Current status of village level hydropower in eastern and southern Africa

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Abstract

Decentralised, village level hydropower stations can play an important role in energising rural areas in Africa, particular those areas remote from the national electricity grid. This article describes the current status of village level hydropower in eastern and southern Africa, including an analysis of the current barriers towards large scale uptake of the technology.

Although the technical aspects of hydropower are well understood, the number of hydro projects implemented does not reflect the enormous potential that exists in Africa. This suggests that other barriers than the technology itself are still persistent.

One of these barriers is the limited information available on successfully implemented projects. This article is a contribution to enlarging the knowledge base on village level hydropower in Africa in order to provide a basis for the development of best practices around the implementation of this technology.

Keywords: hydropower; Africa.

Introduction

Approximately 10% of the world's hydropower potential is found in Africa, most of which is located in the Sub-Saharan part of the continent. However, in no other continent the gap between actual hydropower generation and the technical exploitable potential is larger than in Africa where only 5% of the potential been exploited (ESHA, 2006; Min Conf Water for Agriculture and Energy in Africa, 2008). For the small and micro scale hydropower the gap between the potential and the actually developed sites is most probably even bigger, 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!

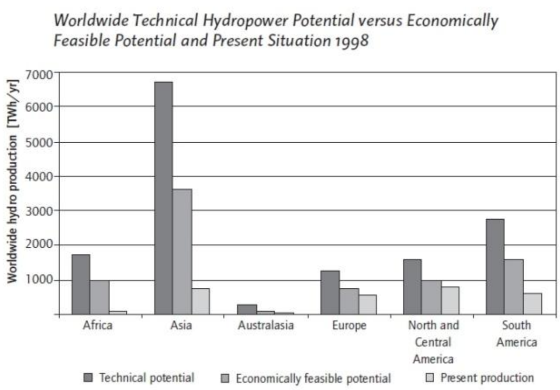

Figure 1: Hydropower potential worldwide (IEA, 2003)

The role of small hydropower in energizing rural areas in Africa

Sustainable energy provision is regarded as a major challenge, especially in Africa where large proportions of (rural) population do lack access to (basic) energy services. On the continent nearly 600 million people do not have access to electricity. This translates to two thirds of the population, while in rural areas up to 92% of the population lives without electricity. Although the electrification rates do differ per country, rural areas in general lack access to adequate, affordable, and reliable energy services. It has generally been agreed that providing access to energy is an absolute necessity in order to reach the Millennium Development Goals (DFID, 2002; UNDP, 2005).

The lack of access to modern energy services is particularly prominent in Sub Saharan Africa (see Table 1) and has prompted several donors and multilateral organizations to pay specific attention to improving this situation. In most instances the possible role of small scale hydropower has been recognized, as in the new draft energy strategy for the World Bank that does specifically highlight small scale hydropower as an important component of future World Bank activities in Africa (World Bank, 2010)

The traditional way of providing electricity to rural areas through the extension of the national electricity grid becomes prohibitively expensive due to geographical barriers (distance and terrain) and due to initial low demand for electricity. A viable alternative for grid extension is provided by renewable energy sources that use local resources.

Table 1: Electricity access Africa (IEA, 2008)

	Population without electricity millions	Electrification rate %		
		Natio-nal	Urban	Rural
Africa	589	40.0	66.8	22.7
North Africa	*2*	*98.9*	*99.6*	*98.2*
SSA	*587*	*28.5*	*57.5*	*11.9*
Developing Asia	809	77.2	93.5	67.2
China & East Asia	*195*	*90.2*	*96.2*	*85.5*
South Asia	*614*	*60.2*	*88.4*	*48.4*
Latin America	34	92.7	98.7	70.2
Middle East	21	89.1	98.5	70.6
Developing countries	**1 453**	**72.0**	**90.0**	**58.4**
Transition economies & OECD	**3**	**99.8**	**100.0**	**99.5**
World	**1 456**	**78.2**	**93.4**	**63.2**

Substantial numbers of projects and programmes have been implemented in Africa providing solar systems to rural populations. However, it has become clear that the costs of photo-voltaic systems are very high and that they do not provide households with the level van energy services they aspire (Krause & Nordstrom, 2004).

Micro scale hydropower, often implemented through local isolated mini grids, is able to offer a higher level of energy services than solar PV. In the case of Kenya, research by Maher et all (2003) revealed that hydro stations in the pico range are able to supply electricity to households at a fraction of the cost to the end-user compared with solar PV or using car battery charged at grid connected charging stations.

Particular in rural areas far away from the national electricity grid that will not be reached by the grid in the near future, stand alone micro scale hydropower plants can play an important role. Through local mini grids microhydro plants can serve local business and households with electricity essential for their economic development.

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 village 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 village level 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 in the region and on the continent (Gaul et al., 2010).

Objectives

The objective of this article is to get a better understanding of the status of village level hydropower in eastern and southern Africa and in that way contribute to enlarging the knowledge base on the technology. The article will give an overview of important aspects hampering the uptake of the technology and identify areas for attention. It will also identify possible areas that need further research in order to establish guidelines for successful implementation of such projects.

Defining village level 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.

As indicated above, no uniform definitions exist in the mini, micro and pico hydro ranges. In this article the term villagehydro is used to refer to hydro installations which are typically used for village electrification using a local distribution network and that typically are not connected to the national electricity grid. Although no strict upper limit of installed capacity has been applied, in general it can be assumed, in line with the definition used by Fraenkel et all (1991) for micro hydropower, that village hydroplants have an installed capacity below 300 kW.

Village level hydropower in Africa

There is enormous exploitable hydropower potential on the African continent, but despite this massive potential for large and small scale hydropower, Africa has one of the lowest hydropower utilisation rates. While large-scale hydropower development is becoming a challenge due to environmental and socio-economic concerns, and more recently its vulnerability to changing climates and hence water availability in the main water bodies, micro hydropower development continues to be an attractive resource especially in remote parts of Africa. The fact that microhydro installations tend to use only part of the available water in rivers makes them less vulnerable to changes in water quantities due to climate change.

Microhydro is a proven technology that can adequately contribute to the electricity needs of African countries.

Micro scale hydropower has a long history in general, but also in Africa. For example the first system in South Africa was a 300 kW station on the slopes of Table Mountain, which was inaugurated in 1895 (Barta, 2002). All over Africa church missions were particularly active in implementing small scale hydropower installations. In Tanzania, more than 16 small hydropower systems were installed by church missions in the 60’s and 70’s of last century that are still operating (Mtalo, 2005), while in Zimbabwe for example large scale commercial farmers in the Eastern Highlands of the country 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 but others because of lack of maintenance or pure neglect.

Recently initiatives have seen the light in a number of countries in Africa to revive the hydropower sector, either through international development agencies or through private sector led initiatives. Particular in Central Africa (Rwanda), East Africa (Kenya and Tanzania) as well as Southern Africa (Malawi, Mozambique and Zimbabwe) new initiatives are focusing on implementing small scale hydropower projects.

Barriers

Although several projects and programmes have seen the light in recent years, the low number of existing hydropower stations shows that there are still many barriers hampering the dissemination of this technology.

The challenges facing micro hydropower exploitation in general are many and most of them are part of the larger picture of general barriers for the uptake of renewable energy and independent power producers. These generic barriers can be summarised into the lack of clear-cut policies on renewable energy and associated requisite budgetary allocations to create an enabling environment for mobilising resources and encouraging private sector investment, and the absence of lost-cost, long-term financing models to provide renewables to customers at affordable prices while ensuring that the industry remains sustainable.

Specifically for small hydro, large scale implementation is hindered by:

- Policy and regulatory framework: the policies and regulations needed to govern the development of (small) hydropower do not exist. Sometimes hydropower developments are either not regulated at all or are part of a broader regulatory framework made for rural electrification in general. Generic frameworks might lack clarity on a number of hydropower specific issues like access to water and associated payments.
- Financing: the lack of funds for hydro developments is a major bottleneck. Currently most of the hydro projects in Africa are relating in one form or the other on donor financing. Tapping into alternative funding sources is needed to upscale the uptake of hydropower.
- Capacity to plan, build and operate hydropower plants: another serious challenge is the missing knowledge and awareness on small hydro potential for rural electrification. 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 which hydro developments can be based.

Regulatory and legislative frameworks

Policies and strategies that are in support of small scale renewable energy development are a clear prerequisite for the uptake of small hydropower. Such strategies 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 very few countries in Africa have been able to develop such strategies and policies. Almost all Sub-Saharan African countries now have rural electrification plans but mainly focus on grid extension and hardly focus on renewable energies, let alone specifically support small hydropower deployment. An example in case is the Mozambican rural electrification agency FUNAE, which has renewable energies in its portfolio but so far only three hydroplants in the pipeline.

Another important issue is the availability of rural electrification plans. The availability of long-term grid extension plans enables the small hydro investor to assess financial project viability. These plans provide useful information on whether a locality will soon enjoy grid extension or whether the set-up of an independent mini-grid makes sense. 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 or is able to operate in parallel to it.

Funding of hydropower schemes

Funding of small hydropower developments in the eastern and southern African region can be distinguished in three broad categories:

1. Private funding for systems that serve one household / farm with or without commercial activities attached to it. 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 and typically are not designed to harness as much energy as possible at their specific site. As these systems do typically not supply outside entities their existence is quite often not publicly know 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 build by farmer Pieter Weber in the 1960s and operated till 1990 when the national grid reached the farm (microhydropower.net, 2011).
2. Public funding, often through the national or municipal power company, for grid connected systems. This typically involves larger systems like the 2 MW Mantsonyane plant in Lesotho.
3. 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.

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

A good example of the first is a renewable energy feed-in tariff paying the owner of the system a premium based electricity tariff. In the eastern and southern African region only Kenya, South Africa and Uganda do have specific feed in tariffs for hydropower. The feed-in tariff in South Africa is a flat ZAR 0.98 / kWh (approx. US$ 0.14) (NERSA, 2009) for hydro stations in the 1 – 10 MW range, while Kenya has a feed in tariff for hydropower that is depending on the size (see Table 2)

Table 2: Hydropower feed in tariffs Kenya (Ministry of Energy Kenya, 2010)

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

Also Uganda has announced a hydro feed in tariff depending on the 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 2 will be used (ERA, 2010).

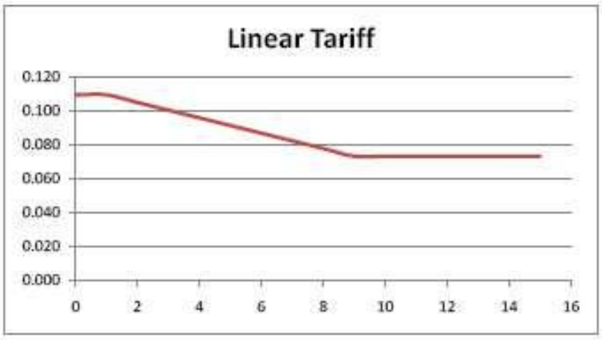

Figure 2: Uganda feed in tariff for hydropower (ERA, 2010)

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.

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 list of CDM funded projects will increase dramatically in the (near) future.

Capacity building

Essential towards the successful operation of small hydropower in countries in Africa is the establishment of local capacity to plan, design, build, operate and maintain hydroplants. 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 of turbines and other components of hydroplants have been piloted by in particular Practical Action, but with the limit regional market these efforts have not seen the wide spread of 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 deficit for a successful operation in Sub-Saharan Africa.

The limited number of microhydro projects in the eastern and southern African region have resulted in few people with practical experience in the technologies involved. Gaul et al. (2010) identify four approaches to address this deficit:

1. Establish international or regional knowledge networks and induce foreign expertise by training local technicians.
2. Strengthen technical schools and science institutes to build up local capacity.
3. Project-driven approach, involving local engineers in the planning and implementation of projects and at the same time building up their skills.
4. 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.

Table 3: CDM hydropower projects in eastern and southern Africa (UNDP RISOE, 2011)

Country	**Name of project**	**Sub-type**	**MW**	**Status**
Kenya	Redevelopment of Tana Hydro Power Station Project	Existing dam	19.6	At Validation
	Optimisation of Kiambere Hydro Power Project	Existing dam	20.0	At Validation
	Sondu Miriu Hydro Power Project.	Run of river	60.0	Validation negative
Madagascar	Small-Scale Hydropower Project Sahanivotry in Madagascar	Run of river	15.0	Registered
South Africa	Clanwilliam Hydro Electric Power Scheme	Existing dam	1.5	At Validation
	Bethlehem Hydroelectric project	Run of river	7.0	Registered
Tanzania	LUIGA Hydropower Project in Mufindi District, Tanzania	Run of river	3.0	At Validation
Uganda	West Nile Electrification Project (WNEP)	Run of river	3.5	Registered
	Bugoye 13.0 MW run-of-river Hydropower project	Run of river	13.0	Registered
	Ishasha 6.6 MW Small Hydropower project	Run of river	6.6	At Validation
	Buseruka Mini Hydro Power Plant	Run of river	9.0	At Validation
	Bujagali Hydropower Project	Run of river	250.0	At Validation

Table 4: Overview of current initiatives on small hydro in eastern and southern Africa

Implementing agent	**Project name**	**Country / region**	**Description**	**Important component**
UNEP/GEF	Greening the tea industry	East Africa	Development of small hydroplants at tea factories, including rural electrification component	Linking rural electrification with existing industrial activity
GTZ	Energizing Development	Rwanda	Support to private sector to develop hydroplants	Need to incorporate requirements of financial sector
Practical Action / EU	Catalysing Modern Energy Service Delivery to Marginal Communities in Southern Africa	Malawi. Mozambique, Zimbabwe	Rehabilitating existing systems, development of local/regional capacity	Inclusion of capacity building component
Practical Action / UNDP/GEF-SGP	Tungu-Kabiri hydro project	Kenya	Community owned system to power micro enterprises centre	Legislative framework prohibited connection of households

Current initiatives

At the moment several initiatives are ongoing to assist developing small hydropower in eastern and southern Africa. Table 4 does give an overview of these initiatives, while detailed descriptions follow below.

A number of UN agencies like UNDP, UNEP and UNIDO are active in support programmes to remove barriers to the harnessing of the large small hydropotential, small hydro support centres are established or in the process of being established in a number of countries and a number of national rural electrification programs does include electricity generation by small hydro. Also bilateral donors and NGOs have embraced small hydropower as a means to provide energy to rural areas.

The United Nations Industrial Development Organisation (UNIDO) is active in a number of African countries in the field of hydropower. In 2007 UNIDO and the Chinese International Centre for Hydropower did organise a conference around the theme “Lighting up Rural Africa”. The aim was to set up a South-South Cooperation to scale-up small hydro development in Africa through the development and production of 100 projects in the next 3 years. The current status of this initiative is unknown.

In 2005 the UNIDO Regional Centre for SHP (RC-SHP) was established in Abuja, Nigeria with the mandate to provide technical assistance to countries within the region. The centre did host a number of conferences and seminars but seems to be less active nowadays.

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.

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).

A recent evaluation of existing micro hydro systems in Tanzania (Jonker Klunne & Michael, 2009) looked at the cases of three isolated mini grids in Tanzania using microhydro technology to serve a total of 1100 households, 32 institutions and 84 commercial loads with electricity. Careful planning procedures catering for technical capacity, good institutional arrangements, managerial capacity and economic considerations, as well as multi-stakeholder involvement from the planning phase onwards, have resulted in the sustainable operation of the three hydro plants. The analysis does suggest that village level scale hydrostations are best managed in a business-like fashion, although it also concludes that community engagement/involvement is crucial in all phases of the hydro site development.

Discussion

The research described in this paper aimed at providing information on the current status of village level hydropower in the eastern and southern regions of 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 village level 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 village level hydropower the needed impulse.

The research does clearly indicate interest in the region for village level 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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