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An Affordable Approach to Mini-Hydro Based Rural Energy Development Rwanda: Impacts, Problems Faced, and Lessons Learned



**UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION**

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An Affordable Approach to Mini-Hydro Based Rural Energy Development Rwanda: Impacts, Problems Faced, and Lessons Learned



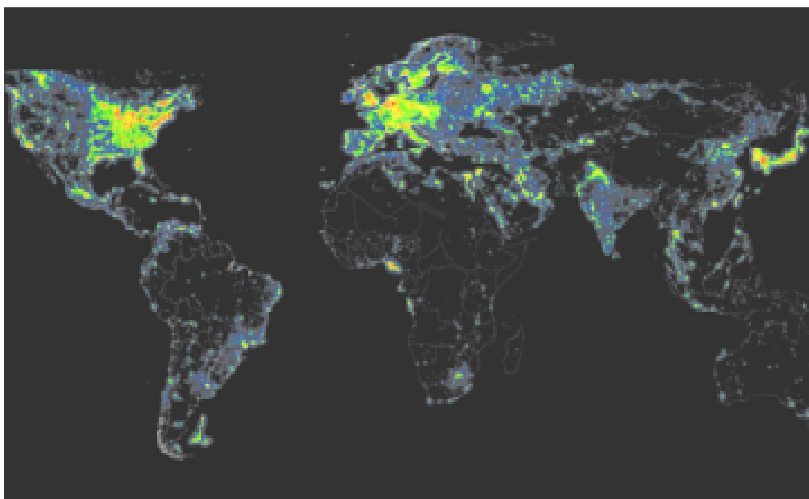
UNITED NATIONS INDUSTRIAL DEVELOPMENT ORGANIZATION

Vienna, 2010



Providing access to modern energy for poverty reduction and economic growth in Rwanda

It is widely recognized that access to affordable, modern energy services is a prerequisite for poverty alleviation and economic growth. More specifically, energy access is an essential input for achieving the Millennium Development Goals. In Rwanda, where the mean electrification rate is less than 6%, this situation has resulted in a lack of off-farm income generating activities and poor basic community services.



Access to modern energy in Sub-Saharan Africa is between zero - 20 percent

As in many sub-Saharan African countries, the majority of the population in Rwanda lives in peri-urban and rural areas, far from the main grid, with little, or no, prospects of being connected within the foreseeable future. Therefore, it is expected that decentralized off-grid technologies will be the most economically viable solutions

and, in some cases, might be the only option for providing energy services.

In response to the Rwandan Government's request for quick and coordinated interventions, UNIDO and the Rwandan Ministry for Infrastructure (MININFRA) have implemented a programme of activities to meet the increasingly growing need for modern energy, particularly in the new settlements and rural areas in Rwanda. Through the utilization of locally available, renewable and cleaner energy sources, the programme aims to provide the prerequisite energy input for poverty alleviation and stability and enhance efforts for promoting renewable-based energy development for productive uses.



Sites with potential hydro resources are prioritize and selected according to the potential productive uses

Removing the barriers to providing energy access

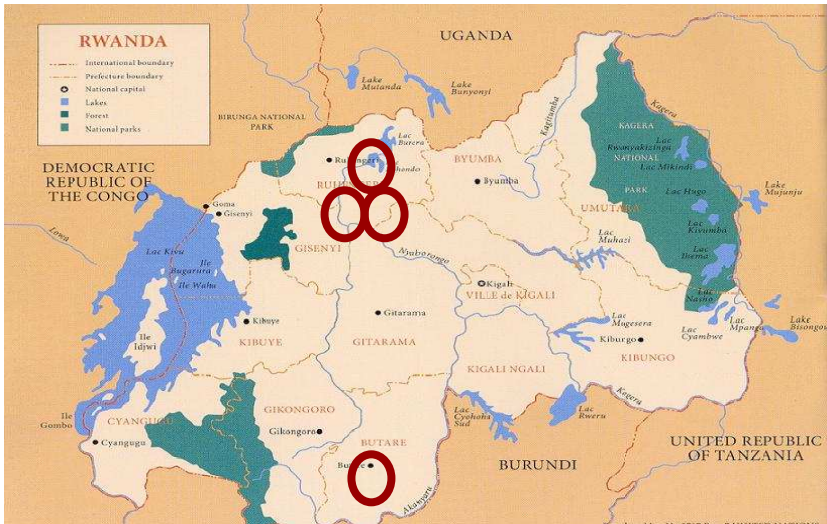
The programme aims at removing policies, technical and technological barriers to providing modern energy access in rural and peri-urban areas. It demonstrates a participative and affordable approach to rural energy development, through constructing mini hydro facilities and using the process for both on-job training and awareness building.



Participation of local beneficiaries and communities as paid and unpaid labors in establishing the mini hydro facilities.

The outcomes of project activities included the review and recommendations of policy guidelines and mechanisms to enhance the development of a renewable energy market development, to encourage private sector investment, and promote the establishment of energy service providers. Through the

construction of four mini-hydro facilities, the programme is demonstrating an affordable and sustainable approach to rural energy supply. Using a learning by doing approach, the process of establishing these facilities has offered the opportunity for both building awareness, and developing a range of technical skills and capacities covering, planning, construction, operation, maintenance, and management of mini hydropower facilities.



Four mini hydro facilities established demonstrating South-south cooperation: an affordable approach to modern energy access and using the process for a learning-by-doing capacity building.

Nyamyotsi-I, 100 kW

| Parameters Nyamyotsi I | |
|-----------------------------|---------------|
| Capacity | 100kW |
| Type of Turbine | Turgo Impulse |
| Length of Head race channel | 483m |
| Generation Voltage | 400V |
| Length of distribute line | 4.5km |
| Length of Penstock path | 394m |

- Located in Nyabihu district in the Western province
- Operational since Aug 2006
- Serving 200-250 households, schools, health centers, small business, etc.
- Community management, supported by local authority
- Commissioned and handed over Feb 2007





Nyamyotsi I power house

Mutobo, 200 kW

| Parameters Mutobo | |
|-----------------------------|---------------|
| Capacity | 200kW |
| Type of Turbine | Turgo Impulse |
| Length of Head race channel | 417m |
| Generation Voltage | 400V |
| Length of distribute line | 8.5km |
| Length of Penstock path | 223m |

- Located in Musanze district in the Northern province
- Operational since June 2009
- Serving some 800 households, schools, health centers, small business, etc.
- Community management, supported by local authority
- Commissioned and handed over March 2010



Mutobo Power house

Gatobwe, 200 kW

| Gatobwe Parameters | |
|--------------------------------|---------|
| Capacity | 200kW |
| Type of Turbine | Francis |
| Length of transmission line | 525m |
| Length of LT distribution line | 2,300km |
| Length of penstock line | 50m |
| Head | 24m |

- Located in Nyarugura district in the Southern province
- Operational since Nov 2009
- Serving some 200 households, schools, health centers, small business, etc.
- Beneficiaries set to increase as new transmission and distribution lines are being constructed
- Most likely community or private sector management supported by local authority
- To be commissioned and handed over October 2010



Maximizing the use of locally available materials



Unskilled labors gradually becoming skilled



Gatobwe power house



Nyamyotsi-II, 100 kW

- Located in Nyabihu district in the Western province
- Operational since September 2010
- Serving 150 households, schools, health centers, small business, etc. – set to increase
- Most likely community or private sector management supported by local authority
- To be commissioned and handed over by November 2010

| Parameters Nyamyotsi II | |
|--------------------------------|---------------|
| Capacity | 100kW |
| Type of Turbine | Turgo Impulse |
| Length of transmission line | 2.5km |
| Length of LT Distribution line | 5.0km |
| Length of Penstock line | 1,050m |



Nyamyotsi II power house



Cost effectiveness and affordability

The total budget of the programme, including the policy and awareness building components is USD 1,840,000 of which USD 1,350,000 is provided by the Government of Rwanda Trust Fund, thereby demonstrating leadership and commitment to development.

In total 600 kW of capacity are installed. Through a simplified calculation the costs of installed kW through this intervention is then between USD 2300 to 2600, including transmission and distribution lines. Internationally acceptable range is between USD 2500-6000.

Affordability of the energy service

The affordability issue is essential in energy access and rural electrification. This is because of the fact that users in rural and peri-urban areas can hardly afford to pay for energy services. There is therefore a need to optimize the energy facility to reduce the capital costs and to operate and manage the energy enterprise in an economically sustainable manner. These will lead to a reduced costs per kWh produced and make it more affordable to a wider range of rural income groups.

Productive uses and affordability

The larger the extent the energy generated is used for productive uses purpose, the more affordable becomes the unit cost of energy and more financially sustainable grows to be the energy enterprise.

These happens in two ways: (i) the use of electricity will revive and increase the local economy leading to increased employments and income generation, and thus more potential users will be able to

afford paying for the electricity services; (ii) the use of electricity from a given energy facility for productive uses is usually during the daytime and off peak hours. This means increasing the use and sales of additional kWhs for the same investment and running costs. This will be translated, by its turn, into lower cost per kWhs and therefore, increase the affordability of the energy generated.

South-South Cooperation

One of the main features of this programme has been the promotion of South-South cooperation in the area of mini hydro based energy access projects for rural areas. Highlights of the programme include:

- The international project team includes experienced Sri Lankan consultants and subcontractors. The successful experience and lessons learned from Sri Lanka, regarding affordable approaches to mini hydro development for rural areas, has been adapted, modified and implemented to suit the conditions of the recipient country.
- The international training and networking are done in collaboration with the UNIDO small hydro center based in China.
- Equipment is procured from China.
- The Ministry of Energy of Congo has recently signed a Memorandum of Understanding with their Rwandan counterpart, MINIFRA, as a framework for south-south cooperation between the two countries on sharing experiences for mini hydro development.
- This Rwandan programme has triggered similar activities in Burundi where a mini hydro site of 300kW is being developed and two 750kW units have been added to an existing facility.



On-job training for unskilled labors

Impacts of energy access

Micro impacts – Socio-economic

In addition to the technical profile of any targeted mini hydro project, the socio economic profile of the target community, both in terms of existing activities and potential activities that could be triggered by having access to energy, are essential criteria for the selection and prioritization for establishing an economically and financially sustainable hydro power energy facility.

Quantitative and qualitative surveys were undertaken in each of the 4 sites to obtain baseline data in terms of patterns of energy consumption (based on traditional fuels, e.g., kerosene, candles, batteries, etc) and to measure both the economic and social impacts following the provision of electricity services.

Early results indicate that the introduction of electricity services in Nyamyotsi-I and Mutobo has led to a number of significant benefits, with people reporting improved quality of life both personally and communally

Residents of Nyamyotsi-II and Gatobwe expect similar benefits once they also have electricity access. However, results also reveal that the extent to which these benefits can be realized, and the satisfaction of the people, will be dependent on both the level and quality of the service provided and the associated cost.

Further periodic impact assessments are planned in order to measure impacts and help define the needs for guiding the process of future projects. A separate report is dedicated for the detailed impacts assessment of providing energy in the communities served by the 4 energy facilities.



Macro Economic Impacts

This UNIDO sponsored demonstration programme has had a significant impact on the Rwandan Government. Building on the outcomes of the project, and using the same south-south cooperation model promoted by UNIDO, the government has set an objective of increasing access to electricity from 6-16% by 2012, with mini-hydro playing the major role in the rural electrification plan. As such, 8 mini hydro plants totaling 6.75MW and a 9.5MW small hydro facility are being constructed. Ten other mini hydro plants are being financed by European donors.

Mini and small hydro power plants the currently under construction, which were triggered by the successful establishment of the four mini hydro facilities

| Hydro Power Plant | Capacity | Remarks |
|--------------------------------------|-----------------|---|
| Rukarara | 9.5MW | To be commissioned by mid 2011. Build and operated by Eco Power Global (Pvt) Ltd; Government funding |
| 8 Micro & small hydro plants | 6.75MW | To be commissioned by mid 2011 Build by Hydropower International Ltd; government funding |
| Around 20 Micro & small hydro plants | | In early stages; financed by donors (NL, EU & GTZ) |

Problems faced

The problems faced during the establishment of the four mini hydro power plants can be grouped into **technical** and of **non-technical** categories.

Problems of technical nature

Problems of technical nature can be summarized as follows:

1. Environmental – soil and river bank erosion, lack of long-term hydrological data;
2. Less than expected ownership by the community and the need to turn them from passive beneficiaries into active players;
3. Lack, or non-existence, of needed basic technical knowledge and skills; and
4. Logistical and administrative barriers related to transportation and clearance of equipment.

An overview of these problems, the consequences, the solutions implemented and the lessons learned so far is given below.

Severe erosion of soil and river banks and lack of long term hydrological and topographical data

The lack of river protection measures lead to soil erosion and high sand content of the river water. As this water enters the turbine it increases erosion of the turbine's runners, thus shortening turbine lifespan. Possible solutions for this problem are:

1. Plantations were established using bamboo, locally available grasses and plant species known for their effectiveness in preventing erosion and for their positive integration into existing biodiversity.
2. Special openings and canals were built to collect and stream the rainwater so that it does not increase soil erosion.

3. A second de-silting tank was constructed with larger capacity and the intake and the canals were modified to reduce the amount of sand carried.

Lessons learned:

1. Designing for high sand content of water during and after rainfall in that region of the Rwanda.
2. Urgent need to implement country-wide river bank and soil protections measures.
3. Ensuring that the runners of the turbine and valves are of high resistance to erosion.
4. Dimensioning for a higher capacity de-silting tanks.



Erosion on river banks



Plantation on river banks to reduce silt in water



Special design arrangements to match the desilting needs of the river water

Less community ownership than expected

At Nyamyotsi-I, where community management is in place with close support by the local authority, less than expected ownership was shown by community. At the start, and over time, fewer and fewer users were paying the tariff and the Consumers' Society was reluctant to take appropriate actions to motivate paying or cutting the non-payers off the mini grid. This is despite the fact that the needed and appropriate efforts were made including: extensive extension work to raise awareness; providing technical and entrepreneurial training, participatory process of decision making and formulation and strengthening the Consumers Society to oversee the management of the mini hydro facility, with the support of the local government authority; finding an adapted formula to use the workforce available in the community (against market based remuneration, in addition to, one day a month voluntary work for the mini hydro construction).

As a consequence, less cash was available to fully cover the regular planned expenditures: operators' salaries, spare parts and maintenance and re-investing in selected productive uses business. Additionally, two of the three trained operators have left the job because of the irregular and reduced salary.

Solutions implemented:

1. Advocacy and providing advice on best management practices, based on experience learned elsewhere.
2. With assistance of the Ministry of Infrastructure provided further awareness and capacity building efforts, to the local authority and the consumers' society. Some improvements have been observed recently.



Intensified awareness and capacity building efforts



Lessons learned:

1. To conceive means and mechanisms to strengthen the ownership of community and turn them from passive beneficiaries into active players.
2. To shift to the private management contract option that was rejected by the Consumer Society and local authority at the beginning of the project.
3. Ensure that a private management contract /service providers is the choice for managing the other 3 mini hydro plants. As they are of a higher power capacity (200, 200 & 100 kW), they will require a more rigorous management set up.

Lack or insufficient technical knowledge

Although identified during the formulation phase of the project, the lack or non-existence of needed technical knowledge and skills were considered by the subcontractor a challenge calling for innovation and smart adaptation by modifying and adapting plans and pre thought modalities to the situation on the ground.

Lessons learned: A region specific experience needs to be built up and capacity building efforts combined with financial mechanisms to operationalize the system need to be put in place.

Logistical and administrative barriers related to transportation, loss and clearance of equipment

The logistical and administrative barriers carried out excessive delay and extra costs. In this case, the problems were mostly considered unavoidable.

Problems of non- technical nature

Management arrangements of the mini hydro power facilities

There is/was a strong preference from the Government to give the management of the mini hydro power plants to the Rwandan Electrical Corporation (RECO). However, the Project Manager, while understanding the Government's rationale, pointed out the fact that ELECTROGAZ/ RECO, as a utility company, is an expensive institution for the small and mini hydro power sector, and normally, are not interested in this small fragmented business.

Subcontracting the **management to the private sector** has also been proposed. The management contract will define, among others things, the roles and responsibilities of the private sector service provider, the local authority, MININFRA, and the consumers'

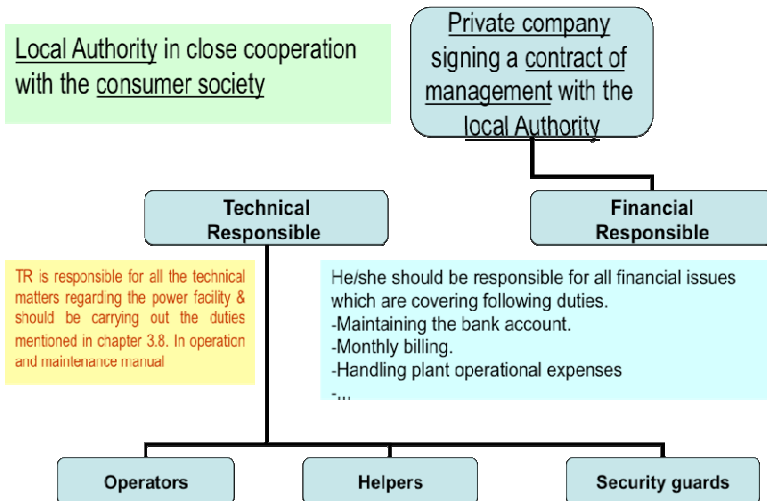
society. Also, issues relating to connecting beneficiaries, collecting fees, setting and identifying the different items for which fees revenues are to be used, together with the responsibilities for preventive maintenance, and maintenance resulting from accidents and natural disasters will be defined.

Community management is the management model set up implemented in Nyamyotsi-I. As mentioned previously, it has proved very problematic until recently when some improvements have been observed. Usually, community management is more appropriate to smaller capacity facilities, however, it is vulnerable to the way consumer societies and local authorities perceive their respective roles and responsibilities. However, this can be improved through more intensive awareness and capacity building efforts.

The slow learning curve experienced in the community based management of Nyamyotsi-I and the reluctance to adopt private sector management arrangements (considered an relevant alternative and more appropriate to higher capacity facilities, e.g., 200kW), is believed to have contributed to the delay of handing over other projects, especially of Mutobo, causing consequent delays of payment of associated installments due to the lack of a signed Certificate of Acceptance.

UNIDO subcontractor subcontracted by counterpart for construction of other sites

Although considered a very positive step towards scaling up mini hydro based energy access, and an example of the Government's commitment to development and replication of positive experiences, the Government's decision to use UNIDO's subcontractor for the construction of additional mini hydro projects



Proposed management arrangement.

throughout Rwanda, was too great for the real absorption capacity of the subcontractor (who was extremely content to get around USD 12 million). The addition of, originally 8, then 7, small hydro sites to the subcontractor’s work load led to delays and complications in the subcontractor ongoing commitments, to both UNIDO and the Government. It would have been better if consultations between the partners took place prior to the Government’s decision, whereby UNIDO could have used its network and proposed other subcontractors for selection. Other than avoiding work overload, this would have also resulted in a healthier market situation where a number of subcontractors compete, and consequently clients and beneficiaries benefit from better services and improved quality/price ratio.

Suggested improvement – Next steps

Based on the experiences gained from this demonstration programme in Rwanda, further improvements of the approach will be needed in order to replicate the successes of this programme elsewhere.

Some of these improvements include:

- Establish a technical unit/entity for regular preventive **maintenance** and maintenance resulting from accidents.
- Improving the **management of the energy enterprise** through consideration (by both the Government and beneficiaries) of private contract management arrangements. In this regard, consultations and preparation are on-going.



Workshop powered by new connections.



Shop powered by new connections.



Grain milling machine

- Increasing the promotion of **productive uses**. Results of surveys undertaken to evaluate the impacts of having access to energy, and discussions with beneficiaries, have indicated the need to increase awareness and capacity building through demonstration projects that promote the establishment of micro and small productive enterprises, e.g., in the area of food processing, carpentry, metal work workshop and skills, etc. Such enterprises are not only reliable clients for the energy service provider but also help in creating new clients, through the provision of employment within the community. Local Consumer Societies can play an active role in this regard.



- Improving awareness of the **required specifications of equipment** able to be used with the available energy supply. Survey results and discussion with beneficiaries have

highlighted that, because of extreme poverty, a significant number of the productive users are using very old machines/equipment; often self manufactured and unsafe (e.g., welding machines). Moreover, such equipment requires so much load to get started that either they do not function or cause short circuits in the mini grid.

- Providing access to **potable water**. The access to energy should also be valorized to establish water purification facilities to produce and distribute potable water for the community served by the hydro electricity.



- Improving education outcomes. Provision of electricity access has significant benefits for the **education sector**. Among other possibilities, collaboration with Rwanda Microsoft project for the provision of computers for students and teachers could be sought.

- Improving **health** outcomes. As far as possible, all health centers in the areas surrounding of the 4 mini hydro plants were connected to the local mini grid. However, in the vicinity of Gatobwe (200kW) a new hospital built recently by the Belgian Development Agency remains unconnected due to a lack of available funding. It is therefore important that all infrastructure and operational costs are built into development projects especially in the critical areas of health and education.



Local population and authorities expressed in various occasions the need for skill and vocational training. They appreciated the learning by doing approach which enabled knowledge and skill transfer and upgrading while still creating paid jobs.



On-the-job training and capacity building on the project site.

- Improving and **streamlining training** and capacity building to enhance the creation of a critical mass of technical capacity (through in classroom lectures and on-job training). This would gradually lead to the existence of service providers/small enterprises providing the service and skills needed to identify, design, construct, manage, operate and maintain mini hydro facilities.
- Conceiving and operationalizing an appropriate **financial mechanism** for supporting public private sector partnerships. This financial mechanism, in combination with improved capacity building, will be the driving force for turning local engineers and technicians into enterprises capable and active in renewable based electrification, thus replacing foreign skills, and ultimately making access to energy more affordable.



REPUBLIC of RWANDA
Ministry of Infrastructure
Mutobo Mini Hydro Power plant



Major Project Parameters:

- Capacity: 200kW
 - Type of Turbine: Turgo Impulse
 - Length of Headrace Channel: 417 m
 - Net Head: 123 m
 - Generation voltage: 400 V
 - Length of T & D Line: 8.5 km
 - Length of Penstock Line: 223 m
- Start of Construction:** July 2006 **Start of Operation:** June 2009

Subcontractor:



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