusiwasi	Private	Lusiwasi	Zambia	Pondage	12
Cahora Bassa	HCB	Zambezi	Mozambique	Reservoir	2,075
Wovwe	ESCOM	Wovwe	Malawi	Pondage	4.35
Nkula Falls A&B	ESCOM	Shire	Malawi	Pondage	124
Tedzani	ESCOM	Shire	Malawi	Pondage	90
Kapichira stage I	ESCOM	Shire	Malawi	Pondage	64

Source: The Zambezi River Basin: A multi sector investment opportunities analysis, 2010.Vol.3.State of the basin. The World Bank .Washington, USA.

6. Future Hydropower in ZRB

To overcome the energy deficit experienced by several countries in the region, there is now a serious drive to build new generating capacity and rehabilitate and upgrade existing hydro and thermal power stations. Several HPPs, including the Kariba North and South and KGU, have already been refurbished. An intertie was also constructed between Songo in Mozambique and Malawi. Financing is also being sought to extend the Kariba North and South banks and Itezhi Tezhi. In addition, several generation-planning studies are either underway or were recently completed, both at the national level (such as the generation-planning study of Tanzania) and the regional level. Power utility members of the Southern African Power Pool (SAPP) have developed formal and informal generation plans for systems that are either isolated or partially integrated by existing interties. This fragmented approach results in significant differences of reserve margins across countries. In addition, the overall regional reserve margin exceeds the reserve that would be needed should the regional grid be integrated.

Table 2. Future Hydropower in Zambezi River Basin

Project	Status	Utility	River	Country	Type	Base case Capacity (MW)	Base case Operating year	Alternative case Capacity (MW)	Alternative case Operating year
Tedzani 1 & 2	refurbishment	ESCOM	Shire	Malawi	Pondage	40	2008	40	2008
Kariba North	refurbishment	ZESCO	Zambezi	Zambia	Reservoir	120	2008–2009	120	2008
Kafue Gorge Upper	refurbishment	ZESCO	Kafue	Zambia	Pondage	150	2009	150	2009
Kapichira II	extension	ESCOM	Shire	Malawi	Pondage	64	2010	64	2010
Kariba North	extension	ZESCO	Zambezi	Zambia	Reservoir	360	2010	360	2012
HCB North Bank	extension	HCB	Zambezi	Mozambique	Reservoir	n/a	n/a	850	2012
Itezhi Tezhi	extension	ZESCO	Kafue	Zambia	Reservoir	120	2013	120	2013
Kariba South	extension	ZESA	Zambezi	Zimbabwe	Reservoir	300	2014	300	2014
Songwe I, II & III	new project	ESCOM	Songwe	Malawi, Tanzania	Reservoirs	340	2014–2016	340	2024
Batoka Gorge South	new project	ZESA	Zambezi	Zimbabwe	Pondage	800	2017	800	2023–2024
Batoka Gorge North	new project	ZESCO	Zambezi	Zambia	Pondage	800	2017	800	2023–2024
Kafue Gorge Lower	new project	ZESCO	Zambezi	Zambia	Pondage	750	2017	750	2017–2022
Mphanda Nkuwa	new project	EdM	Zambezi	Mozambique	Pondage	1,300	2020	2,000	2024
Lower Fufu	new project	ESCOM	S. Ruhuru	Malawi	Run-of-River	n/a	n/a	100	2024
Kholombidzo	new project	ESCOM	Shire	Malawi	Pondage	n/a	n/a	240	2025
Rumakali	new project	TANESCO	Rumakali	Tanzania	Reservoir	222	2022	256	n/a

Source: The Zambezi River Basin: A multi sector investment opportunities analysis, 2010.Vol.3.State of the basin. The World Bank .Washington, USA.

7. Institutional Context for Tran boundary Cooperation in ZRB

Across Africa, Regional Economic Communities (RECs) have made progress particularly in the area of market integration, infrastructure cooperation, and resource sharing. Increased intraregional trade and improvements in international competitiveness are key common objectives among Africa's integration arrangements such as ECOWAS (Economic Community of West African States), CEMAC (Central African Economic and Monetary Community), EAC (East African Community) and COMESA (Common Market for East and Southern Africa).

8. Southern African Development Community (SADC) members signed protocol on shared watercourse system in 1995. Signatories to the agreement included Angola, Botswana, Lesotho, Malawi, Mozambique, Namibia, South Africa, Swaziland, Tanzania, Zambia, and Zimbabwe. In 2000, the SADC member countries signed the *"Revised Protocol on Shared Watercourses"*. The original protocol established the framework for the use of watercourses shared by two or more member countries, and it emphasized the following principles: the right of each member country to use shared watercourses; maintenance of a balance between development and conservation; collaboration between riparian member countries on developments affecting shared watercourses; free exchange of relevant information between riparian countries; and, the pursuit of equitable exploitation of the River's resources among member countries. Furthermore, the protocol outlined a number of specific obligations for the member countries on prevention of pollution, elaboration of impact assessments, prevention of introduction of alien species, and notification in emergency cases, among others. Member countries view the protocol on shared watercourse systems as a high priority for developing sustainable water resources management for the regions scarce water resources and for reducing and resolving conflicts over these resources. Following chart describes the SADC water policy

The **SADC Drought Monitoring Center** was established in the early 2000s. One of the center's main services is delivering regular regional weather forecasts at sub regional level, especially on rainfall. The forecasts are also crosschecked with **SARCOF** (Southern Africa Regional Climate Outlook Forum) and it contributes to alleviating the weaknesses in hydrometric networks across the region. The Southern African Climate Outlook Forum (SARCOF) is a collaborative effort between a series of organizations. They include the SADC Drought Monitoring Center (DMC) and the World Meteorological Organization (WMO), United Nations Inter Agency International Strategy for Disaster Reduction (UN/ISDR), the Department of Meteorological Services of Lesotho, and other partners.

The Zambezi River Authority (ZRA) between Zambia and Zimbabwe was established in 1987 through endorsement of the Zambezi River Authority Act. The purpose of the Act was primarily the effective management and water use of the Kariba Dam and reservoir to enable improved hydropower generation and delivery.

The **eight riparian countries** sharing the Zambezi River Basin have different institutional arrangements for managing water resources. The countries names are: Angola, Botswana, Malawi, Mozambique, Namibia, Tanzania, Zambia and Zimbabwe.

Gabinete do Plano de Desenvolvimento da Região do Zambeze (GPZ) :The Gabinete do Plano de Desenvolvimento da Regiao do Zambeze (GPZ) in Mozambique (the Zambezi River Valley Development Authority) is a multipurpose government institution that promotes, plans, coordinates and supervises the resources in the Zambezi River Valley.

Zambezi Valley Development Initiative (Zambia): The Zambezi Valley Development Initiative (ZVDI) is a non-governmental organization and is located in the part of Barotseland that lies within Zambia's Western Province. Its mission is dedicated to improving the living conditions of people living in the Upper Zambezi Valley (primarily but not exclusively the Lozi people). It has adopted a multiple objective approach, mainly focusing on cultural heritage and education, though its programs include food security, management of wetland zones, and biodiversity in the floodplains.

9. Challenges

The success of hydropower in Africa will depend significantly on how project developers overcome the challenges that impact on this resource. These include:

- Hydropower depends on river flows, which vary seasonally and cyclically with relatively little forecast. Power generation will therefore vary along with flow, especially in the ZRB.
- Capital costs for hydropower are high compared with thermal and nuclear options, mainly due to intensive civil works. This presents a major challenge for the development of hydropower in the Basin, given the difficulties in securing large-scale financing.
- Reservoirs trap sediments which has two major detrimental effects. First, sediment filling affects the operation of the power plant and requires remedial measures—such as reservoir flushing and dredging— with associated maintenance costs. It may also severely affect downstream reaches where, during the wet season, river bank erosion occurs for which the deposition of sediment from upstream reaches can no longer compensate.
- With the creation of a manmade lake, access to natural resources and ecosystem services for livelihoods is also negatively impacted.
- Hydropower construction is characterized by long periods of negotiating with third parties and the construction of water reservoirs, which makes it susceptible to political changes and unforeseen risks. Delays in the pre-construction phase of many hydropower projects often result in costly budget and time overruns.
- Some regional communities challenges are also important such as, Proliferation and overlapping membership, Limited capacity and inadequate funding, Lack of supranational authority and weakened implementation of agreed programs, Low popular participation in

the regional integration debate and agenda, Lack of information regarding the costs and benefits of integration, Controversy surrounding the path and pace of regional integration and liberalization.

10. Conclusion and Suggestion

Zambezi River Basin's hydropower resources have the potential to significantly contribute to solving the region's power problems. The resource is readily available and produces cheaper and cleaner electricity than other traditional resources such as coal and oil. Hydropower is highly versatile and can be used to meet national electricity grid requirements, rural electrification programs and industrial power needs. However, Frost & Sullivan advises that careful consideration needs to be given to pre-construction phases in hydro power projects to ensure that mechanisms are developed to deal with possible challenges that might impact the long term reliability of these projects. So there are some suggestions for management of Zambezi River Basin:

- The policies and strategies for the management of the Zambezi River basin should be converging towards economic integration with joint and cross border water resources investments between or among the riparian countries.
- Within the agreed policy and legal framework, an agreement should specify the basic roles and responsibilities of each country and stakeholders in the water resources management including the management of flow regulations, abstraction rates or water rights, water degradation and pollution control.
- It should also specify the rights and obligations of riparian states and basin institutions in the advancement of integrated and joint water resources management. The translation of the policy into a legal agreement should include defining institutional mechanisms for the implementation and fulfillment of the objectives of the policy, the SADC Protocol on Shared Watercourse systems and the ideals of SADC related to water resources management at basin level. There is no doubt that there should be a Zambezi River Commission or similar institution under the basin agreement. Next Figure shows a schematic diagram of the recommended institutional set up for Zambezi River Basin Commission and affiliate agencies, River Authorities and River Water Boards.

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