Water for Agriculture and Energy in Africa

The Challenges of Climate Change

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HYDROPOWER RESOURCE ASSESSMENT OF AFRICA

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Hydropower Resource Assessment of Africa

Executive Summary

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.

Compared to other developing countries the level of access to electricity in Africa is very low, despite the continent's rich resources. Over 90% of rural population relies on traditional biomass energy sources such as wood, charcoal, crop waste, manure, etc. for cooking and heating, candles and kerosene for lighting.

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.

NEPAD's 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 76 000GW/year. A comparison with the Gross theoretical hydropower potential of about 4 000 000 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 industrialisation 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.

1.0 Introduction

1.1 Global Overview of Hydropower

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.

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) (Bartle, 2002).

Due to its short gestation period, small hydro is attracting worldwide attention. Of all the non-conventional energy resources small hydro represents the highest density of resource. Global installed capacity of Small hydro is around 50 000 MW against the estimated potential of 180 000MW (Baidya, 2006). SHP plays a crucial role in remote off-grid hydropower development. Asia and particularly China is set to become the leader in SHP development. By the end of 2007, China's SHP installed capacity was 47 380MW from 50 000 SHP stations. Canada with a long tradition in using hydropower is currently developing SHP to replace diesel generation. Australasia-Oceania region makes the least contribution to global hydropower capacity. In countries such as Australia and New Zealand, present developments are focusing on SHP plants.

1.2 Hydropower and Poverty

A number of research studies have indicated a strong correlation between energy consumption and economic growth. Access to modern energy services directly contributes to economic growth and poverty reduction through the creation of income generating activities. Contributions to poverty reduction may come from freeing up time for other productive activities.

The Millennium Development Goals (MDGs) are the international community's commitment to halving poverty in the world's poorest countries by the year 2015. Whilst some of these countries have seen tremendous success in poverty reduction over the past decade, others, especially in the

Sub-Saharan African region, are lagging behind. Electricity is essential for the provision of basic social services, including education and health, and also for powering machines that support income generating activities which tends to reduce poverty. Harnessing hydropower to generate electricity has the potential for ensuring energy security which can be an effective way of reducing poverty in Africa.

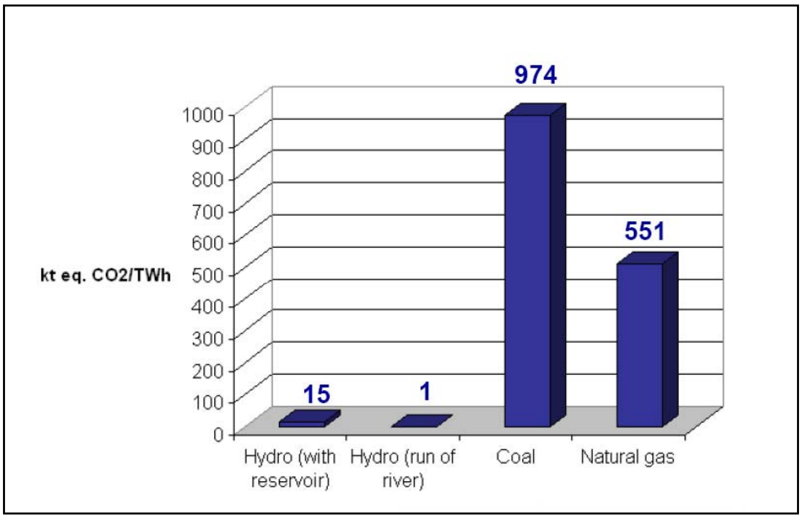
1.3 Hydropower and Climate Change

Energy derived from moving water is environmentally benign as compared to that obtained from burning fossil fuels. Hydro energy does not lead to the emission of greenhouse gases (GHG) and therefore do no contribute significantly to global warming. It was previously held that dam reservoirs do not emit any greenhouse gases. This view is changing due to Clean Development Mechanism (CDM) studies which were undertaken.

Under the Kyoto Protocol industrialised nations are committed to reducing their greenhouse gas emissions, including carbon dioxide and methane emissions. One mechanism for achieving emissions reductions is the CDM approach, where countries can reduce emissions by purchasing emission credits from other countries that invest in projects and programs that avoid GHG emissions and produce a net global reduction in emissions. CDM depends on the ability to assess accurately the emissions avoided such that a net reduction can be verified and valued. Studies carried out on dams to verify their suitability for CDM projects have shown that dam reservoirs do produce small quantities of greenhouse gases. Figure 1.1 shows GHG emissions from selected power generation technologies. Hydropower from run-off-river shows the least GHG emission. However, compared to conventional fossil fuels the effect of hydropower on climate change is minimal.

The current scientific consensus of climate change is that global temperatures will rise by 1.4 - 5^{o}C with an expected increase in global precipitation levels by 5 - 20% by the end of the next century, depending on regions (Harrison et. al, 2000; Atushi, 2007). Whilst increased global precipitation could suggest more water available for hydropower, the increased temperatures imply increased evaporation levels. These changes will have a direct influence on the viability of a hydropower project. Possible extreme events such as flooding could have impact on sediment risks and measures. More sediment, along with other factors such as changed composition of water, could raise the probability that a hydropower project suffers greater exposure to turbine erosion. An unexpected amount of sediment will also lower turbine and generator efficiency, resulting in a decline in energy generated (Atushi, 2007).

Figure 1.1: Greenhouse Gas Emissions of Selected Power Generation Technologies



Source: Scanlon, 2007

2.0 Hydroelectric power development in Africa

Energy supply is the main economic challenge facing the African continent. Electricity production is mainly from hydropower and fossil fuels. Access is very low in most countries the lowest per capita consumption being 80KWh as compared to a continental average of 359 KWh. This is very low when compared with EU average of 3 750KWh. New research indicates a direct correlation between energy usage and economic development. China for example has moved 300 million of its people out of poverty since 1990 due to increased access to energy.

2.1 Hydroelectric power potential in Africa

Africa has 14% of the world's population but only 4% of the global energy. Majority of Africans live in rural areas using traditional biomass for cooking. Africa has enormous potential for hydropower development due to adequate water resources both perennial and non-perennial which need to be harnessed for socio-economic development. It has one of the biggest hydropower potentials in the world but currently uses only a fraction of this potential. The total installed capacity is 21 000MW, 90% of which are concentrated in eight countries (D.R Congo, Egypt, Gabon, Ethiopia, Nigeria, Zambia, Madagascar, Mozambique). Figure 2.1 shows the hydropower potential for ten top countries in Africa. It shows DR. Congo with the highest potential. Figure 2.2 shows the total hydropower potential by continent. It indicates that Africa has one of the least exploited potentials in the world.

Table 2.1 shows the summary of Africa's hydropower development. It indicates that the installed hydropower capacity is about 20.3GW with a total generation from hydro plant of about 76 000 GWh/year. Comparison with the gross theoretical hydropower potential of 4 000 000 indicates that the current production of hydropower in Africa is about 20% of the total potential. The technically feasible hydropower potential of Africa is around 1 750TWh which is about 12% of the global capacity. Only 5% of this technically feasible potential is exploited. Hydropower potential of the continent is estimated around 100 000 MW, the bulk of which can be found in the INGA in the Congo basin. The INGA Rapids which is one of the various sites that have been identified has estimated hydropower potential of around 40 000 MW.

Figure 2.: 1 African Hydropower Potential

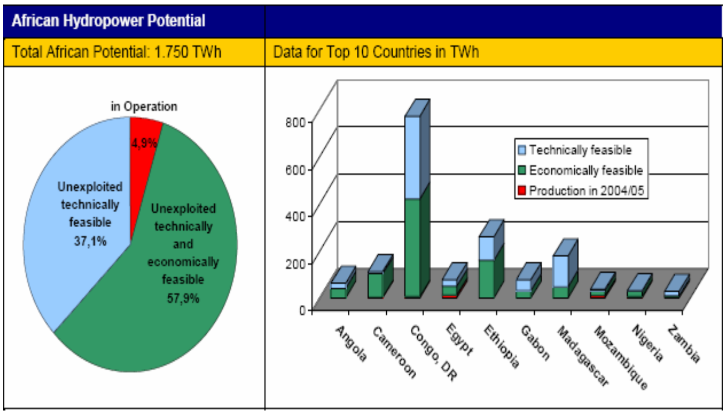
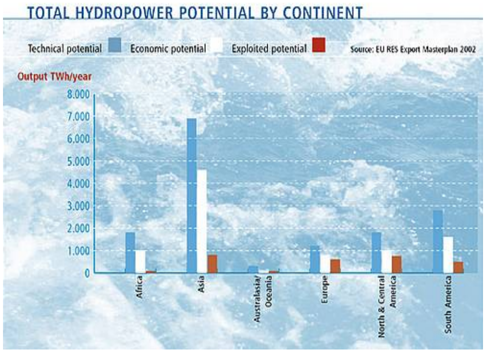


Figure 2.2: Global Hydropower Potentials



Source: European small hydropower association, Belgium

2.2 Large Hydro Power/SHP Development in Africa

2.2.1 Current Status of Large Hydropower

The technical hydropower potential of Africa is around 1 750TWh which is about 12% of the global capacity. Only 5% of this technically feasible potential is exploited. Small hydropower development is poor in the whole of Africa and it is anticipated that SHP will be part of the solution to the growing demand for rural electrification programmes in Africa.

Table 2.2 shows the installed large hydropower by region. Countries with installed capacity of more than 1 000 MW have a total installed capacity of about 13 GW comprising 65% of the total hydropower installed capacity of Africa. The remaining 45 countries account for 35% of the total installed hydro capacity.

Table 2.1: Summary of Africa's Hydropower Development

Theoretical hydropower potential (GWh/year)	Technically Feasible hydropower potential (GWh/year)	Economically feasible hydropower potential (GWh/year)	Installed hydropower capacity (MW)	Generation from hydropower plants (GWh/year)	Hydropower capacity under construction (MW)	Planned hydro capacity (MW)
4 000 000	1 750 000	1 000 000	20 300	76 000	>2 403	>60 000

Source: World Atlas and Industry Guide, International Journal of Hydropower & Dams, 2001

Table 2.2: Installed Large Hydropower by Region

Country	Sub region	Capacity
Egypt	North Africa	2 810
DRC	Central	2 440
Mozambique	Southern Africa	2 180
Nigeria	West Africa	1 938
Zambia	Southern	1 634
Morroco	Northe Africa	1 205
Ghana	**West Africa**	**1 072**
Total		13 279

Source: International Journal on Hydropower & Dams, 2004

2.2.2 Current Status of SHP

Small hydropower plays a dominant role in rural renewable energy markets. SHP plays a great role in remote off-grid communities with typical applications in areas such as rural residential community lighting, TV, radio and telephony, rural small industry (agriculture and other uses) as well as grid based power generation. SHP can serve two main purposes: social and commercial. The social SHP supplies electricity in stand alone mode characterised by small capacity and poor load factor. Often used in distribution and normally government supported. Overheads and maintenance costs are recovered through user charges collection. Commercial SHP on the other hand have larger capacities, sells power to power distribution or trading companies, are grid connected and have higher load factor.

Table 2.3 shows the regional contribution to global SHP installed capacity. It indicates that Africa has one of the lowest SHP installed capacities despite the enormous potentials for SHP development.

Table 2.3: Regional contribution to global SHP installed capacity

Region	Installed Capacity (MW)	% of Total
Asia	32 642	68
Africa	228	0.5
South America	1 280	2.7
North & Central America	2 929	6.1
Europe	10 723	22.3
Australasia-Oceania	198	0.4
Total	**47 997**	

Source: International Journal on Hydropower & Dams, 2004

2.2.3 Barriers

The key barriers hindering the development of SHP in Africa can be summarised as follows:

(1) Lack of infrastructure in the design and manufacture of turbines, installation and operation.

(2) Lack of access to appropriate technologies pico, micro, mini and small hydropower. Networking, sharing of best practices and information dissemination through forums and conferences.

(3) Lack of local capacity (local skills and know how) in developing SHP projects. There is the need for technical assistance in the planning, development and implementation.

(4) Lack of information about potential sites (hydrological data).

(5) Lack of SHP awareness, incentives and motivation.

(6) Lack of private sector participation in SHP development.

(7) Lack of joint venture (public and private sector partnership).

2.2.4 Regulation

There is no single definition for SHP in Africa and indeed across the globe because of different development policies in different countries. Table 2.4 shows the definition of SHP in certain organisations and countries. In most countries and organisations small SHP falls within the 0.5-10MW range.

Table 2.4: SHP Definition and classification

	Classification of SHP (kw)		
Organisation/Country	Micro	Mini	Small
IN-SHP	<100	101-500	501-10 000
UNIDO	<100	101-2 000	2001-10 000
China	<100	101-500	501-10 000
India	<100	<2000	
Sweden	-	-	101-15 000
Phillippines	-	51-500	<15 000
Nepal	<50	<5 000	<5 000
USA	<50	501-2 000	15 000
Brazil	-	-	<15 000
Bolivia	<100	101-500	
Kenya	5-100	100-1 000	1 000-10 000
Nigeria	<500	501-1 000	1 001-10 000

The regulatory framework in most countries is by act of parliament. The mission of such acts will among other things seek to ensure adequate, safe reliable and affordable power supply. Electricity regulatory commission may be tasked with the following responsibilities:

(i) promotion of competition and fair market practices

(ii) protecting the interest of the consumers

(iii) ensure cost recovery and adequate ROI

(iv) Ensure best practice in power and service delivery

The electricity regulatory commission may also perform the following functions:

(i) Issuance of license to operators

(ii) Setting of tariffs

(iii) Arbitrating of disputes

(iv) Performing audits

(v) Reporting regulatory activities to government.

The above definition indicates that SHP schemes with capacities less than 1 MW may not require license but still come under regulations of the electricity regulatory commission.

With respect to SHP the regulatory commission's tasks will include licensing/registration, tariff setting, setting performance and customer service standards. The regulation of SHP schemes is found to be problematic due to complexities arising from factors such as the small sizes, high unit cost and the dispersed nature of SHP projects. The large number of projects involved makes it difficult to adopt a case-by-case treatment. Additional factors such as remoteness of the site, civil works involved (waterways), transmission lines, generating equipment (turbines, generators etc) leads to cost variations adding to the complexities of regulation.

The small scale nature of SHP makes it difficult for operators to carry regulatory burdens such as licensing fees, operating charges, operating standard codes, high technical standards for power supply, service delivery and performance requirements.

For the promotion of SHP in Africa, it is imperative for the above regulations to be lessened to favour the small player. Such relaxed regulations may include just allowing a new entrant to register or receive a permit, flexibility in quality regulation between categories of providers and the use of subsidies to bridge the gap between tariffs and cost recovery levels.

The primary goals of effective SHP regulation will incorporate increased SHP penetration into the electricity market, SHP sustainability, system cost reduction, development of local industry, sound investment climate and simplicity of implementation.

In the promotion of SHP growth, three main approaches have been used: feed-in law, tendering policies and renewable portfolio standards (RPS). The most widely adopted mechanism is feed-in law. Under the feed-in law arrangement, Utility companies are required to sign long term power agreement at non-competitive but guarantee prices with renewable generators using technologies such as SHP. Guarantee contract enhances the growth of Renewable Energy (RE).

2.3 Regional Energy Integration: The Regional Power Pools

A recent study conducted by WEC members in Africa discovered that the conventional approach of limiting energy planning and provision to the individual nation states is detrimental to energy access issues on the continent. The nation based planning is not the best in several respects including the following:

- (i) Cheapest and cleanest source of energy may be found across national boundaries.
- (ii) National energy markets are often too small to justify investments
- (iii) Cross border energy could contribute towards energy security due to diversification of energy sources.

The study further revealed four major benefits that regional integration could bring. These are: improved security of supply, enhanced environmental quality, wider deployment of RE resources and better economic efficiency.

The uneven regional and country distribution of Africa's energy resources which often creates demand-supply imbalance and the small size of most African economies suggest that individual country strategies of energy sector development cannot be optimal. This provides the driving force for exploring more regional integration. Africa's energy development could be sustained through the optimal use of its enormous resources.

In West Africa, regional integration project such as West Africa Power Pool (WAPP) was devised to improve the power supply situation across the whole region, and also to drive integration within the ECOWAS area. The main energy resources in the region are natural gas (mainly in Nigeria) and hydropower (in Ghana, Nigeria and Guinea). Countries in the region with limited energy resources rely on importation of expensive heavy oil or gas, or electricity imports from neighbouring countries. WAPP is designed to improve access and provide affordable electricity supply within the ECOWAS region.

Major hydropower Projects under development under the WAPP partnership framework includes:

- Four nations (Guinea, Senegal, Gambia and Guinea Bissau) agreed to build two dams on the river Gambia: 2 000 kilometres of 225 kV transmission loop linking the networks of the four countries and associated hydropower projects; the 240 MW Kaleta hydropower plant (on river Gambia in Guinea) and Sambanglou (on river Gambia in Senegal).
- 62 MW Hydropower project at Felou dam on river Senegal in Mali and expansion of existing 225 kV transmission system in Senegal.

The long-term scenario is for WAPP to help meet the region's projected electricity demand by harnessing additional electricity from:

* An expansion of gas-fired power generation through increased access to Nigeria's enormous proven natural gas reserves (4 trillion cubic meters). The West African Gas Pipeline (WAGP) project will fuel thermal (new and existing oil fired) stations in Ghana, Togo and Benin.

* The substantial but untapped hydropower potential resources of Guinea, some 6 000 MW which is potentially economic to be developed to produce electricity at relatively low cost.

The Manantali dam on the River Senegal with a capacity of 200MW is another example of Regional Integration project serving Senegal, Mali and Mauritania. The objectives for the project are to install power generation capacity to generate economic and financial benefits, to minimise the cost of electricity supply to the three countries and to provide hydropower to help meet the increased demand of electricity in Dakar, Bamako and Nouakchot.

In East Africa, a number of countries have faced power shortages which have caused power supply rationing. The origin of the crisis is the decrease of water level in rivers and lakes that are feeding the hydropower plants and lack of investments in power generation. Countries in the region have responded to the challenges by embarking on aggressive measures in the production as well as transmission of energy, interconnecting countries and sharing available capacity. The creation of the Eastern Africa Power Pool (EAPP) is one of the major steps undertaken in this regard. Under the EAPP framework, Ethiopia with its abundant hydropower resources will play a significant role. Ethiopia's planned hydropower projects up to 2015 total additional capacity of 3 600 MW against the current installed capacity of 810 MW.

In 1983, the Economic Community of the Central African States (ECCAS) was formed. The treaty creating the community encourages cooperation in the field of energy between member states. The energy protocol commits member states to cooperate in the exploitation of hydropower and other renewable energy sources. In 2003 the Ministers of Energy of the ECCAS member states signed the Inter-Governmental Framework Agreement creating the Central Africa Power Pool (CAPP).

Governments and companies from countries in the region are considering the options of strengthening power networks in parallel with the rehabilitation of existing power plants. Access to modern energy services is vital for the socio-economic development in Africa. The problem of low access could be mitigated through projects such as the INGA. The largest hydro potential of Africa could be developed as a regional rather than a national project. This would help expand energy markets in the area and secure supply to those who have no access to electricity.

The utilisation of the INGA sites hydropower potential however, relies mainly on building new power plants and interconnection lines designated as power highways originating from the INGA sites for supplying the various African sub-regions in particular.

(i) the DRC -Congo-RCA-Sudan-Egypt interconnection

(ii) the DRC-Congo-Gabon-Cameroon-Nigeria interconnection

(iii) the DRC-Angola-Namibia-RSA

Table 2.5 gives a summary of the INGA projects. The Grand INGA is listed as a priority of the Southern Africa Development Community (SADC), the New Partnership for African Development (NEPAD) and WEC. The capacity of the Grand INGA is estimated around 39 000 MW which is more than a third of the total electricity currently produced in Africa. There are plans to develop INGA III with a capacity of 3 500 MW, which is a presidential priority of South Africa government to export electricity to South Africa. Few private companies would be prepared to invest in the kind of infrastructure that will only generate profits in the long term, unless they expect their infrastructure to remain operational for many years to come. This has not been the case for many years at INGA because of sustained conflict in DR Congo.

Another factor that makes the development of Grand INGA more likely is the rise in carbon emissions trading. Companies and countries that are deemed to have generated more than their fair share of greenhouse gases are required to invest in carbon neutral or compensatory schemes elsewhere in the world. This could include massive tree planting schemes of species that absorb more carbon than they produce, or renewable energy schemes.

The main objectives of a project such as the INGA are to bring affordable and clean energy to the African Continent and to improve standard of living. The project will lead to cross boarder cooperation in Africa and beyond. This will bring interdependence and prosperity to Africa.

Table 2.5: Summary of the INGA Projects

Name	Year	Capacity (MW)	Current Status
INGA I	1972	351	Operational/undergoing rehabilitation
INGA II	1982	1 424	Operational/undergoing rehabilitation
INGA III	2012	3 500	-
Grand INGA	Unknown	39 000	-

Source: www.internationalrivers.org/en/africa/grand-inga-grand-illusion

The power crisis in Southern Africa is getting worse according to the Southern Africa Power Pool (SAPP). The main drivers for the increase in demand for electricity in the region are: economic growth of more than 5% in SADC countries and 6% in South Africa, no tangible investment in generation capacity during the past twenty years and the 2010 world cup that would be hosted by South Africa. The world cup has attracted a lot companies into building infrastructure including stadium, roads, hotels and shopping complex.

To address the situation, SAPP is currently in the process of implementing short term generation projects that will add an additional 4,000 MW to the SAPP grid. Most of these projects are in South Africa and Zambia (on the Zambezi River) and will be completed before 2010. The major existing and on-going projects and their capacities are summarised in table 2.6. Large hydropower potentials are currently under study at the Kafue lower sites in the Kafue River of Zambia.

Table 2.6: Major Hydropower Plants in the Zambezi and its Tributaries

Name	Country	Installed Capacity (MW)
Victoria Falls	Zambia	108
Kariba North bank	Zambia	660
Kariba South bank	Zimbabwe	666
Kafue Gorge	Zambia	900
Cahora Bassa	Mozambique	2 075
Nkela falls	Malawi	124
Tedzani 1,2&3	Malawi	90

Source: www.utip.org-mz/news/index.html

The Northern Africa countries do not face energy crisis. The total installed capacity of COMELEC countries consisting of Mauritania, Egypt, Libya, Algeria and Tunisia is 21 000MW according to Comite Maghrebin de l'Electricite report 2006. The bulk of the energy in the region comes from thermal (about 90%), 9% hydropower and 1% renewable.

2.4 Security of Supply and Accessibility

Security of supply involves ensuring uninterrupted daily operation of power supply systems at the same time coping with short term problems such as international price volatility and environmental concerns and industrial action. Security of supply underpins the development of interconnection between countries and regions. In the long term, security of supply involves the depletion of global and national energy resources and the capacity to diversify energy supply options.

3.0 Large Hydroelectric power /SHP data for Africa

3.1 Overview

There is enormous exploitable large hydropower potential on the African Continent. In spite of this, Africa has one of the lowest electricity utilisation rates in the world. Presently, 20% of this potential has been harnessed. Africa has many rivers running through the Eastern, Western, Central and Southern parts of the Continent which provide excellent opportunities for hydropower development. Tables 3.1-3.5 show LHP/SHP data in terms of installed, potential, on-going and pipe-line project capacities for the five regions in Africa. Many countries in Africa do not have coherent data on both large and small hydropower potentials. UNIDO Regional Centre on SHP (U-RC-SHP) in Abuja is currently collating such information. SHP potential is great across the continent but currently poorly developed. The data presented in tables 3.1-3.5 shows that SHP is poorly developed in the whole of Africa, even among the nations with great potentials for SHP development. The data also indicates that a number of countries have huge potentials that need to be harnessed in order to improve access to modern energy services across the continent.

3.2 Regional Contributions

In this report we adopt the five Africa regional classification model based on social, cultural and economic diversity. Under this model, Africa is divided into North, South, East, West and Central regions.

3.2.1 North Africa

Countries like Algeria, Egypt, Libya, Morocco and Tunisia are grouped under this region. Out of the current 20.3GW about 23% is located in North Africa. Table 3.1 shows the LHP/SHP data for North Africa. The table indicates that in terms of large hydropower development, Algeria, Libya and Tunisia are poorly developed. These countries depend more on sources of electricity other than hydropower. Egypt and Morocco have installed capacities of 2 810 and 1 205 MW respectively making the greatest contribution to the total hydropower installed capacity in the region. The potential of North Africa is almost exhausted. Majority of the installed capacity can be traced along the Nile with the Aswan Plant taking about 2 100MW of Egypt’s total capacity.

Table 3.1: LHP/SHP Data for North Africa.

Country	LHP(MW)				SHP(MW)				Projected Demand (GWh/Year)
	Dam/Installed capacity /cost	River/ Potential	Dam/ Ongoing	Dam/ Pipeline	Dam/Instal led capacity	River/ Potential	Dam/ On-going	Dam/ Pipeline	
Algeria	275				42				N/A
Egypt	*Aswan high dam, Wsna,* etc /(2 810)/ over $1bn		64	56	20	68.2	2.2		50 927
Libya	-								N/A
Morocco	*Allal el Fassi, Al Wahda, Al Massira,etc,* /(1,205)				30				N/A
Tunisia	64		300		25	37.1		9.1	

Table 3.2 Data for LHP/SHP for Southern Africa.

Country	LHP(MW)				SHP(MW)				Projected Demand (GWh/Year)
	Dam/Installed capacity /cost	River/ Potential	Dam/ Ongoing	Dam/ Pipeline	Dam/Instal led capacity	River/ Potential	Dam/ On-going	Dam/ Pipeline	
Botswana	-				1				
Lesotho	106				3.54				
Madagascar	220	4 112			106				
Mauritius	59				6.7				
Mozambique	Cahora Bassa etc/2,500				0.1	1.2			
Namibia	Ruacana/ 240		360						
South Africa	Vanderkloof, Gariep/ 780				0.4				
Swaziland	55				24.4				
Zambia	Kariba etc/1,700	6 000			61.9				
Zimbabwe	Kariba etc/2026								

3.2.2 Southern Africa

The countries that constitute the Southern Region are: Botswana, Lesotho, Madagascar, Namibia, South Africa, Swaziland, Zambia and Zimbabwe.

The region has about 60% of its potential exploited. South Africa has very little hydropower potential left to be exploited. Table 3.2 shows the LHP/SHP for Southern Africa. Mozambique has the largest LHP installed capacity of 2 500 MW but very little SHP installed capacity (0.1MW). The LHP plant is located on the Cahora Bassa River. Botswana has very little potential and relies more on other sources of electricity. Zambia has the second largest potential in the region after Mozambique (2 500MW) and has developed 30% of it. A lot of the potential in Zambia is along the rivers Zambezi and Kariba rivers, shared by Zambia and Zimbabwe. Plans are in place for the exploitation of the potential in the region. The Zambezi River and its major tributaries have been developed for hydropower generation. Hydropower projects on the Zambezi have been constructed in Zambia, Mozambique, Malawi and Zimbabwe. Table 3.2 indicates that SHP is poorly developed in the region. Zambia has a relatively high installed SHP capacity oh 62 MW.

3.2.3 East Africa

East Africa has the second largest potential in Africa with about 20% of its capacity developed. It comprises the following countries: Burundi, Kenya, Djibouti, Eritrea, Ethiopia, Kenya, Malawi, Rwanda, Somalia, Sudan, Tanzania and Uganda.

Table 3.3 shows the hydropower data for countries in the region. Somalia, Eritrea and Djibouti are poorly developed in terms of both LHP/SHP. Ethiopia has the greatest LHP potential in the region with a capacity of 15, 000MW followed by Kenya with 9 000MW. Kenya has, however, developed more of its potential (13%) than Ethiopia (4%). Ethiopia has a reasonably high SHP installed capacity (80 MW). In order to respond to the energy challenges, countries in the region have embarked on measures in the production and transmission of energy, interconnecting countries and sharing available capacity. The creation of the Eastern Africa Power Pool in 2005 was one of the major steps and regional plans undertaken to exploit the potentials as indicated in section 2.3.

Table 3.3: Data for LHP/SHP for East Africa.

Country	LHP(MW)				SHP(MW)				Projected Demand (GWh/Year)
	Dam/Installed capacity /cost	**River/ Potential**	**Dam/ Ongoing**	**Dam/ Pipeline**	**Dam/Installed capacity**	**River/ Potential**	**Dam/ On-going**	**Dam/ Pipeline**	
Burundi	43	300			14.5				
Djibouti					32.93				
Eritrea									
Ethiopia	*Awash I&II, Gilgel Gibe I*/ 589	15 000			80	133			
Kenya	*Turkwel,* /1 197/	6 000			6.28	3 000			
Malawi	*Kapichira, etc*/283				4.5				
Rwanda	33.3	100			1				
Tanzania	*Kidatu, Lower Kihansi*/380				4	68.12			
Uganda	*Kira*/205	500			8	736			

3.2.4 West Africa

West Africa's contribution to installed large hydropower capacity is about 25%. Table 3.4 illustrates the data for the installed, potential and on-going projects within the countries. Nigeria and Ghana are the biggest LHP contributors. The potential for large hydropower is enormous in countries such as Guinea (6 100MW) and Nigeria (11 500MW). Sierra Leone, Togo, Gambia and Cape Verde are poorly resourced with hydropower potential. The contribution from SHP is very small in the whole of West Africa despite the high potential in countries such as Nigeria and Ghana. This could be due to reasons such as high initial cost, lack of hydrological or baseline data, lack of technical knowledge in SHP development, lack of government support, policies, environmental concerns and awareness.

3.2.5 Central Africa

Central Africa includes the following countries: Angola, Cameroun, Central African Republic, Chad, Congo, D.R. Congo, Gabon, Equatorial Guinea and Sao Tome & Prinicipe. The region has enormous hydropower potential concentrated around the Congo basin. D.R Congo contributes the greatest. The current installed capacity of large hydropower is around 3 816MW and a potential of 419 000MW with the highest contribution coming from the INGA sites as shown in table 3.5. This indicates that D.R: Congo has exploited just 1% of its potential capacity. SHP is poorly developed in Central Region just like the other four regions.

Table 3.4: Data for LHP/SHP for West Africa.

Country	LHP(MW)				SHP(MW)				Projected Demand (GWh/Year)
	Dam/Installed capacity /cost	**River/ Potential**	**Dam/ Ongoing**	**Dam/ Pipeline**	**Dam/Installed capacity**	**River/ Potential**	**Dam/ On-going**	**Dam/ Pipeline**	
Benin	*Nangbeto*/66	300	*Adjaralla*/100	150	1				
Burkina Faso	62	75	1	62.5	3.4				
Cape Verde					12				
Ivory Coast	*Taabo*/614	973	350						
Gambia								9.1	
Ghana	***Akosombo, Kpong*/1,072**	**1 205**	**Bui dam /400**	**120**	**10**	**795**			
Guinea	117.8	6 100	75		4.55	14.24			
Guinea Bissau	127								
Liberia	10				11	20			
Mali	*Manantali*/ 200				5.8				
Mauritania	61								
Niger	372				31				
Nigeria	1 938	11 250			33	3 500			
Senegal	200								
Sierra Leone					4				
Togo					4				

Table 3.5: Data for LHP/SHP for Central Africa

Country	**LHP(MW)**				**SHP(MW)**				**Projected Demand (GWh/Year)**
	Dam/Installed capacity /cost	**River/ Potential**	**Dam/ Ongoing**	**Dam/ Pipeline**	**Dam/Installed capacity**	**River/ Potential**	**Dam/ On-going**	**Dam/ Pipeline**	
Angola	*Capanda* etc/665	18 000				0.5			
Cameroun	*Edea, etc*/ 949				4.18	615			
Central African Republic	19				18.75				
Chad									
Congo	*Makoukoulou, Imboulou*/194/ $236m								
D R Congo	*Inga etc*/ 3 816.80	419 210	3 500		65				
Gabon	320				6.2	126			
Equitorial Guinea									
Sao Tome & Principe									

4.0 Africa's Hydropower Project Partners

A number of financial institutions have provided and continue to provide billions in assistance for large hydropower projects in Africa. This section seeks to highlight a few of these donors and the projects they have funded.

4.1 Large Hydropower Projects

4.1.1 Multilateral Banks/World Bank & AfDB

Multilateral Organisations such as AfDB and the World Bank have financed a number of Large Hydropower Projects in Africa. AfDB for example has provided financial support for the following projects:

- US$14 million for part of the INGA II project.
- US$18.7 million grant to finance hydropower project in Conakry, Guinea.
- US$16 million for Bumbuna dam project, 50MW, in Sierra Leone, West Africa.

World Bank Projects:

- US$300million Bujagali Hydropower project on River Nile, Uganda, 250MW capacity on-going and to be commissioned in 2011.
- Uganda, 200MW Karuma Falls hydropower project.

4.1.2 China

The power sector in Africa attracts the largest amount of Chinese financing. Much effort is concentrated in hydropower schemes. By the end of 2007 the Chinese were involved in the construction of a number of major hydroelectric power dams in some African countries with a combined generating capacity of 6 000MW of electricity. The location, capacities and current status of some of the projects are as follows:

Table 4.1: Some Chinese funded power projects.

Country	Capacity (MW)	Status
Mambilla dam, Nigeria	2 600	Under Federal government discussion
Merowe dam, Sudan	1 250	Advanced stage of construction
Katue, Zambia	Over 1 000	Under construction
Bui dam, Ghana	400	Under construction
Mphanda Nkuwa dam, Mozambique	1 200	Near completion
Souapati dam, Guinea	-	-
Poubara, dam Gabon	-	-

Source: www.internationalrivers.org/en/node/823

The projects total cost is around US$5billion out of which the Chinese are financing US$3.3billion. The Chinese use African natural resources to secure some of the financing. For example on-going projects on the Congo River in Congo and Bui dam in Ghana are financed by China Ex-Im Bank loans backed by guarantees of crude oil and in Congo and Ghana respectively.

4.1.3 Others

East African Development Bank (EADS):

EADS partly financed the installation of 150km high voltage transmission line from Kiambre power station to Nairobi, Kenya.

4.2 Small Hydropower Projects

4.2.1 World Energy Council (WEC)

The World Energy council is a Multi-International Organisation covering all type of energy resources with members in 94 countries. WEC's mission is to promote sustainable supply and use of energy for the benefit of mankind.

Accessibility is one of WEC's millennium energy goals in Africa where access rate is the lowest in the world. WEC believes that the development of the huge Africa hydropower potential will bring clean and affordable electricity supply to the region.

WEC's Policy framework for Africa's Hydropower development can be summarized as: improving existing hydropower capacity, advancing the development of regional projects identified, implementing identified projects (INGA, Mepanda Uncua, etc), identify and implementing other regional projects and building capacity for small and medium hydropower project

WEC/NEPAD Initiatives

Under the WEC/NEPAD policy framework, the following policy initiatives were established:

- Establish a Committee on Hydro Power Development with specific task:
  - Map out the existing facilities and identify opportunities for improving their performance
  - Identify centers of excellence within each sub region to serve as training centers for sharing of experience
- Work with Regional Economic Commissions (REC) and appropriate institutions at the national level to:
  - Support the Development of Identified Regional Projects like Grand INGA
  - Finance Facilitation of Country Projects
  - Develop Policy at Sub-Regional Levels
  - Support African Energy Commission (AFREC) to institutionalize actions mentioned above
  - Set up a fund to facilitate the development of small to medium hydro projects to which corporate entities could apply
  - Produce annual hydropower publications in Africa to provide information on new projects and status of on-going works
  - Support and collaborate with hydro power research centers and networks.

4.2.2 UNIDO

UNIDO has identified SHP as tool for rural industrialization and poverty reduction in Africa.

- UNIDO-IC-SHP/Lighting up Rural Africa

UNIDO and International Centre for SHP in 2007 organised the 3rd Hydropower potential in China with the theme 'Lighting up Rural Africa'. Under the South-South Cooperation, UNIDO in collaboration with IC-SHP have plans to scale-up SHP production in Africa through the development and production of 100 SHP projects in the next 3 years.

- **UNIDO-RC-SHP/Pilot Projects in Africa**

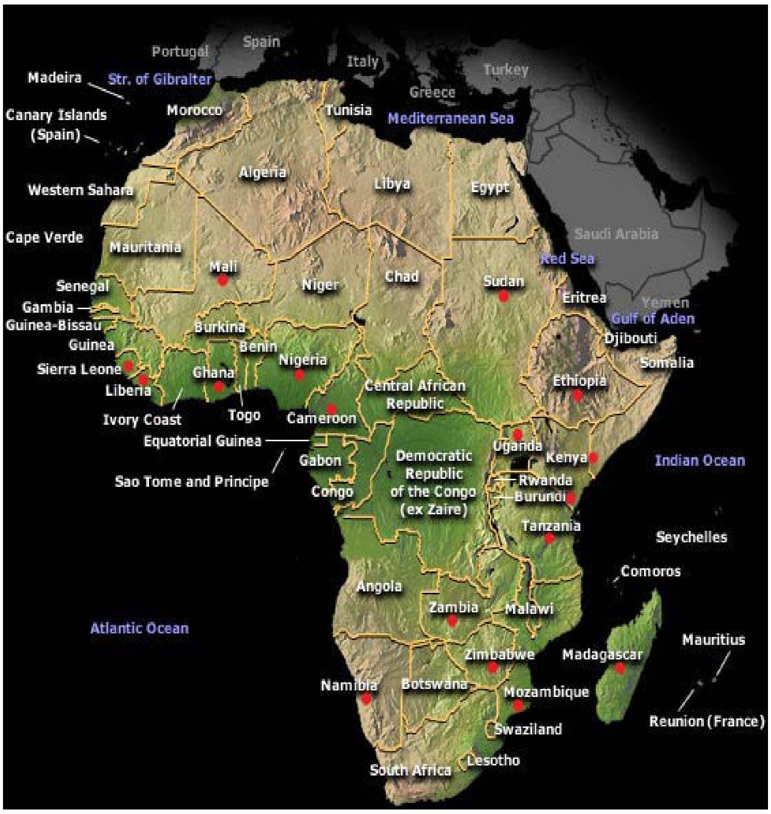
UNIDO Regional Centre for SHP (RC-SHP) was established in 2005 in Abuja, Nigeria with the mandate to provide technical assistance to countries within the region. U-RC-SHP hosted the 4th International Hydropower for Today Forum in Abuja, Nigeria on Small/Mini/Micro hydropower development and management in Africa. UNIDO is currently running a number of pilot projects on SHP in countries such as Tanzania (75 KW), Nigeria (34 KW), Madagascar, Uganda (250 KW) etc. UNIDO-RC-SHP has also carried out SHP refurbishment projects in the following parts of Nigeria: talata mafara, Zamfra State (3.4MW) and Oyam Dam, Ogun State (9 MW). Table 4.2 is a list of UNIDO projects in selected African countries.

RC-SHP is currently involved in activities such as the collection of data and creation of SHP database for Africa, organising workshops and conferences for capacity building and SHP potential site identification. Figure 4.1 shows current UNIDO- IC-SHP small hydropower promoting activities in seventeen African countries under the Lighting up Rural Africa scheme. The main objective of the project is to augment on/off grid rural electrification based on pico/micro/mini hydropower systems and linking energy services with productive uses for poverty reduction in selected African countries. The participating countries were selected based on availability of small hydro resources, willingness of local communities to support SHP systems and potential for productive uses in and around SHP systems.

Table 4.2: UNIDO Project in Africa

Nigeria	1. Enugu 2. Waya	40 kW 150 kW
Rwanda	1. Nyamyotsi 1	75 kW
Kenya	4 sites	2 kW pico
Tanzania	1. Kinko	12 kW
Mali	1. Sirakorbougou	3-5 kW

Figure 4.1: UNIDO & IC-SHP
SHP Activities in Africa



- UNIDO-AFREC

Africa Energy Commission (AFREC) has a plan of action which complements U-RC-SHP in Abuja's activities. AFREC's plan of action includes:

- Develop information system database for SHP
- Develop a continental master plan for SHP
- Identification and removal of barriers
- Technology transfer
- Capacity building- design short courses and training session
- Finance- organise symposium on strategies for attracting finance for SHP projects.

5.0 Impacts

5.1 Interlinkages between agriculture and hydropower

Availability to water is of considerable importance to agriculture. The vast majority of dams are constructed primarily for irrigation or agricultural purposes, thus contributing to the world food production. Most African staple foods need processing, conserved and cooked, and these require modern energy for reasonable quality of life. Paradoxically, most countries in Sub Saharan Africa that suffer from hunger also suffer from major on-farm and off-farm food losses which could be reduced through improved harvesting and storage facilities by the introduction of modern energy, and so reduce large food imports.

On the other hand, the construction of dams affects land use, either directly or indirectly. For example hydropower projects with reservoirs transform forests and land into aquatic ecosystems, thereby effectively reducing available farmlands. Dams constructed for power generation can also compete in part with the use of water for irrigation since using the energetic potential of hydropower by running turbines means that the water is only available at a lower altitude afterwards. For this reason there has been consensus in most countries that an integrated approach to the management of water resources serves best the exploitation of hydropower resources. In such cases, the dam must be operated very carefully to maximize the overall benefits derived from it. One of the main challenges is determining the optimal allocation of scarce water for the competing sectors (i.e. hydropower and agriculture). Information describing the value of water in competing uses will assist water resource managers and decision makers in identifying the basis for making socially acceptable trade-offs and identifying the potential for improving and creating linkages with water allocation options (Reuben et al, 2008).

5.2 Dams construction assessment

- *World Commission on Dams Report*

The World Commission on Dams (WCD) was established to address the controversial issues associated with large dams. In 2000, the WCD produced a report which made certain recommendations to ensure that the social and environmental aspects of large dams are addressed adequately in the planning, construction and operation phases. The report summarises the lessons learned from a Global Review of experience with large dams and elaborates the development framework within which the controversies and underlying issues can be understood and addressed and proposes a decision-making process based on negotiated outcomes. It offers a set of strategic priorities, principles, criteria and guidelines to address the issues around existing dams and to use in exploring new water and energy development options. The Commission's framework for decision-making is based on five core values - equity, sustainability, efficiency, participatory decision-making and accountability.

- *IUCN*

Many organisations and governments have reacted to the World Commission on Dams report following its release. For most, the report does not offer a final verdict on dams; instead it provides a new framework for improved decision making for water and energy development (UNEP, 2001). Several other organisations, however, are in favour of the recommendations and are committed to its dissemination. One such body is the International Union for the Conservation of Nature (IUCN). Founded in 1948, its headquarters is located in the Lake Geneva area in Gland, Switzerland, the IUCN brings together 83 states, 108 government agencies, 766 Non-governmental organizations and 81 international organizations and about 10 000 experts and scientists from countries around the world. IUCN has many years of experience in ecosystem rehabilitation and participatory management and more specifically in field level activities.

Following up from the WCD report the IUCN developed a programme which provides a good basis for acting proactively in support of the WCD recommendations. It provides a clear mandate to make full use of the WCD report through the effective management and restoration of ecosystems, and the assessment of biodiversity and of other related social and economic factors. Furthermore, IUCN aims to demonstrate how the ecosystem approach to water management should be implemented through a new portfolio of 30 projects around the world. At these sites, IUCN will play an important role in fostering implementation, adaptation and testing of the WCD recommendations by working with the main dam stakeholders (UNEP, 2001).

- *Public and private investors*

As seen from the discussion in the previous sections, dams are generally built to generate hydroelectricity, provide irrigation water, or as a part of flood control programmes. Depending on the interest group, dam building has either brought major benefits or has spelled considerable human suffering, or has had a harmful effect on the environment. These factors have had considerable impact on the prospect of building large dams.

Globally, only a handful of private sector hydroelectric projects have managed to attract the investment required, most relying on state involvement in one form or another. One reason is that hydropower is perceived as carrying a number of financial risks which make dams a less attractive investment than other power projects (Hildyard, 1998).

5.3 Economic Impacts

Hydropower schemes generally involve a huge civil engineering effort and are characterised by high capital costs. The payback on the investment required can be a lengthy process and sometimes have a detrimental effect on a nation's economy. In Africa, where financial resources are scarce, the high up-front costs of hydropower investment pose a barrier to the development of this resource (EU, 2007).

Despite the high upfront costs hydropower is a well-established and proven technology with low operating and maintenance costs. In terms of countries which depend heavily on fuel imports, hydropower could be of benefit to its economy as it is not dependant on energy imports and thus unaffected by fluctuating international energy prices.

The construction and operation of dams can lead to many positive economic impacts. The actual construction of a dam can provide employment for the local communities. However, this employment is only for a limited period of time as when the dam is completed, the use for labour will no longer be required. If there are no other investments around the construction site, the employment opportunities will diminish.

As has been highlighted in the previous sections, the construction of dams may necessitate the relocation of the people living near the river. In some cases, whole communities and even towns that have been subsiding next to each other for decades have no choice but to relocate. This could indicate loss of lands especially those whose farmlands are to be occupied by the dam. Although compensation might be paid, the loss of farmlands could be detrimental to the economic well being of those affected.

Conclusions:

The major conclusions and recommendations are listed below:

- Africa is currently using 20% of its hydropower potential with non-uniform regional distribution. Some regions are more endowed than others. A few countries with installed capacities more than 1 000 MW constitute about 65% of the total energy installed. The energy imbalance needs to be addressed through regional integration.
- Financing of energy projects is low due to low level of hydropower technology and huge cost of power projects in Africa.
- Private public partnership option to raise capital and share investment risk should be adopted.
- The power sector should be reformed to attract private sector participation and financial flow.
- Africa is characterized by low level of technology on hydropower, in particular SHP development. Hydropower technology is widely available elsewhere worldwide and technology transfer is the immediate option to enhance development.

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