BARRIERS TO THE UPTAKE OF SMALL HYDROPOWER FOR RURAL ELECTRIFICATION IN AFRICA

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1. Introduction

Small hydropower is a proven technology that can adequately contribute to the electricity needs of rural areas in Africa. Currently only a (very) small fraction of the huge hydropower potential on the African continent is harnessed. For large scale hydropower, utilisation percentages of between 4 and 7% are being mentioned, while for small scale hydropower the gap between the potential and the actually developed sites is most probable even bigger.

Although the technical aspects of small hydro are very well understood, the number of small hydropower plants in Africa is minimal, suggesting that other barriers then the technology itself do persist.

This article will investigate the different barriers in Africa toward rural electrification and the application of renewable energy technologies in general and to those hampering the uptake of small hydropower in general. The article will describe the role of policy and regulatory frameworks, financing, local and regional human and industrial capacity, as well as the limited information on the available resource.

2. Background

Of the total hydropower potential of the world approximately 10% can be found on the African continent, with the majority of that in Sub-Saharan Africa. However, only 4 to 7% of the potential for large scale hydropower has been exploited (ESHA, 2006; Min Conf Water for Agriculture and Energy in Africa, 2008). For small and micro scale hydropower this percentage is most probably even lower, although no proper statistics are available. To indicate the low rate of development of small hydropower on the African continent, Gaul et al. (2010) compare the 45,000 plants below 10 MW in China with a total of a few hundred developed sites in the whole of Africa. While the European Small Hydropower Association (2006) is even referring to 100,000 units in the micro spectrum as installed in China!

Small hydropower can play a pivotal role in providing energy access to remote areas in Africa that are currently not connected to the national electricity grid, either in stand-alone isolated mini grids or as distributed generation in national grids. The potential role of small hydropower in eradicating energy poverty has been recognized by a number of national governments and bi- and multilateral donors. An example is the new draft energy strategy for the World Bank, which does specifically highlight small scale hydropower as an important component of future World Bank activities in Africa (World Bank, 2010)

The large knowledge base on technical aspects of microhydro in general does suggest a proper understanding of the technology. However, the relatively small number of small and micro hydropower projects implemented in Africa does not reflect the enormous potential for the technology on the continent, suggesting that other barriers than the technology itself are still persistent.

Although small hydropower projects have been implemented in several countries on the continent, information on the current state of affairs is scattered and incomplete. To a (very) limited extend information is available on technical details of implemented projects, however, information on implementation models followed and their successfulness is not available in most cases (Michael, 2008; Pigaht & van der Plas, 2009). Basic technical information on existing hydrostations might be available, but is definitely not complete nor consistent over the different information sources. This lack of information does severely hamper the possibility to learn from past experiences and is a barrier to large uptake of village level hydro on the continent (Gaul et al., 2010).

3. Defining small hydropower

At this stage no internationally agreed definitions of the different hydro sizes exist. A generic distinction though is between “large” hydro and “small” hydro. The most generally accepted definition of “small” has been set by the World Commission on Dams, which set the upper limit for small hydro at 10 MW of installed capacity, although large countries as China and India tend to put the limit higher at 50 MW and 25 MW respectively.

Recently some international donors seem to use a maximum capacity of 15 MW when referring to small hydro.

Within the range of small hydro, distinction can be made between mini hydro (often limited to an installed capacity of maximum 1 MW), micro hydro (below 300 or 100 kW depending on the definition) and pico hydro (below 20, 10 or 5 kW), each with its own specific technical characteristics. Micro and pico hydro installations are mostly found in developing countries for energy provision to isolated communities where the national electricity grid is not available, whereas mini hydro tends to be grid connected. Micro and pico hydro can also differ from mini hydro due to the extended possibility of using local materials and labour in the case of first two, while mini hydro typically involves more traditional engineering approaches and will usually need for example heavy access roads for delivery of materials and electro-mechanical equipment.

In this article the upper limit of 10 MW of installed capacity is being used when referring to small hydropower.

4. Small hydropower in Africa

Small hydropower is a proven, mature technology with a long track record, also in Africa. The gold mines at Pelgrims' Rest (South Africa), for example, were powered by two 6 kW hydro turbines as early as 1892, complemented by a 45 kW turbine in 1894 to power the first electrical railway. In several African countries church missions did build small hydropower installations, like in Tanzania where church missions installed more than 16 small hydropower systems during the 1960's and 70's that are still operating (Mtalo, 2005). Another example is large scale commercial farmers in the Eastern Highlands of Zimbabwe that installed hydro stations as early as the 1930's (Klunne, 1993).

Many countries in Africa do have a rich history of small scale hydropower, but over time large numbers of these stations have fallen in disrepair. Some because the national grid reached their location, some because a lack of maintenance or even pure neglect.

Recently initiatives have seen the light in a number of countries in Africa to revive the small hydro sector, either through international development agencies or through private sector led initiatives. Particular in Central Africa (Rwanda), East Africa (Kenya, Tanzania and Uganda) as well as Southern Africa (Malawi, Mozambique and Zimbabwe) new initiatives are focusing on implementing small hydropower projects. In South Africa the first new small hydro station in 20 years was opened in 2009, with more under development.

5. Barriers

Most of the challenges facing small hydropower exploitation are not specific for hydropower but generic for all types of renewable energy and rural electrification projects. General barriers for renewable energy projects are the absence of clear policies on renewable energy, limited available budget to create an enabling environment for mobilising resources and encouraging private sector investment, and the absence of long-term implementation models that ensure delivery of renewable energy to customers at affordable prices while ensuring that the industry remains sustainable.

Looking specifically at small hydropower development, the following barriers can be identified:

- **Policy and regulatory framework**: unclear or non existence of policies and regulations that govern the development of (small) hydropower. In some countries hydropower developments under a certain threshold are not regulated at all, while in other countries it might be part of a broader regulatory framework for rural electrification in general. Generic frameworks often lack clarity on a number of hydropower specific issues like access to water and water infrastructure and the associated payments.

- **Financing**: hydropower developments are faced, even more than other sources of renewable energy, with high up-front costs and low O&M costs, something most available financing models do not favour. Nearly all of the new developments on the continent are relying in one form or the other on donor financing. Development of alternative financing models, including tapping into alternative funding sources, is needed to facilitate small hydro developments.

- **Capacity to plan, build and operate hydropower plants**: national and regional knowledge and awareness on the potential of small hydro in rural electrification is missing or very minimal. This includes knowledge at political, government and regulatory entities, as well as knowledge on local production of parts and components.

- **Data on hydro resources**: linked to the limited knowledge about the technology is the lack of proper resource data on water availability and flow on which hydro developments can be based.

Regulatory and legislative frameworks

A clear prerequisite for the uptake of small hydropower are policies and strategies that are in support of small scale renewable energy development. These should show long-term vision, as well as concrete targets and implementation plans with associated budgetary allocations. Preferably they include coordination efforts on support by international donors.

Unfortunately, in Africa very few countries have been able to develop such strategies and policies. Although almost all Sub-Saharan African countries have rural electrification plans, their main focus is on grid extension and most of them do not address renewable energies, let alone specifically support small hydropower deployment.

The availability of long-term grid extension plans is essential to enable small hydro investor to assess financial project viability. Grid extension plans can provide the needed information on whether an area will see grid extension and thus whether the set-up of an independent mini-grid will be viable. More often than not the national electricity grid reaching an isolated small hydroplant has resulted in the hydroplant being decommissioned and the community being connected to the national grid. Only very few examples exist where an existing small hydro station is being integrated in the national grid (e.g. Mantsonyane in Lesotho) or is able to operate in parallel to it (e.g. Matembwe in Tanzania).

Next to the needed regulation and legislation with respect to the electricity aspects of small hydropower, rules and regulations with respect to water use and use of physical water infrastructure are essential in developing small hydropower.

Funding of hydropower schemes

Three broad categories of funding of small hydropower developments can be distinguished:

- **Private or balance sheet funding** for systems that serve one household / farm or are part of the operations of a commercial enterprise. These systems tend to be designed to supply a small load consisting of domestic energy use and more power demanding applications like milling or grinding. As these systems do typically not supply outside entities their existence is quite often not publicly known and information is rather difficult to get. Funding of these systems normally does not involve external parties. A typical example is the Horseshoe Falls system in Sabie in South Africa, which was designed and built by farmer Pieter Weber in the 1960s and operated till 1990 when the national grid reached the farm (microhydropower.net, 2011). Another example is the use of hydropower at tea estates in eastern Africa.

- **Public funding**, often through the national or municipal power utilities, for grid connected systems. This typically involves larger systems like the 2 MW Mantsonyane plant in Lesotho. Specific funding could be available for off-grid installations through Rural Electrification Agencies and Rural Electrification Funds.

- **Systems funded by bilateral donors** (e.g. from Austria, Belgium, China, Germany, Japan, Netherlands, UK and Sweden) and multilateral donors (World Bank, AfDB, GEF, UNDP, etc). These systems will often form part of a national programme on energy access / rural electrification.

Table 2 does indicate what type of support is available for hydro projects in a number of selected African countries.

Financial incentives for hydropower systems can be provided through generation based incentives or installed capacity based incentives.

The best known example of the generation based incentives are renewable energy feed-in tariffs, which do pay owners of renewable energy generators a premium based electricity tariff. In African region only Kenya, South Africa and Uganda do have specific feed in tariffs for hydropower, while the feed-in tariff in Tanzania does not make a distinction between different generation technologies. The feed-in tariff in South Africa does not make a distinction on the installed capacity of the small hydro plant and the initially announced rate amounts to ZAR 0.98 / kWh (approx. US$ 0.14) (NERSA, 2009) for hydro stations in the 1 – 10 MW range. This tariff was revised downward to between ZAR 0.671 and ZAR 0.68 / kWh depending on the implementation year

(NERSA, 2011). However, in the current South African competitive bidding process for renewable energy the announced REFIT has been put aside.

Kenya has a feed in tariff for hydropower that is depending on the size of the installation:

Plant capacity (MW)	Max firm power tariff	Max non-firm power tariff
0.5 – 0.99	0.12 US$/kWh	0.10 US$/kWh
1 – 5	0.10 US$/kWh	0.08 US$/kWh
5.1 – 10	0.08 US$/kWh	0.06 US$/kWh

Table 1 Hydropower feed in tariffs Kenya (Ministry of Energy Kenya, 2010)

Also Uganda has a hydro feed in tariff which varies with plant size. Between 500 kW and 1 MW of installed capacity a tariff of US$ 0.109 / kWh will be paid. For installations between 9 and 20 MW a tariff of US$ 0.073 / kWh is applicable, while in between 1 and 8 MW a linear tariff as displayed in Figure 1 will be used (ERA, 2010).

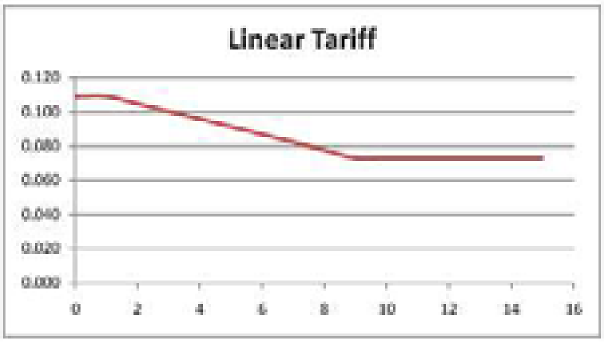

Figure 1 Uganda feed in tariff for hydropower (ERA, 2010)

Capacity based incentives do provide up front funding to offset the high investment needed for hydropower and are typically modelled as once-off investment subsidies. Particularly for off-grid systems capital investment support is considered a preferred form of support as long as it is supplemented by a business model to operate the facility in a sustainable way. This support can be given in the form of grants and loans, or as tax incentives on the investment.

A specific form of financing is provided by the Clean Development Mechanism (CDM) under the Kyoto protocol. Most of the hydropower projects world-wide that benefit from CDM funding related to avoided carbon emissions are in Asia (India and China) while very few can be found in Africa (see Table 3). The uncertainties around the CDM funding after the end of the Kyoto protocol in 2012 make investors hesitant to follow this route. Coupled with a general lack of CDM project development capacity in Africa it is not likely that the number of CDM funded projects will increase dramatically in the (near) future.

Linked to the carbon emissions avoided tradable renewable energy certificates can be issued for hydropower plants, which can provide an additional revenue stream for the operator. At the moment only South Africa has an operational system for tradable RECs in place in Africa. The South African RECs initiative has the 3 MW Friedenheim plant in Nelspruit as one of its contributors (ZARECS, 2010).

Country	Feed in tariff	Tradable REC	Capital subsidy	Investment / production tax credits	Reduction in sales tax	Public Investment Loans / grants	Public competitive bidding	Rural electrification agency
Botswana					X			X
Ethiopia					X	X		
Kenya	X				X			X
Lesotho						X		X[1]
Madagascar								X
Malawi								X[2]
Mozambique						X		X
South Africa	X	X	X				X	
Tanzania	X		X		X			X
Uganda	X		X		X			X
Zambia					X			X
Zimbabwe								X

Table 2 Support for renewable energy (based on REN21, 2011 and own research)

Project Name	Type	Country	Credit Buyer	Status	Capacity (MW)	Credit Period (yrs)
Tsiazompaniry	New	Madagascar	France (ORBEO)	Validation	5.25	10 fixed
Sahanivotry	New Run of River	Madagascar	Austria (Kommunalkredit Public Consulting Gmb)	Registered	15	10 fixed
Clanwilliam	Existing Dam	South Africa	Denmark (Danida)	Validation	1.5	7 renew
Bethlehem	New Run of River	South Africa	Netherlands (Statkraft Markets BV)	Registered	7	7 renew
LUIGA	New Run of River	Tanzania	-	Validation	3	7 renew
Buseruka	New Run of River	Uganda	Denmark (Danish Energy Agency)	Validation	9	10 fixed
Ishasha	New Run of River	Uganda	Netherlands (C-Quest Capital LLC)	Validation	6.6	10 fixed
Bugoye	New Run of River	Uganda	Norway (Public)	Registered	13	10 fixed
West Nile Electrification Project	New Run of River	Uganda	Netherlands + Finland (PCF)	Registered	3.5	7 renew

Table 3 Overview of African small hydro projects in CDM pipeline (Chu, 2011)

Capacity building

Local capacity to plan, design, build, operate and maintain hydroplants is essential towards the successful operation of small hydropower in Africa. Without proper resource assessments and associated feasibility studies no project will be developed. Similar, without proper maintenance and technical capabilities to repair systems, sustainable operation will not be possible.

National and regional capacity to plan and design systems has been and currently is being build by (international) NGOs funded by development assistance funds from developed countries. Also local production

[1] GEF project
[2] Bilateral project

of turbines and other components of hydroplants has been piloted by in particular Practical Action, but with the limited regional market these efforts have not resulted in wide spread local production.

In an analysis of best practices on microhydro developments, including detailed descriptions of four installations on the African continent, Khennas and Barnett (2000) pointed out that the lack of knowledge about financial management and utilisation of electricity to generate revenues is a main bottleneck for a successful operation in Sub-Saharan Africa.

The limited number of microhydro projects in Africa has resulted in few people with practical experience in the technologies involved. Gaul et al. (2010) identify four approaches to address this deficit:

- Establish international or regional knowledge networks and induce foreign expertise by training local technicians.
- Strengthen technical schools and science institutes to build up local capacity.
- Project-driven approach, involving local engineers in the planning and implementation of projects and at the same time building up their skills.
- Technology transfer either north – south or south – south. Particular the small hydro expertise in countries like Nepal and Indonesia could be targeted for technology transfer.

6. Current initiatives

Several initiatives are currently ongoing to assist developing small hydropower Africa. Table 4 does give an overview of these initiatives, while detailed descriptions of some of those initiatives follow below.

The United Nations Industrial Development Organisation (UNIDO) is currently running a number of pilot projects on small scale hydropower in countries such as Tanzania (75 kW), Nigeria (34 kW), Madagascar, Uganda (250 kW) etc. (Min Conf Water for Agriculture and Energy in Africa, 2008).

Linked to the UNIDO Regional Centre for SHP was an UNDP/GEF initiative on small hydropower in 10 countries in West Africa. A network was launched at a high level meeting in Vienna, but unfortunately it has not resulted in substantial developments in the region, highlighting the challenges in the sector. In fact, the project initiative, which was to be funded by the GEF, has been withdrawn.

The United Nations Environment Programme (UNEP) is implementing a Global Environment Facility (GEF) funded project that looks at the possibilities of applying small hydro at tea estates to generate electricity in the Eastern Africa region. Starting from the premises that tea does need altitude and water to grow, which incidentally are requirements for hydropower as well, a collaboration of the East African Tea Trade Association (EATTA), UNEP, the African Development Bank and the GEF has set up a facility to accelerate the uptake of hydropower. The project received huge interest by the tea estates due to the current unreliable power supply from the national electricity grids. The project aims to establish 6 small hydro power demonstration projects in at least 3 of the EATTA member countries, preferably with an attached rural electrification component, as well as to prepare additional pre-feasibility studies. Both studies and planned installations will serve as training grounds for the entire tea sector in the region. The project includes a special financing window to assist individual tea processing plants to move into "green power generation". A key feature of this Greening the Tea Industry in East Africa project is linking the energy requirements of the tea industry with the available hydro resources and using this as a basis to develop viable projects that preferably do include a rural electrification component.

Under the header of the EU funded project "Catalysing Modern Energy Service Delivery to Marginal Communities in Southern Africa", the British NGO Practical Action is implementing a regional micro hydro project in Malawi, Mozambique and Zimbabwe. The project seeks to promote the use of renewable energy through creating micro hydro expertise in poor communities by equipping community members with micro hydro scheme management skills, such as installations, fabrication of equipment, etc. The project aims at the installation of 15 micro hydro units in the three countries concerned. The project is in the initial phases of its implementation and currently supports three hydro systems in different phases of implementation. The project does look into the development of a regional pool of microhydro expertise, including local manufacturing, quality standards and work on removing of political barriers. Also management and ownership models will be tested and evaluated under the project (Mika, 2009). At this stage three different financial models are being implemented and will be evaluated on their merits. In the "ShareD" financial model, as is implemented in Chipendeke in Zimbabwe, local community members do provide sweat equity to the project that will be converted in shares in the commercial enterprise that will be running the hydro plant. The "generator model" as implemented by Practical Action together with their Mozambican counterpart Kwaedza Sumukai Manica (KSM) is build around a private entrepreneur generating electricity for the community. In this model the local transmission and distribution infrastructure will be owned by the community. Thirdly Practical Action is applying an adapted version of Build, Operate and Transfer model (BOT) to have a smooth transition towards community ownership of the installation (Mutubuki-Makuyana, 2010).

Location	Project	Implementer	Description	Important component
East Africa	Greening the tea industry	UNEP/GEF	Small hydroplants at tea factories, including rural electrification component	Linking rural electrification with existing industrial activity
Kenya	Tungu-Kabiri hydro project	Practical Action / UNDP/GEF-SGP	Community owned system to power micro enterprises centre	Legislative framework prohibited connection of households
	Rural Energy Access Model	GPower	11 small hydroplants initially off-grid, later to be interconnected. Incl. local turbine production	Long term planning, integration with grid, part of larger development plan, local turbine manufacturing
Malawi. Mozambique, Zimbabwe	Catalysing Modern Energy Service Delivery to Marginal Communities in Southern Africa	Practical Action / EU	Rehabilitating existing systems, development of local/regional capacity	Inclusion of capacity building component
Mozambique	Access to modern energy services	GIZ	Rehabilitation of microhydro mills	Direct link with productive use
Nigeria	UNIDO Regional Centre for Small Hydro Power, Abuja	UNIDO	National and regional capacity building	Capacity building, linkages with International Centre for Small Hydro Power, Hangzhou, China Current status unclear
Rwanda	Energizing Development	GTZ	Support to private sector to develop hydroplants	Need to incorporate requirements of financial sector
	Rural energy development in Rwanda	UNIDO	Rural energy development	Learning-by-doing project – increased role of private sector in construction and O&M
Tanzania	Kinko Village hydro, Lushoto	UNIDO / MoEM / TANESCO / TaTEDO	Establishment of village hydro scheme	Integration of productive uses (grain milling and ICT centre)
South Africa	Bethlehem hydro	NuPlanet	7 MW capacity at Sol Plaatjie and Merino sites	CDM project
Uganda	Kisiizi Hospital hydropower	Kisiizi Hospital Power Limited	300 kW crossflow turbine serving hospital and local community	Hospital as anchor client
West Africa (Cameroon, Mali, Central African Republic, DRC, Gabon, Congo, Rwanda, Equatorial Guinea, Togo and Benin)	First regional micro/mini-hydropower capacity development and investment in rural electricity access	UNDP/GEF	Regional integration project aiming at developing 36 small hydropower stations. Included a network on small hydropower.	Establishment of regional network. PLEASE NOTE: project cancelled.

Table 4 Overview of current initiatives on small hydropower

7. Discussion

The research described in this paper aimed at providing information on the current status of small hydropower in Africa, as this lack of information is seen as a major stumbling block towards larger uptake of the technology. Precisely this lack of information did hamper the research as the knowledge base on small hydro is not well documented and does feature internal inconsistencies.

The research did find a large number of promising activities in the region that can bring small hydropower the needed impulse.

The research does clearly indicate interest in the region for small hydropower, but also highlights the embryonic stage of the development of sustainable implementation models. Which is surprising seen the maturity of the technology involved.

It is recommended that further research is done towards removing the barriers towards larger uptake of the technology and into implementation models that ensure sustainable operation once the physical infrastructure has been established

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