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INTERNATIONAL CENTER
ON SMALL HYDROPOWER

World Small Hydropower Development Report 2022

Case Studies

Selected UNIDO Projects

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1. Ghana's first small hydropower plant as a centre for capacity building and tourism

CATEGORY:
SHP FOR SOCIAL AND COMMUNITY DEVELOPMENT

COUNTRY:
GHANA

Author:
Chinedum Ibegbulam, Renewable Energy and Development Practitioner

Table 1. Project Overview

SHP plant name: Tsatsadu SHP plant
Location: Alavanyo, Volta Region, Ghana
Installed capacity: 45 kW
Water source: Tsatsadu Waterfall
Key actors: Ministry of Energy, Bui Power Authority, UNIDO, IN-SHP, UNDP, the technical implementation committee
Construction cost: USD 400,000
Support schemes: Additional funding from UNDP, technical support from UNIDO and IN-SHP.
Ownership: Bui Power Authority (appointed by the Ministry of Energy)
Status of the SHP project: commissioned by the Government of Ghana on 21 November 2020

Benefits

Economic:

- Income generation for the community and local entrepreneurship development.

Environmental:

- Conservation of local river and forest ecosystems;
- Reduction of CO_2 emissions.

Social:

- Youth empowerment and capacity building;
- Learning and research opportunities for students and young engineers
- Better working and living conditions for local communities

Potential: Similar hydropower plants can be constructed on other waterfalls.

Figure 1. Approximate Geographic Location

Source: Google Maps

1. INTRODUCTION

Access to sustainable energy is of great importance in Ghana. Small hydropower (SHP) plants can contribute to the country's energy mix and provide a source of reliable power supply for local communities. If carefully planned, SHP plants can also protect the river and forest ecosystems. Furthermore, SHP plants can boost economic development and become a centre of touristic attraction and capacity building for young engineers. The example of the Tsatsadu plant, described in this case study, is a good demonstration of such important benefits for the communities and the environment.

In 2005, aiming to realize the potential of SHP in the country, the Ministry of Energy signed a Memorandum of Understanding with the United Nations Industrial Development Organization and the International Network on Small Hydro Power (IN-SHP) to undertake studies on the potential of SHP development in the country and provide technical consulting.

The Bui Power Authority (BPA) was appointed to develop the first SHP project in the country on behalf of the Government and review all project documentation, including site assessment surveys, detailed topographical surveys and engineering drawings for the project.

Figure 2. First small hydropower plant in Ghana

Based on the analysis, the experts selected the Tsatsadu Waterfall site, located at Alavanyo Abehenease in the Hohoe District of the Volta Region, as a location for a pilot project (Figure 2).

Young engineers of the BPA, who were earlier trained during the development of the 400 MW Bui hydropower plant, were empowered to further develop their skills and knowledge and undertake the entire Tsatsadu plant construction works. Capacity building and local youth skill development became an important element of this hydropower project in Ghana.

The 45 kW Tsatsadu plant was commissioned in 2020. According to the BPA, the cost of the SHP project was USD 400,000.[1] The biggest part of the funds came from the BPA, with a contribution of USD 80,000 offered by the United Nations Development Programme (UNDP), which received funding from the Government of Denmark.

At the ceremony of inauguration of the country's first SHP plant, President Nana Addo Dankwa Akufo-Addo said: *"This important project is going to assist the people of Volta Region and Ghana as a whole, and we will get the best out of it because it is wholly owned by us, the Ghanaian people. The design and engineering and its construction is all Ghanaian owned. It's been done 100 per cent by the engineers and the workers of the Bui Power Authority. For us also to get the full benefit, there is going to be a research site for those who are going to be operating it to get the necessary knowledge."*

Based on the successful finalization of this pilot project, the authorities of Ghana started looking for other waterfalls in the region that may be viable for the construction of hydropower plants. The Government expressed its commitment to build more SHP plants across the country, to increase power supply from the national grid, according to the Ghana News Agency (Hydro Review, 2019).[2]

Table 2. Project Stakeholders

- The Ministry of Energy — commissioned the project;
- UNIDO and IN-SHP — provided technical support and conducted studies on SHP potential;
- BPA — coordinated the project management on behalf of the Government.

Technical committee to implement the project:
- The Renewable and Alternate Energy Directorate of the Ministry of Energy;
- The Energy Commission of Ghana;
- The UNDP, Renewable Energy Technology Transfer Project Implementation Unit;
- The Electricity Company of Ghana.

Other stakeholders:
- The Alavanyo Traditional Council;
- Foyer de Charité;
- The Alavanyo Abehenease Community

Donors:
- BPA;
- UNDP (funding from the Government of Denmark);
- UNIDO (in kind, technical support).

2. TECHNICAL CHARACTERISTICS

Table 3. Key Technical Characteristics of the Tsatsadu SHP Plant

Item	Value
Turbine output	Upgraded to 45 kW
Total output	45 kW
Site condition and parameters of the plants	Run-of-river plant (no dam)[3] Landscape is intact[4]
Type of generator	Asynchronous generator

The plant uses a run-of-river scheme, which does not require the formation of a reservoir. It consists of a concrete diversion weir, an intake structure, diversion channel, a forebay, steel penstock, a powerhouse and a transmission line to feed the electricity generated into the distribution grid. The weir diverts part of the river flow through an intake channel into the diversion channel. The diverted water goes through a penstock (30 centimetres in diameter) to the base of the hill where the powerhouse, which houses the turbines and the generator, is located. The water drives the turbines and flows out through the tailrace channel and into the downstream of the waterfall.

Following the initial studies, UNIDO donated a 30 kW generator and a Turgo Turbine with associated electromechanical equipment to the project. Then the project, which was designed as a 30 kW stand-alone system was upgraded to a 45 kW grid-connection system (with the possibility of upgrading the capacity of the turbine up to 60 kW). A new 45 kW capacity Asynchronous generator and a new load controller were procured to replace the existing 30 kW generator and load controller.[5]

The BPA estimates that the plant can generate power for seven months a year and the other five months are needed for the maintenance work.

3. BENEFITS

The Tsatsadu SHP plant delivers energy to rural areas and helps create local employment, alleviate poverty and generate income. In particular, the following benefits can be highlighted:

Economic benefits

The stable access to electricity through the SHP plant provides opportunities for better working conditions and development of local industries and entrepreneurship. For example, the plant became a touristic attraction, generating additional income for the Hohoe Municipality and its inhabitants.

Environmental benefits

The plant was built in such a way that there is no impoundment or reservoir formation, minimizing its environmental impact. On the contrary, the SHP plant helps to protect the local ecosystem. In the absence of alternative energy sources, the local communities were relying on the wood, cutting trees around. Generation of renewable electricity by the SHP plant helps protect the local forest and reduce emissions. Furthermore, a reforestation programme implemented at the project site seeks to restore the vegetation in order to protect the river's shoreline against siltation, sedimentation, erosion, nitrogen and phosphate loading. As a result, the planted trees and the forest conservation contribute to climate change adaptation and climate resilience.

Social benefits

The SHP plant, which is the first of its kind in Ghana, is a point of interest for academia and tourists. It can be used, among other things, as a practical tutorial plant for engineering students and young energy experts across the country and the West-African region.

The plant supports the improvement of living conditions and creates employment opportunities for the local population (such as employees operating the plant, security personnel and plant maintenance staff).

4. BUSINESS FIGURES

Table 4. Business Figures of the Tsatsadu SHP Plant

Total investment	USD 400,000
Break-even	10–15 years [3]

5. LESSONS LEARNED AND CONCLUSIONS

A few lessons can be highlighted:

1. **SHP plants can use different water sources available in rural communities.** For example, they can be successfully constructed next to the waterfalls, as presented in this case study.
2. **The engagement and commitment of the Government plays an important role in developing and upscaling alternative energy**, such as SHP (as part of a strategy to diversify the country's energy sources). The Government authorities can, for example, help undertake initial studies, conduct pilot projects, develop mechanisms for financing SHP plants and promote successful practices on the municipal, regional, national and international levels.
3. **SHP plants can be constructed and operated by the local experts, including young engineers.** This case study from Ghana illustrates that SHP can provide a great opportunity for upgrade of skills, local employment and entrepreneurship development. And for the sustainable operation and maintenance of a plant, the involvement of local experts is very important.
4. **SHP plants are not only a source of energy, but can also be a touristic attraction and a centre of local capacity building.** The aforementioned example in Ghana demonstrates such an indirect but still very significant benefit from developing a power plant in rural areas.
5. **Areas where SHP plants are built can be used for reforestation programmes**, which contribute to climate change mitigation. In Ghana's rural areas, which heavily rely on wood as a source of energy, such programmes would be of great significance.
6. **A thorough feasibility study is an important element of developing a successful project**. As in the example in Ghana, the study helped to select the right characteristics of a plant and analyze the potential for upgrading its capacity later.

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2. Electrification of rural areas in Tanzania

CATEGORY:
SHP FOR SOCIAL AND COMMUNITY DEVELOPMENT

COUNTRY:
Tanzania

Author:
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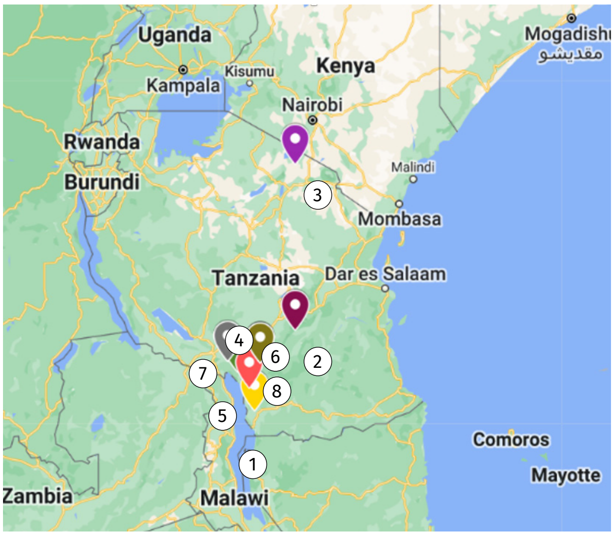
Figure 1: Approximate Locations of Eight Mini-Hydropower Projects in Tanzania



Source: Google Maps[4]

Table 1. Project Overview

SHP plant name and Location:

1. **Andoya Mini-Hydropower** (Mtandasi River) Mbangamao village, Mbinga District, Ruvuma Region
2. **Mbingu Mini-Hydropower** (Mfumbi River) Mbingu Village, Ifakara, Morogoro Region
3. **Usa River Mini-Hydropower** (Usa River) Usa River, Meru district, Arusha Region
4. **Ludilu Micro-Hydropower** (Salala Stream) Ludilu Village, Makete District, Njombe Region
5. **Madope Mini-Hydropower** (Madope River) Ludewa District, Njombe Region
6. **Lupali Mini-Hydropower** (Lupali River) Njombe District, Njombe Region
7. **Ijangala/Tandala Mini-Hydropower** (Ijangala River) Makete District, Njombe Region
8. **Mpando Mini-Hydropower** (Mpando Stream) Njombe District, Njombe Region

Installed capacity: 4,881 kW (cumulative)
Key actors: Government of Tanzania, UNIDO and GEF
GEF grant: USD 3,350,000
Ownership: private investors, charity, NGOs, community co-operatives
Status of the SHP projects: finalized in 2018

Benefits

Economic benefits:

- Selling energy to local communities and neighbourhoods

Environmental benefits:

- Reduction of approximately 335,658 tCO_2e directly

Social benefits:

- New jobs created, capacity building, knowledge dissemination, electricity access in rural areas, better living and studying conditions

Support schemes/incentives: with the financial support of GEF, UNIDO, European Union

1. INTRODUCTION

Tanzania is one of the Least Developed Countries (LDCs) in Sub-Saharan Africa. According to the World Bank's data (2020), only approximately 39.9 per cent of the country's total population of 59.7 million has access to electricity (72.9 per cent of urban and 22.0 per cent of rural population). [1,2]

To address this gap in electricity access rate between the rural and urban population, an appropriate energy mix is required to ensure a sustainable decentralized energy supply in the country. Among the renewable energy sources, the proven potential for small hydropower (SHP) in Tanzania is approximately 480 MW, and less than 10 per cent of this potential has been tapped so far.3

Realizing the potential and the energy challenge in Tanzania, the Global Environment Facility (GEF) and the United Nations Industrial Development Organization (UNIDO) undertook a project in 2012 to promote SHP-based grids to augment sustainable rural electrification.

The project strengthened human and institutional capacities at all levels and supplemented the country's effort in improving the rural electricity rate. The project team undertook resource assessments to analyze the SHP potential of Tanzania, conducted feasibility studies for identified demonstration sites, disseminated the scientific, engineering and technical skills and built the infrastructure necessary for the design, development, fabrication, installation and maintenance of the SHP plants in the country.

Key achievements of the project

Establishment of the Technical Centre
The Small Hydropower Technical Centre (SHP TC) (Figure 2) hosted at the College of Engineering and Technology, University of Dar es Salaam (UDSM) was established to provide technical support and consulting, information dissemination, training and capacity building services in the country. Within the project, the SHP TC fabricated five cross-flow turbines locally in Tanzania: two with a capacity of 5 kW, two with a capacity of 25 kW and one with a capacity of 1 kW.

Strengthening national capacities
The project strengthened the country's institutional and individual capacities in the area of the SHP technology (Figure 3). The capacity building activities included study tours to SHP plants and manufacturing facilities, trainings on development and detailed design of SHP plants as well as on fabrication of cross-flow turbines, scholarships, etc.

Figure 2. Promotion of the SHP Centre

Figure 3. A Group Picture of the Technology Transfer Training in Indonesia

Demonstration plants in different parts of the country
Within the project, eight demonstration hydropower sites were developed, with a cumulative installed capacity of 4,881 kW (surpassing the original installed capacity target by 1,681 kW). These hydropower plants provide significant socio-economic advantages for local communities and environmental benefits. For example, the plants are expected to reduce greenhouse gas (GHG) emissions resulting from the use of traditional energy sources in rural Tanzania by over 300,000 tons of CO_2 equivalent per year. These eight demonstration sites are briefly described in Table 2.

Table 2. Overview of Eight Projects

Name	Developed by	Water source	Location	Technical characteristics	Total installed capacity
Andoya Mini-Hydro-power Project	Andoya Hydroelectric Power Company (AHE-PO), a local entrepreneur from Mbinga	Mtandasi River	Mbangamao village, 14 kilometres away from Mbinga Town, which is 1,050 kilometres away from Dar es Salaam	Two units of Francis hydropower turbines, each with 500 kW	Total installed capacity is 1,000 kW
Mbingu Mini-Hydro-power Project	Saint Franciscan Sisters of Charity in the village of Mbingu, Ifakara	Mfumbi River	Mbingu village, 13.5 kilometres away from the Sisters convent and Mbingu village, which is 550 kilometres away from Dar es Salaam City	One unit of Francis hydropower turbine, a generator and a concrete penstock	850 kW
Usa River Mini-Hydro-power Project	Kiliflora limited, the largest flower farm in the country based in the town of Usa River	Usa River	Meru district, 25 kilometres away from Arusha in the northern part of Tanzania, approximately 620 kilometres away from Dar es alaam city	One unit of Turgo turbine	230 kW
Ludilu Micro-Hydro-power Project	Evangelical Lutheran Church of Tanzania mission, Ludilu Parish in collaboration with the private sector	Salala Stream	Ludilu village. It is located approximately 120 kilometres away from Njombe, which is approximately 700 kilometres away from Dar es Salaam City.	One unit of cross-flow hydropower turbine	68 kW
Madope Mini-Hydro-power Project	Njombe Development Office (NDO), a dedicated entity made up of a collaboration between Njombe Roman Catholic Diocese and ACRA (an Italian non-governmental organization)	Madope River	Lugarawa village, Njombe Region, approximately 100 kilometres away from Njombe Township and approximately 700 kilometres away from Dar es Salaam city	One Pelton hydro-power turbine	1,700 kW
Lupali Mini-Hydropower Project	Benedictine Sisters of Saint Gertrude Imiliwaha Convent, which is under the Roman Catholic Njombe Diocese	Lupali River	Boimanda village, 50 kilometres away from Njombe Township. Njombe is approximately 700 kilometres away from Dar es Salaam City	One unit of Francis hydropower turbine	353 kW
Ijangala Mini-Hydro-power Project	Tanzania Diaconical Centre, a charity organization in Tandala village	Ijangala River	Tandala village, 12 kilometres south of Tandala village, approximately 90 kilometres away from Njombe	Three units of 120 kW Francis hydro-power turbine	360 kW
Mpando Mini-Hydro-power Project	Community-based cooperative association of farmers	Mpando Stream	Imalinyi, approximately 20 kilometres awaya from Njombe.	Two units of 160 kW Kaplan hydropower turbine	320 kW

Table 3. Project Stakeholders

Donors

- GEF
- UNIDO
- European Union
- Switzerland

Partners

- Rural Energy Agency
- Andoya Hydro Electric Power Company
- Ministry of Energy and Minerals
- College of Engineering and Technology
- Division of Environment — Vice President's Office
- Tanzania Electricity Supply Company Limited
- International Center on Small Hydro Power (ICSHP)

Project stakeholders

This multi-element project has been possible through the collaboration of various stakeholders, including project developers, the Government of Tanzania and the financers. Apart from the project developers, other key stakeholders are presented in Table 3.

2. BUSINESS MODEL

The SHP projects have different financing and ownership structures, which are presented in Table 4.

Table 4. Overview of hydropower plants and their financing structures

Project name	Type of managing organization	Project financing					
		Total (million USD)	UNIDO/ GEF	REA	Own equity	Bank loan	Other
Andoya Mini-Hydropower Project	Private	4.00	12%	11%	23%	54%	-
Mbingu Mini-Hydropower Project	Charity	5.50	4%	-	1%	-	95%
Usa-river Mini-Hydropower Project	Private	1.80	8%	3%	77%	12%	-
Ludilu Micro-Hydropower Project	Community and private	0.40	61%	26%	-	-	13%
Madope Mini-Hydropower Project	Charity and NGO partnership	9.00	6%	5%	14%	-	74%
Lupali Mini-Hydropower project	Charity	1.85	11%	39%	1%	49%	-
Ijangala/Tandala Mini-Hydropower Project	Charity	1.23	19%	54%	3%	11%	13%
Mpando Mini-Hydropower project	Community corporative	1.24	18%	11%	1%	64%	6%

3. BENEFITS

Out of the eight demonstration SHP plants supported under this UNIDO project, four were fully operational in 2018: Andoya, Mbingu, Usa River and Ludilu. The benefits of these four cases were well documented, verified by the evaluation committee and are presented in this case study (the information presented below is as of 2018).

The hydropower plants provided different socio-economic and environmental benefits to the rural communities, such as reliable power supply to local villages, possibility to sell excess power and generate additional revenues, new jobs created, replacement of carbon emitting technologies such as backup diesel generators and reduction of CO_2 emissions and others.

The benefits for individual projects are highlighted below.

Andoya Mini-Hydropower Project

Socio-Economic Benefits
The power generated is supplied to three villages: Kilimani, Mbangamao and Lifakara with approximately 200 households. The excess power goes into the Tanzania Electricity Supply Company isolated mini-grid at Mbinga, which was previously powered by diesel generator sets. The project created permanent employment for 20 people and temporary employment for approximately 60 others, including semi-skilled and unskilled workers around the project area.

Environmental Benefits
The project replaced diesel generators used to supply the Mbinga area through the isolated mini-grid. The project resulted in the prevention of direct GHG emissions amounting to approximately 6,300 tons of CO_2 equivalent per year.

Mbingu Mini-Hydropower Project

Socio-Economic Benefits
The electricity generated is supplied to a sisters' convent, which provides various social and economic services including health facilities, schools and milling activities. The hydropower plant is providing power 24 hours a day to several institutions within the Saint Franciscan Sister of Charity including Saint Franciscan Sister of Charity Mbingu convent (accommodates 200 sisters), Saint Judas Thaddeus Health Centre (operating room, ultrasound, pathology clinic), an orphanage (54 children), a secondary school for girls (260 girls), a kindergarten school, workers' houses, a spiritual centre and workshops (candle making and carpentry). In total, this plant supplies energy to an estimated 1,000 people—600 women and 400 men.

Environmental Benefits
The project provides clean energy for socio-economic activities in the sisters' convent as well as productive activities in Mbingu. The project resulted in the prevention of direct GHG emissions by 2,680 tons of CO2 equivalent per annum.

Usa River Mini-Hydropower Project

Socio-Economic Benefits
The power generated meets the energy demand of the flower farm facilities at Usa River. The project intends to supply the excess power to neighbouring communities. The weir also serves as a bridge connecting two different communities. Kiliflora farm employs more than 1,300 people in various activities. The project facilitated a good working environment for the workers and resulted in savings that are partly directed to supporting community development projects in the area. Thanks to the project, seven enterprises have been created employing 157 people—145 men and

12 women. As part of its civic responsibilities, Kiliflora farm organized training for nine enterprises on different vocational activities.

Environmental Benefits
The flower farm was using standby generators due to the erratic situation of the grid power supply. The hydropower plant changed the situation. Before the installation of the hydropower plant, the farm used approximately 20,000 litres of diesel fuel every month. Currently, almost 100 per cent of their power needs are provided by the hydropower plant. This helps the company to achieve significant savings (cutting expenditures for fuel) and as a result mitigate CO2 emissions. The project resulted in the prevention of direct GHG emissions amounting to approximately 1,450 tons of CO2 equivalent per year.

Ludilu Micro-Hydropower Project

Socio-Economic Benefits
The project supports approximately 150 households, institutions and micro-industries as well as agro-processing activities at Ludilu village. This site has been operational since August 2017 with 50 customers (45 households and 5 small- and medium-sized enterprises) connected to the distribution network. And it is planned to extend the distribution network. The local beneficiaries include an Orphanage (17 children), a carpentry shop, a tailoring training college, an agro-processing enterprise and a welding machine. The village is very isolated, thus making it difficult to gain access to social services. The availability of power is therefore very important for the economic empowerment and improvement of living conditions in the village.

Environmental Benefits
The project helped reduce the use of kerosene and firewood for lighting in the village, safeguarding the forests in the village, which have been seriously diminishing. The project resulted in preventing direct GHG emissions amounting to approximately 450 tons of CO_2 equivalent per year.

4. LESSONS LEARNED AND CONCLUSIONS

1. **The successful development of SHP in a country requires a favourable business environment** (availability of local skills, policies, financial and technology transfer mechanisms, incentives for the business, etc.). Realizing this, the Government of Tanzania together with UNIDO and donors developed a comprehensive project, which aimed not only to build demonstration plants, but also to create enabling conditions for the further uptake of hydropower.
2. **It is essential to create local institutional and individual capacities.** For example, in this project in Tanzania, the trainees from private, academic and government institutions had an opportunity to learn about SHP technologies and approaches in theory and practice. Two study tours were conducted to Vienna, Austria and Bandung, Indonesia. A group of participants was trained on the fabrication of micro-hydropower and cross-flow turbines. This knowledge and experience will be of the highest value for the development of future projects in the country.
3. **Demonstration projects help to build experiences, develop local capacities and know-how. But it is also important to disseminate good practices.** In this project, the demonstration sites became the centres of research and capacity building: the local experts were able to develop skills in designing, developing, fabricating, installing and maintaining SHP plants. After the project finalization, the information and training materials were developed and distributed among the different stakeholders.
4. **Development of SHP in rural areas can provide good business opportunities for local entrepreneurs and community cooperatives as well as be part of charity activities.** In Tanzania, several demonstration projects are driven by business and community interests. The local plants are managed by different stakeholders, e.g., local charity organizations, community cooperatives and private investors.
5. **It is important to consider the knowledge management, continuity and sustainability aspects when developing hydropower projects.** In Tanzania, one of the significant project achievements was the establishment of the Technical Centre. It continues providing know-how, training local experts and consulting on the development of SHP in the country. In addition, each of the eight demonstration plants has its own sustainability plan: how it is going to maintain and develop its activities and financial flows over a period of time.

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3. Shiwang'andu Small Hydropower Plant: sustainable electrification of rural Zambia

CATEGORY:
SHP FOR SOCIAL AND COMMUNITY DEVELOPMENT

COUNTRY:
ZAMBIA

Author:
Mwape Chikonkolo Mwewa, Energy Consultant – Polyjute Enterprises Co. LTD, Zambia

Source: Google Maps[4]

Table 1. Project Overview

SHP plant name: Shiwang'andu SHP plant
Location: Shiwan'gandu District, Muchinga province, Zambia
Installed capacity: 1 MW
Water source: Mansha River
Key actors: ZESCO Limited, UNIDO, GEF, REA
Construction cost: USD 7.506 million
Ownership: ZESCO Limited
Status of the SHP project: Commissioned and operating

Benefits
Economic:
- New opportunities for developing business activities and establishing a district status of the area

Environmental:
- Reduction of CO2 emissions by 1,669,800 kg

Social:
- Improved quality of life and education
- Better conditions for operating schools, health centres, churches, etc.

Potential: Zambia has abundant renewable energy resources, which can be used to facilitate electrification in rural areas in a sustainable way.

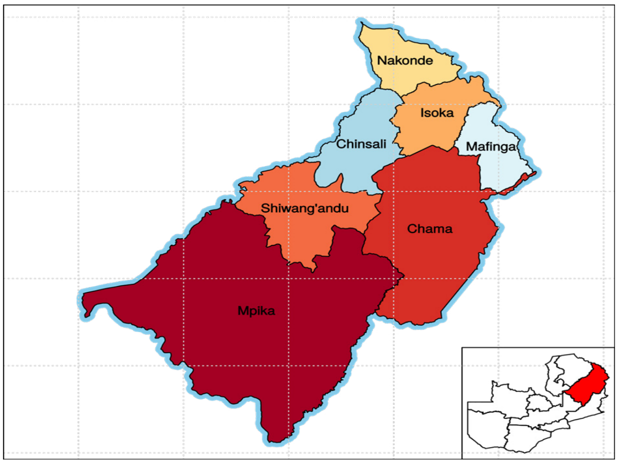
1. INTRODUCTION

In Zambia, 85 per cent of installed electricity capacity is hydro based and the national access to electricity rate stands at 31 per cent. However, 67 per cent of the urban population is connected as compared to only 4 per cent connected of the rural population. The Government has set an overall target of universal electricity access for Zambians by 2030, primarily by using the potential of country's vast renewable energy sources (USAID, 2021).[1]

Before 2012, residents in the rural villages of Shiwang'andu District, Muchinga Province, had never been connected to the national grid. Located in isolated communities, they relied on biomass as a source of energy for cooking and kerosene for lighting at night. Only a few wealthy people had access to limited electricity supply from diesel-powered generators, which they would run 2 hours per day on average.

On 5 December 2012, the late 5th president of Zambia H. E. Michael Chilufya Sata commissioned the Shiwang'andu mini-hydropower plant to supply power to over 25,000 people in the district.

Figure 2. Map of Muchinga Province



Source: Muchinga Province Provincial Administration[2]

The Shiwang'andu power plant, the first after the Kafue Gorge hydropower plant was commissioned in 1976, was constructed as part of the renewable energy project implemented by the United Nations Environmental Programme division of Technology, Industry and Economics (UNEP DTIE). The project was realized with the financial support of the Global Environmental Facility (GEF) and the state-owned energy utility, ZESCO Limited. The United Nations Industrial Development Organization (UNIDO) acted as an executing agency. The key partners in Zambia included the Ministry of

Energy and Water Development, the Development Bank of Zambia (DBZ) and the Rural Electrification Authority of Zambia (REA). The project implementing agent was the International Center on Small Hydro Power (ICSHP) of the Ministry of Water Resources of China.

The Shiwang'andu run-of-river plant consists of two 500 kW units. The 33 kV distribution line (almost 250 kilometres-long) connects the local communities with 24-hour access to electricity.

The electricity access considerably changed the life of the community: it boosted the business activities, income generation and improved the living conditions of people. ZESCO employees and locals were trained by ICSHP in the operations and maintenance of the plant, which made it possible and easy to manage it locally.

Plant construction was carried out with environmental considerations. A cofferdam diverted water during dam construction. This ensured that the downstream waterfall, an important tourist attraction in the area, continued its normal flow. A 1.5-metre fish gate within the dam helps migrating river life, such as fish, crabs and shrimp.

Figure 3. Shiwag'andu SHP plant

Table 2. Project Stakeholders

- The Government of Zambia, Ministry of Energy and Water Development
- United Nations Industrial Development Organization (UNIDO)
- ZESCO Limited
- United Nations Environmental Programme (UNEP)
- Global Environmental Facility (GEF)
- Development Bank of Zambia (DBZ)
- Rural Electrification Authority of Zambia (REA)
- Center on Small Hydro Power (ICSHP) of China

2. TECHNICAL CHARACTERISTICS

Table 3. Key Technical Characteristics of Shiwang'andu SHP Plant

Turbine Type	Axial Flow Tubular Type GDJ530
Generator	SFW500-14/1430 (horizontal shaft)
Design Discharge	27.5 m^3/s
Gross head	13.5 m
Net wáter head	12.8 m
Design flow	10.2 m^3/s
Annual output	682 x10^4 kWh
Firm output	563 kW (75% flow of 5.5 m^3/s)
Transformer	1.2 MVA (0.4/33 kV)

There are two 0.5 MW tubular turbines. Power is generated at 0.4 kV and transmitted at 33 kV via a wooden pole line. The total coverage of the transmission line is approximately 250 kilometres with between 1,000 and 2,000 connections.

Figure 4. Two 0.5 MW tubular turbines

Figure 5 (a) and 5 (b).
Participatory approach for skills transfer

5a.

5b.

3. BUSINESS FIGURES

The GEF and ZESCO Limited provided financing for the project, with a total budget of USD 7.506 million (USD 2.95 million from the GEF grant and USD 4.556 million of financing from the Government of Zambia through ZESCO Ltd).

The project served as a demonstration of mini-grid development in the country. Lessons learnt in the project became a good basis for establishing a legal, institutional and policy framework for renewable energy-based mini-grids and enabling favourable conditions for independent power producers (IPPs) and build-operate-transfer (BOT) business models.

Table 4. Business Figures of Shiwang'andu SHP Plant

Total investment	USD 7.506 million
Estimated generation of electricity per year	682X10^4 kWh
Break-even	10 years turnover period
Lifespan	40 years

4. BENEFITS

Benefits of the project are multi-fold:

Connectivity
Facilities of the local infrastructure connected to Shiwang'andu include residential houses, schools, hospitals, clinics, churches, shops, tourism lodges, farms, district government offices, such as the District Commissioner's (DC) offices and police, communication towers, TV receivers, chief's palaces and Zambia Wildlife Authority camp (Mano Camp) in the North Luangwa National Park.

Social benefits
The initiative provides access to energy to almost 30,000 people. Over the course of the project, more than 300 locals were hired, trained and 8 of them have been employed permanently to run the power plant.

Having access to electricity considerably enhanced the quality of life, options for generating income, employment opportunities and local services. People started engaging in such activities as establishing hair salons, raising chickens, fabricating door frames and windows, setting up traditional hammer mills for processing staple foodstuffs, and running pubs, restaurants and resorts.

As a demonstration of its dedication to corporate social responsibility, the power plant's operator, ZESCO Limited, built a clinic for the community, planted 80,000 fish fingerlings in the dam and trained 20 locals in fish farming.

"Today we are planting fish in this dam, the thing I never thought was possible. The power plant has created employment, put our area on the map and improved the health and quality of life of the people. I am happy that the district of Shiwang'andu is one of the fastest developing in Zambia, all because of this power station. I thank ZESCO, UNIDO, REA and the Government of Zambia for this development," said the late local chief Mukwikile who played an important role in persuading the Government to develop the hydropower plant.

Furthermore, almost 20 phone/TV signal (communication) towers have been connected to the grid improving the communication quality in the area.

Education benefits
The Shiwangándu grid connects a number of schools, including the Katibunga Catholic Seminary, Lwanya Basic School, Mwilwa Basic School, Kapisha Basic School, Timba Basic School, Shiwangándu Secondary School, Kabangama Basic School, Mulanga Basic School, Mwilwa Basic School.

"*The electrification of Kapisya Primary School is a game changer because now we can use the electrical equipment such as computers, charge phones, cookers, TVs, radios, etc. The school is now able to teach computers and kids are able to watch TV. To some it is the first time to do that because most of them come from poor families that cannot afford to buy TVs. We expect mindset change and hard work from the pupils, which will result in good pass rates. We have seen an increase in the number of teachers wishing to be transferred to Kapisya Primary School due to the presence of electricity. Previously, we only had four teachers, now we have seven, only limited by the number of houses. I expect the rate of cutting trees to reduce because we can now use electrical stoves as opposed to firewood or charcoal. Kids in the boarding sleep in well-lit rooms. We thank the Zambian Government and their cooperating partners for this project,"* said Mr. Mutale Dominic, the former Headteacher at Kapisya Primary School.

One parent, Mr. Stanley Musonda, added: *"This project has shown a sustainable way of developing rural areas.*

I participated in the construction of the power station by working as a semi-skilled worker. The money I earned was used to build apartments, buy animals (goats, cows). Because of the experience and recommendation letter the International Center on Small Hydro Power gave me, I got a chance to be trained by the Government as a community-based health practitioner. Many of my friends acquired skills such as building, welding, repairing small equipment and are able to make money using these skill sets."

Figure 6. Computers used in schools

Health benefits

Local health facilities were connected to the power plant, including the Kapisha clinic, Shiwang'andu hospital, Shiwang'andu clinic, Mukungule clinic and Katibunga clinic.

There has been a general improvement in the quality of health services as a result of electricity access. **"***The supply from the power station is stable and has facilitated and improved the storage of vaccines and medicines under recommended temperatures using electrical fridges, which was not possible before. Utilization of electrical equipment such as vacuum pumps has helped to reduce the infant mortality rate in the district,"* said Mr. Gershom Sichalwe, who is in charge of the Swiwang'andu clinic.

Sister Kapya Hope, a registered nurse at the Kapisha clinic, expressed gratitude for the improved electricity access to the clinic, which was previously powered by solar energy. *"It was difficult to work during the rainy season. Now we have power 24 hours and a backup solar power systems. We do our work professionally even when we have a maternity case at night. The reporting system to our senior authorities at the district has also been enhanced via the computer and internet availability."*

Quality of Housing

The quality of housing structures has improved (Figure 7). The increased buying power of local people made it easier to build nice houses.

Figure 7. Housing units before and after the hydropower plant was built

Environmental benefits

It is expected that up to 6.6 GWh would be generated annually by the Shiwang'andu SHP plant, replacing approximately 603,000 litres of diesel, thus saving approximately 1,669,800 $kgCO_2e$ annually (assumption: 1 litre of diesel = 10.96 kWh and emits approximately 2.67 $kgCO_2e$), or 171,600 $kgCO_2e$ per year if wood pallets are utilized for equivalent energy generation.

Economic benefits

Access to electricity improved the business environment in the community.

For example, the local shops now use refrigerators. Fresh vegetables, meat, fish and other products can be stocked and sold. The opening hours of businesses are extended.

The facility supplies electricity to C&J Farms, a subsidiary of the Shiwang'andu estates. In the past, they relied on wood for energy supply. Due to the availability of energy, they were able to build a milling facility where over 2,000 small-scale farmers sell their products.

The Shiwang'andu plant also provides energy to Kapisha hot springs, thereby supporting the tourism sector. Mark Harvey, owner of the Kapisha hot springs, confirmed the reduction in energy expenditure (from USD 320 per month to approximately USD 40 per month for electricity).

5. LESSONS LEARNED AND CONCLUSIONS

Hydropower can boost the development of rural areas: socially, environmentally and economically.

In order to support technical and financial viability and sustainability of projects, the following could be relevant:

1. **Using simple yet effective equipment can help reduce costs of an energy project and transfer skills to the local people.**
2. **Legal, institutional and policy frameworks are essential elements for successful mini-grid development.** The Zambia National Energy Plan was an important framework for the development of the Shiwang'andu SHP project.
3. **Capacity building at local, national and regional levels** to promote renewable energy-based mini-grids is of key importance.
4. **Good planning is key** to quickly use up the capacity of a mini-grid for productive purposes and quick payoff.
5. **Putting in place pilot mini-grids based on renewable energy to demonstrate commercial ideas can be a helpful instrument** to drive the interest of the private sector towards future projects.
6. **Creating project management**, coordination and information dissemination systems are important for projects sustainability.

The experience of this project can be relevant for developing other mini-grid projects in the country. ZESCO and UNIDO mobilized funds for the pre-feasibility studies of 12 sites for possible hydropower plant development.

References

1. U.S. Agency for International Development (USAID) (2021). *ZAMBIA | Power Africa | U.S. Agency for International Development. Available at* https://www.usaid.gov/powerafrica/zambia.
2. Muchinga Province Provincial Administration (n.d.). *Website. Available at* https://www.muc.gov.zm/.

UNIDO'S EXPERTISE IN SMALL HYDROPOWER

UNIDO has a long track record and expertise in the area of small hydropower. For 20 years, supported by its broad network of international experts, UNIDO has been providing expert knowledge on SHP development and construction. Solutions are adapted to the needs of Member States and their industries, including SMEs, and UNIDO serves as an enabler and a mediator for projects of varying scales. The Organization develops comprehensive and viable projects and tools by bringing together key elements: partners, knowledge, technologies and funding.

In order to facilitate the mobilization of partners, investments and other resources and help create synergies to achieve a more significant development impact, UNIDO together with the International Center on Small Hydropower (ICSHP) developed the Small Hydropower Service Package. The service model comprises six modules, which enable UNIDO to develop projects that are best suited to a country-specific context and future climate change scenarios. It is available here: **www.unido.org/SHP-service-package**

Six Modules of the UNIDO Service Package

Module 1

ASSESSMENT AND DEMAND ANALYSIS

Understanding the national energy landscape, ensuring stakeholders are on board.

Module 2

POLICY SUPPORT AND INSTITUTIONAL STRENGTHENING

Equipping policymakers with tools for success.

Module 3

CAPACITY BUILDING

Training for everyone, from politicians to technicians.

Module 4

SCALING UP SMALL HYDROPOWER PROJECTS

Making projects feasible and ready for investment.

Module 5

FINANCING AND INVESTMENT DE-RISKING

Ensuring projects are bankable, reducing financial risks.

Module 6

COMMUNICATION AND OUTREACH

Promoting SHP successes and opportunities.

Each module is interlinked, with Module 1 as the cornerstone.

UNIDO's achievements in the area of small hydropower

- 18 ongoing SHP projects (51 MW in total)
- 21 SHP plants currently operational in 12 countries with a combined capacity of 11 MW
- 3 international SHP centres established
- An estimated 5,000 homes and businesses gained access to electricity from UNIDO-developed SHP plants
- Small Hydropower Technical Guidelines are available on the UNIDO website
- Keeping abreast of new trends: 4 editions of the Word Small Hydropower Development Report
- Mobilized US$ 200 million in co-funding and US$ 30 million in funding for SHP-related projects over the last 10 years

Join the UNIDO Small Hydropower community

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