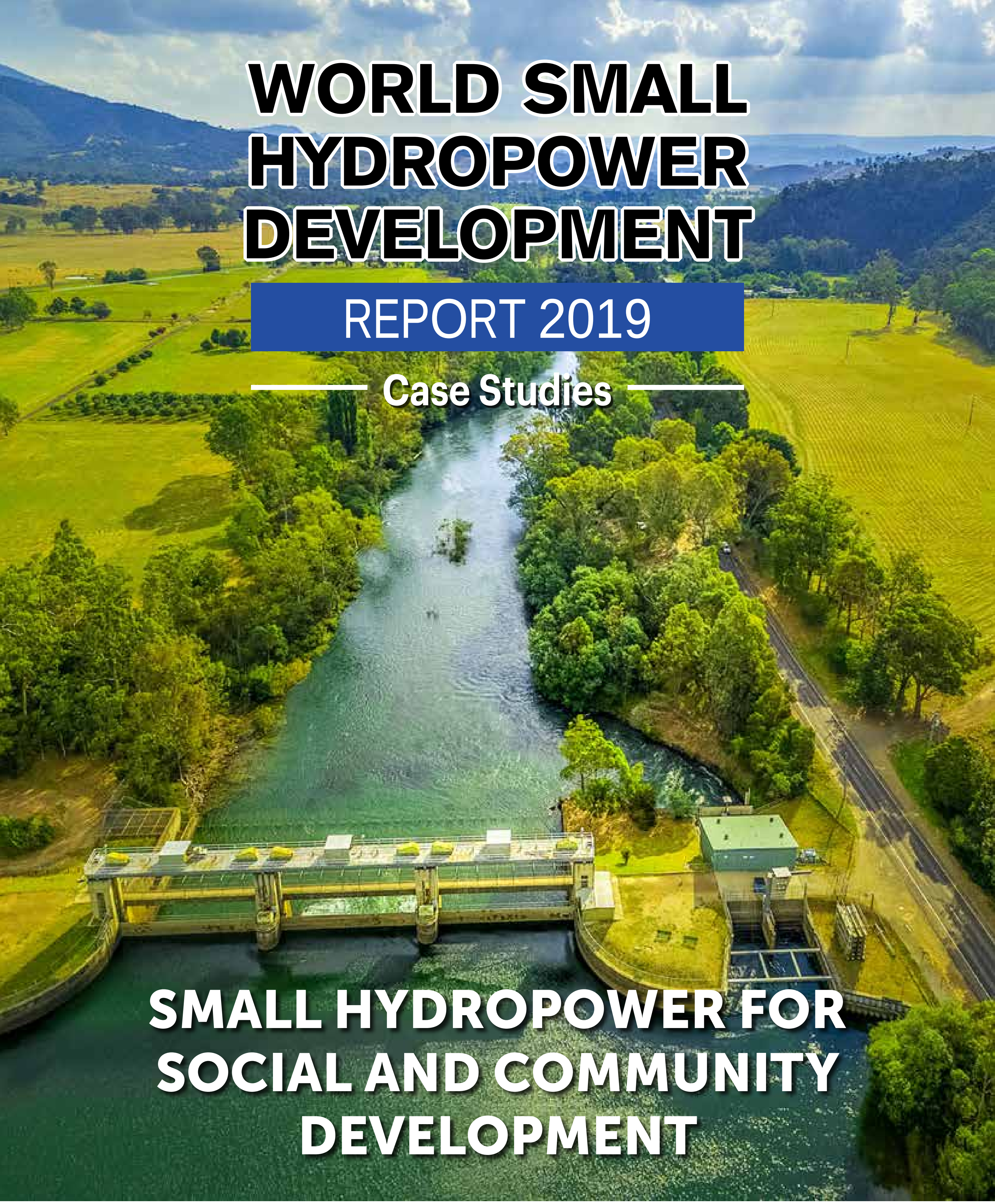

WORLD SMALL HYDROPOWER DEVELOPMENT

REPORT 2019

Case Studies

SMALL HYDROPOWER FOR SOCIAL AND COMMUNITY DEVELOPMENT

UNITED NATIONS
INDUSTRIAL DEVELOPMENT ORGANIZATION

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Suggested citation:

LIU, D., LIU, H., WANG, X., and Kremere, E., eds. (2019). *World Small Hydropower Development Report 2019: Case Studies*. United Nations Industrial Development Organization; International Center on Small Hydro Power. Available from www. smallhydroworld.org.

ISSN: 2406-4580 (print)
ISSN: 2706-7599 (online)

The digital copy is available on **www.smallhydroworld.org.**

Design: TERI Press
Cover Picture: gregbrave -123rf.com

Acknowledgements

The World Small Hydropower Development Report 2019: Case Studies was prepared under the overall guidance of Tareq Emtairah, Director of the Department of Energy at the United Nations Industrial Development Organization (UNIDO) and Deyou Liu, Director General of the International Center on Small Hydro Power (ICSHP).

The Report was headed by LIU Heng, Senior Technical Expert at UNIDO and consulted by HU Xiaobo, Chief of the Division of Multilateral Development at ICSHP. This lengthy, and at times, arduous endeavour was coordinated by Eva Krēmere at UNIDO and WANG Xianlai at ICSHP. The Report is the result of three years of intense research efforts and was backed by a talented and indispensable team of researchers at ICSHP and a vast number of experts in the field of small hydropower.

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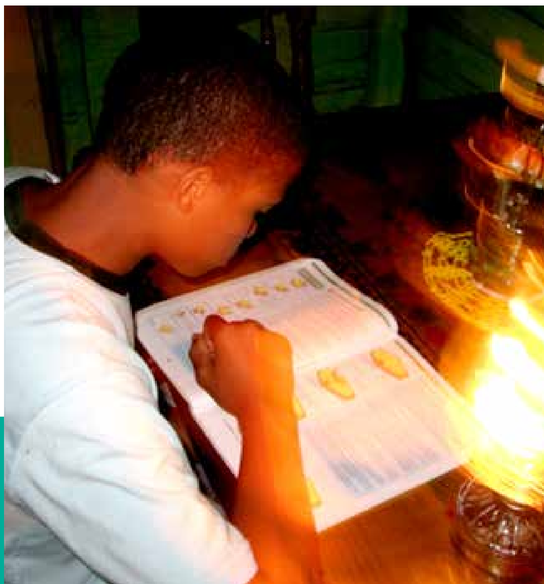
1. COMMUNITY SMALL HYDROPOWER IN THE DOMINICAN REPUBLIC



Michela Izzo, Guakía Ambiente, Josseline Acuña, University of Valencia and Guakía Ambiente, Alberto Sánchez, Small Grants Programme Dominican Republic

The Dominican Republic has seen a steady growth in small hydropower (SHP) projects over the last decade, particularly in community micro-projects which have proved effective in addressing the basic needs of rural poor while contributing towards environmental protection. They also strengthen local capacity, making groups and organizations more autonomous in constructing their own social and community development.

Despite having the highest Gross Domestic Product (GDP) growth rate in Latin America,[1] the Dominican Republic shows high inequity in terms of access to basic services for its population, rating 94th in the world in terms of Human Development Index.[2] Electricity provision is also a major problem, with 2.5 per cent of people having no access to electricity at all with this figure rising to above 4 per cent in rural areas. Where there is provision, the electrical systems are of low quality and unreliable, characterized by frequent interruptions and high loss rates in transmission and distribution – so that in 2017 the World Economic Forum ranked the Dominican Republic 125th out of 137 countries for quality of electricity supply.

The situation is most critical in rural and isolated areas, where lack of electricity constitutes a significant barrier to human, social and community development, specifically impacting vulnerable groups, including women and young people. While the Dominican Republic has limited electricity availability, its climatic and physiographic conditions, such as mountainous terrain, steep slopes, narrow valleys and abundant water resources, are favourable for SHP development and the SHP sector continues to attract interest amongst national and international entities.

The growth in community SHP projects across the Dominican Republic

A direct response to the country's pronounced structural problems, the first community SHP projects were installed in the Dominican Republic more than 20 years ago. Today some 55 community SHP systems are in operation (Figure 1).

[1] The GDP growth rates in the Dominican Republic between 1992 and 2019 averaged 5.5 per cent.

[2] United Nations Development Programme (UNDP) (2018). *Achieving universal access to electricity*. Policy brief No. 1. IEA, UNDP and IRENA, New York.

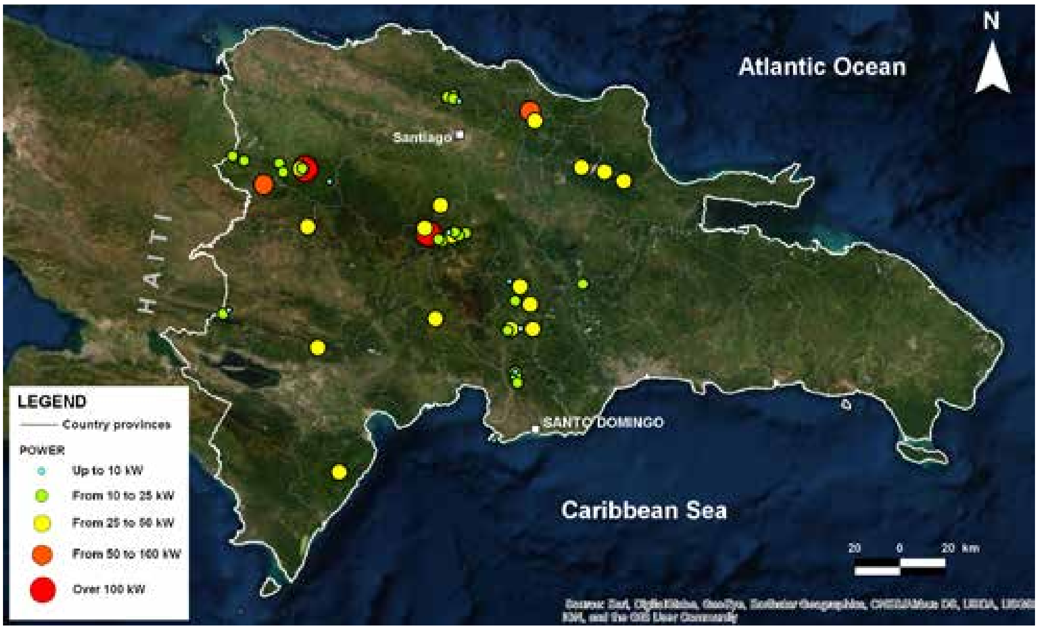


Figure 1. Map of projects in the Dominican Republic

Developed under the leadership of the Dominican non-governmental organization (NGO) Guakía Ambiente and the Global Environment Facility (GEF) Small Grants Programme, these community SHPs enjoy the support of multiple stakeholders including the Government of the Dominican Republic (through the Rural and Suburban Electrification Unit), the Inter-American Foundation, NGOs, the public and private sectors, as well as community-based organizations (CBOs). Collectively, these SHP projects have an installed capacity of over 1.4 MW generating clean, environmentally friendly electricity, which guarantees reliable, electrical supply to more than 5,000 families, or over 20,000 people, many of whom are from rural, marginalized communities. From the environmental perspective, globally these projects directly contribute to climate change mitigation (SDG 13) with more than 25,000 tons of CO_2 absorbed.

Promoting local empowerment, cooperation and multi-stakeholder synergy

During all stages of the projects, there is a strong emphasis on local empowerment, cooperation and multi-stakeholder synergy, which are considered key elements for a successful sustainable development strategy at the local level. From the outset the projects are community-driven, with local groups requesting a reconnaissance visit and preliminary evaluation of the potential for SHP in their area. Communities participate in subsequent feasibility studies as well as the implementation phase, where they establish project management committees and work brigades, before the start-up of the installed SHP systems.

‘Collectively these SHP projects have an installed capacity of over 1.4 MW generating clean, environmentally friendly electricity which guarantees a reliable electrical supply to more than 5,000 families.’

‘Initiatives have a strong commitment to learning by doing and communities are taught the skills necessary to install, use and maintain the SHP systems themselves.’

Furthermore, initiatives have a strong commitment to learning by doing and communities are taught the skills necessary to install, use and maintain the SHP system themselves, which helps build local capacity. Projects are based on highly sustainable management systems, with CBOs responsible for managing all aspects of their respective installations and the community in the overall charge of technical and financial administration. There is also a strong focus on the collaboration of grassroots groups, which receive training to drive forward wider social and community development.

The creation of effective partnerships and initiatives sees the participation of multiple stakeholders, at different levels and across different sectors, working together to respond to the specific and expressed needs of local communities. From a governance perspective, specific strengthening of the governance framework via Government legislation, including Law 57-07 on Incentives for the Development of Renewable Sources of Energy, has had a positive impact on the development of the overall process, creating the bases for replication and up-scaling of community SHP initiatives. While the creation of the Dominican Network for the Sustainable Development of Renewable Energy (REDSER), a national entity which comprises local organizations managing community SHP systems, continues to help voice the community perspective in national energy policy.

Specific benefits of community SHP: from reducing energy costs to promoting autonomy and social and community development

Access to electricity has significantly improved the quality of life of the people living in rural and isolated communities across the Dominican Republic, making it possible to light their homes, charge a mobile phone, and utilize labour saving devices such as washing machines and refrigerators. Women's lives in particular are impacted by a reduction of time spent on household tasks creating opportunities for them to engage in other activities including education, political participation and infotainment, which contributes directly to Sustainable Development Goal (SDG) 5, to "Achieve gender equality and empower all women and girls".

The extension of electricity also allows schoolchildren to study at home at night and this is consistent with an improvement in academic achievement observed in the majority of the communities, contributing to SDG 4, to "Ensure inclusive and equitable quality education and promote lifelong learning opportunities for all" (Figure 2).

Figure 2. A case of self-improvement: Tony Gómez from Fondo Grande (north-west of the Dominican Republic) studying by the light of a kerosene lamp (left). On the right: Tony graduating from a university thanks in part to access to electricity generated by a community SHP.

Financially the SHP systems have resulted in major savings in terms of energy costs for the rural poor. Prior to project implementation families spent typically between US$ 12 and US$ 30 per month on their energy needs, including on kerosene lamps, candles and batteries. Once the systems are in place this is reduced to between US$ 3 and US$ 6 per family per month, an average saving of between US$ 100 and US$ 300 each year. This action directly contributes to SDG 1, to "End poverty in all its forms everywhere" and SDG 10, to "Reduce inequality within and among countries". It also contributes to SDG 3, to "Ensure healthy lives and promote well-being for all at all ages" as the availability of clean energy reduces household pollution caused by kerosene and other fossil fuels.

At present, more than 50 enterprises have been developed through the use of electricity produced by these SHP systems, including eco-tourist facilities which receive over 2,000 tourist visits each year and bring in the much needed revenue to local areas (Figure 3). This productive use of electricity directly contributes to SDG 8, to "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all".

Figure 3. Inocencia Hernández, a community leader and manager of the Angostura Ecotourist Complex, a community enterprise that uses electricity generated by a community SHP in the centre of the country. More than 50 enterprises have been developed and supported through the use of electricity produced by community SHP systems across the Dominican Republic.

Projects also promote organization, autonomy and social capital – or increased community capacity based on people's empowerment as individuals or in groups. The initiatives are shown to make communities more active and autonomous in decision-making, while also stimulating inclusivity, community participation and representation. For example, during construction of the initiatives communities elaborate common rules for system management, while beneficiaries are made aware about the importance of paying for the electrical services that they receive. This directly contributes to SDG 16, to "Promote peaceful and inclusive societies for sustainable development, provide access to justice for all and build effective, accountable and inclusive institutions at all levels".

Linked to this sustainability is the creation of multi-stakeholder partnerships, and the initiatives see the participation of numerous stakeholders at different levels working together to respond to the concrete and expressed needs of local communities – contributing to SDG 17, to "Strengthen the means of implementation and revitalize the global partnership for sustainable development". As well as facilitating fundraising, stakeholder engagement can contribute to replication and up-scaling of the model of intervention. For example, the Government of the Dominican Republic has assumed its own line of intervention and continues to promote community hydropower systems as an efficient and cost-effective solution for the electrification of isolated rural areas.

Moreover, the projects have the effect of stimulating greater awareness of the environment and environmental protection at the local, national and global levels. Specifically, beneficiaries become aware of the importance of preserving forest cover in the area where they live as it ensures the stability of water flow for electricity generation. In practice, this means that the projects ensure the conservation or reforestation of the intervened basins. In this way more than 70 km^2 of land have been restored or conserved, directly relating to SDG 15, to "Protect, restore and promote sustainable use of terrestrial ecosystems, sustainably manage forests, combat desertification, and halt and reverse land degradation and halt biodiversity loss".

Lessons for future SHP development

Knowledge of community SHP projects has spread from area to area within the Dominican Republic motivating local groups to start their own initiatives and leading to a growth of community SHP projects over the last decade. Moreover, due to the adaptability of the model, and based on local empowerment and multi-stakeholder cooperation, the project has great potential to be scaled through South-South cooperation, including in neighbouring Haiti, where communities and institutions have already started to replicate similar processes across the country (Figure 4). Specific lessons for future SHP development include the following:

Figure 4. South-South cooperation: People from Magazen community in the north-east of Haiti, transporting a community SHP generation system, which was inspired by community SHP projects in the Dominican Republic.

Lesson 1: Empowerment of people and community groups is a key element for sustainability

Initiatives in the Dominican Republic demonstrate that the SHP projects are most successful and sustainable, if there is a commitment to the empowerment of people and community groups, for example by building local skills and capacity. Moreover, it is recommended that interventions should be orientated to educating people and groups to be able to make their own decisions and contribute themselves at the appropriate level. Similarly, participating groups may need strengthening, including by building leadership, improving communication, and helping with the clear delineation of roles and functions.

Across all initiatives, engendering a commitment to solidarity and a belief that common goals can be reached by synergic work with different stakeholders proved influential. As with other schemes of mutual help in the Dominican Republic, the SHP projects allowed groups to face challenges and generate a sense of ownership towards the community in which they live. Moreover, solidarity is considered a key element in increasing cost effectiveness of interventions and promoting a continuous improvement spiral.

Lesson 2: The importance of cooperation and multi-stakeholder synergy

Promoting the creation of multi-stakeholder platforms was significant and influential. Through this approach, different entities, each accomplishing its own vision and mission, intervened in a coordinated way to reach commonly established objectives. Importantly, this increased cost effectiveness of actions, while reducing the risk of duplicating efforts.

Lesson 3: The need for community autonomy in management of the SHP system

NGOs or cooperation partners should be mindful of the need for their interventions to help generate autonomy amongst beneficiaries (including social groups) so that they may manage their own development without further intervention in the future, thus ensuring sustainable development.

Lesson 4: An integral approach is recommended, with interventions carried out in a medium- and long-term planning framework

Projects are interventions oriented to solving specific problems and/or responding to concrete needs of the beneficiary groups. Nevertheless, their sustainability and contribution to development depend fundamentally on social factors and the approach used during implementation. According to this perspective, projects should be a means to implement coordinated processes, which are oriented to reaching broader goals.

Lesson 5: Establishing a link between protecting the environment and livelihoods

Establishing a link between the protection of natural resources and livelihood generation proved fundamental in converting people and social groups into custodians of their territory and the ecosystems contained within it. This occurred when individuals and groups accepted that a healthy environment provides a better life quality, including better incomes.

2. TWO SMALL HYDROPOWER PLANTS IN NORTH-CENTRAL NICARAGUA – BEN LINDER ASSOCIATION OF RURAL DEVELOPMENT WORKERS[1] (ATDER-BL)

Rebecca Leaf, ATDER-BL,
Jose Luis Olivas, APRODELBO

Spanning a period of 30 years, the ATDER-BL small hydropower (SHP) project in the mountains of north-central Nicaragua has helped promote rural education and health services, while reducing deforestation in the watersheds. It is also very insightful, in particular underlining the importance of ensuring SHP projects are 'intertied' to the national grid in regions with a dry-rainy season weather pattern.

With an emphasis on local capacity building, this long-standing SHP and rural electrification grid project consists of two SHPs in north-central Nicaragua – the 190 kW Bocay SHP which has been in continuous operation since 1994 and the 914 kW El Bote SHP which came online in 2007.[2] It was designed, built and is operated by the Ben Linder Association of Rural Development Workers (ATDER-BL), a Nicaraguan non-profit, non-governmental organization (NGO) made up of Nicaraguans from local communities and foreign volunteers from the USA and Canada.

The SHPs are located in the village of El Bote in El Cuá municipality and in the town of Bocay in Bocay municipality in Nicaragua's Isabelia mountain range, a low range with elevations between 400 and 1,300 metres. The climate is sub-tropical with a rainy season that usually lasts for eight months of the year and a dry season that lasts for around four months from mid-January to mid-May. The average annual rainfall at higher elevations is approximately 2,500 mm per year, which, together with the hilly terrain, makes this a good area for run-of-river SHPs equipped with impulse turbines.

Access to electricity in this region, given poor road infrastructure and geographical inaccessibility, was historically low. In fact when the project was initiated three decades ago, the electrification rate in the Bocay municipality was 0 per cent and only 3 per cent in El Cuá municipality where hydroelectricity was supplied by a 43 kW SHP. Since then things have progressed. Today the two SHPs (Box 1) and the electric grid system are providing continuous electricity to over 9,000 homes across localities, health clinics, schools and businesses and in El Cuá the electrification rate exceeds 70 per cent.

[1] Asociacion de Trabajadores de Desarrollo Rural – Benjamin Linder.

[2] Current working capacities of the two plants are reported in the case study.

Financially, the ATDER-BL project initially used a combination of private and public donation funds and a major bank loan for the construction of the SHPs and the three-phase, medium-voltage electric line that connects them and interties this rural system to the Nicaraguan national distribution grid. However, during the last decade the project has paid off the bank loan and is operating on a self-sustaining basis, covering all of its operation and maintenance costs and generating a small margin each year that is being used to continue building more grid extensions to increase the rural electrification coverage.

The project focus: building local capacity and watershed conservation

Since its inception in 1987, ATDER-BL's main aim was to convert the fast-flowing creeks and streams of the area into electricity to promote local economic growth and improve social services, such as healthcare and education. However, El Cuá and Bocay municipalities faced major challenges throughout the 1980s - with poor local road infrastructure, non-existent telecommunications, and the risk of landmines and military activity as the region was within the northern zone of the 'Contra War'.

Consequently, the project focused on building local capability and self-sufficiency, with technical training a top priority and this was initially provided by skilled foreign volunteers from the USA and Canada. Furthermore, a metalworking shop was built in El Cuá and equipped with a lathe, milling machine, welding machine and drill press. Training was provided to local technicians and the turbine for the Bocay SHP was manufactured by local machinists and welders, partly as a training exercise. The workshop opened to the public and undertook metalwork jobs and repairs of farm tools for the local population in El Cuá town, the surrounding rural area and the nearby agricultural cooperatives. Auto mechanical skills were acquired as the few vehicles that operated in the area were also brought in for repair. Training in topographical surveying and drafting was also provided and the mapping of the towns of El Cuá and Bocay was useful to the municipal governments and a good practice for the new surveying crew.

When in 1989 a donated 40 kW diesel generator was installed in Bocay, the local lines workers were trained and installed the town's first small electric grid. Training in simple home wiring followed immediately. Overall, training was hands-on and focused on activities of interest and benefit to trainees and the community, e.g. providing extra income from welding or machining shop work, mapping the streets, installing electricity in family homes.

The training process, though slow in part due to the low educational level, was very successful over the long term and ATDER-BL maintains the same basic policies today. These include that any employment created will be given to young people from beneficiary communities; personal characteristics, not formal educational level, are the criterion for selecting candidates; if specialized technical training is needed and unavailable at the local level, the project will hire a Nicaraguan specialist from the cities, or failing that a foreign specialist will be accepted on a temporary basis; training in occupational safety will always be included; permanent employees must all have an affinity for team work and knowledge sharing; and that directors will transparently share with workers all relevant funding, budgeting and accounting information.

These principles helped develop a cohesive, stable, well-motivated and active work force. For example, as well as developing the Bocay and El Bote SHPs, the project engineering and field work team has undertaken over 50 prefeasibility, feasibility, hydrology and design studies for SHPs across Nicaragua. The El Cuá machine shop crew, after building the Pelton turbine for the Bocay SHP, installed over 20 SHP systems (3–25 kW) at remote sites, with turbines manufactured in-house.

A second important focus has been on watershed conservation for SHPs. Calculations of long-term operating costs for all SHP projects include assignment of a percentage of the income from hydroelectricity sales annually for watershed conservation. The El Cuá and Bocay municipalities are located in the 'buffer zone' of the Bosawás Biosphere Reserve, so stopping the alarming rates of deforestation in the watersheds has been a high priority. The project has found that the most effective approach is to dedicate funds each year to working with farm families in the watershed on soil conservation measures and agricultural improvement. Helping families produce more food and higher-yield cash crops reduces their need to clear-cut more of the sub-tropical forest they still have standing. It should be noted that severe poverty in the rural areas is one of the principal causes of deforestation in this northern region of Nicaragua. Moreover, improving agricultural productivity reduces rural poverty, and important progress can be made with a relatively small amount of well-focused, on-going funding taken from SHP sales income.

Benefitting community development, public education and health services

Access to electricity has been a major benefit and the system of two SHPs and electric grid has grown over the years to include 280 kilometres of medium voltage electric lines (24.9/14.4 kV) and 160 kilometres of low voltage lines (240/120 V). These SHPs provide continuous electric service

Box 1. Technical aspects of Bocay and El Bote SHPs

The 190 kW Bocay SHP has a gross head of 200 metres, a 1,400 metres penstock and a single Pelton turbine with two injectors, which was built locally with engineering design support from volunteer engineers in the USA and some free guidance from Canyon Industries, a US turbine manufacturer. It has been in continuous operation since 1994. The control system, initially installed, was a ballast load control governor for Island operation only. However the controls were later upgraded to include synchronization capability. The 914 kW El Bote SHP in El Cuá has a gross head of 120 metres, a 385 metres penstock and two Pelton turbines, both double-injector, purchased from Canyon Industries. Operating since 2007, El Bote SHP has dual controls that allow for selection of Island or Intertie operation.

Figure 1. Bocay and El Cuá municipalities on the map of Nicaragua

to 9,000 houses, farms, schools, churches, health posts, small business and government offices in the El Cuá and Bocay municipalities. Since the 914 kW El Bote SHP entered in operation, the number of local customers has increased by 15 per cent per year, while the electrification rate in the El Cuá municipality has increased to 70 per cent, up from 3 per cent in 1987.

An interesting aspect of rural electrification is the positive impact on rural public education and health services. In communities where electrical services become available, within the first year the health centre becomes better staffed and equipped, and more years of instruction are added at local schools. In the village of El Bote, for instance, prior to electrification the school only offered classes at first, second and third grade of primary education. However, within a year of electricity becoming available, the full six years of primary education were being taught in the same small school building using the classrooms for morning, afternoon and evening classes. Within three years, the school building was improved and expanded, and secondary school classes were started.

This expansion of basic education is actively promoted by the local parents' association and is triggered by access to electricity – largely because electrical service makes the village a more desirable place to live, helping attract certified teachers from larger towns which in turn boosts the education system. Similarly, when villages with electricity become more attractive to qualified nurses or medical staff, a half-abandoned health post can become an effective small health centre that provides reliable basic daily medical attention to the local community.

Electricity access also led to an early expansion of services in both municipalities, starting with the development of a welding and machining workshop and a technical training centre in El Cuá, a carpentry shop with electric tools in La Pita (in El Cuá municipality) and a rice-milling machine in Bocay, all of which led to increased local capacity and generated permanent jobs. Economic development has since progressed. For example, through private local initiatives a wide range of services are now available in the urban municipalities including gas stations, barber shops and dental clinics with electric tools, dozens of eateries and restaurants, ice-cream shops, tire-repair shops, Internet cafés, radio and TV repair shops, hostels, computer schools and recreation centres. The agricultural sector also benefits from a dairy processing plant as well as hundreds of coffee-depulping machines with electric motors which operate on the medium-sized local farms.

Figure 2. Community participation in the construction of a micro-turbine project

Figure 3. Manufacturing a cross-flow turbine at the El Cua metalworking shop

The largest energy consumers are two public hospitals which consume 12,000 kWh per month and approximately 20 cell phone repeater towers installed over the past five years which each consume 1,500 kWh per month. Despite development, the average energy consumption has remained constant at 46 kWh per customer per month. This is largely because while business has developed quickly in urban areas, the project has continued to build grid extensions to small poor rural communities. In these communities, customers have a lower average monthly consumption of 23kWh and mainly use electricity for lighting, infotainment and charging their mobile phones. Productive, commercial and institutional electricity demand in this rural area, with three medium-sized towns and one very small town, has never surpassed 20 per cent of domestic demand – and it is believed that large-scale productive use of electricity will not take place in rural areas due to the distance to the city, poor road infrastructure and the threat of landslides in the rainy season.

Figure 4. Equipment in EL Bote powerhouse

During the entire period of operation of the El Bote SHP (2007–2019), the sale of excess hydroelectricity to the national grid has provided the project with a second income, beyond the sale of electricity to local consumers. This has allowed the project to repay its bank loan, carry out watershed conservation work, purchase necessary parts and materials for maintenance and repair of the hydropower plant, build up a reserve fund for future SHP equipment replacements, and continue gradually expanding the electric grid to benefit more farm families through access to electricity. The central Government has also built grid extensions in the project area as part of the national rural electrification campaign. These connect to the project grid allowing the project to collaborate with the national programme.

Lessons for future SHP development

Lesson 1: Island versus intertied operation of SHPs

Both the 43 kW SHP, which provided the first electricity to El Cuá (1985), and the 190 kW Bocay SHP plant (1994) were designed as 'Island' hydropower plants for rural electrification in remote areas. Having operated these plants over a 15-year period allowed ATDER-BL to closely observe the technical, social and economic aspects of SHP in Island mode – particularly in the context of the seasonal water flow regime with a rainy and dry season weather pattern. ATDER also observed the development of six Island SHPs over a prolonged period in other parts of Nicaragua.

The type of Island SHPs built for rural electrification in remote communities is usually designed with an installed capacity equal to the peak demand projected over 20 years at a constant growth rate. If an annual growth rate of 4 per cent is assumed, the peak demand will double after 20 years. As peak demand is predominantly domestic lighting demand that occurs between 6 pm and 8 pm, with a daytime demand about 50 per cent of the peak and midnight demand about 25 per cent of the peak, the first major problem with SHPs operating only in Island mode becomes apparent – the expensive investment in installed power capacity is seriously under-utilized. With the shape of the 24-hour demand curve just described, an Island plant will operate with a plant factor of only 22 per cent during the first year, increasing to not more than 44 per cent over the 20-year growth period.

This leads directly to the second problem with Island SHP – that hydroelectricity sales income, limited by local demand, is often insufficient to cover SHP and island grid operation and maintenance costs. All Nicaraguan Island SHPs have struggled, especially during the first years of operation, due to lack of sufficient electricity sales income. Some have

Figure 5. Dam of the El Bote hydropower plant

collapsed for this reason. With barely enough income to pay the low salaries, they do not have sufficient resources to buy much needed spare parts for the hydropower plant or pay for the repair of a service transformer in the electric grid. When the plant is out for repairs for a long period of time, the service to the community becomes unsatisfactory and a descending spiral starts. Nicaraguans will not pay high tariffs for electricity. If an SHP plant built with donated foreign funds does not operate satisfactorily, they prefer to let it stop generating and be shut down – and the local people will wait for the Nicaraguan central Government to bring in a diesel generator and provide electric service with subsidized fuel.

The third problem with the Island SHP model in areas with the rainy and dry season weather pattern is that projects can experience water shortage in the stream during the dry season. In Nicaragua water flow during the two driest months is less than 20 per cent of average flow during the rainy season and with insufficient water to sustain full time hydroelectric generation, rationing of electricity becomes necessary. It should be noted that rationing requires SHP civil works to have a reserve water storage volume available,

Figure 6. Annual cleaning of sediment from the headpond at Bocay

Figure 7. ATDER-BL technical team in the Bocay powerhouse

such as a head pond at the dam or a very large forebay. It is advisable to let the head pond fill up during the low demand midnight hours and use this stored water to cover the peak load the next day. However, as the customer numbers grow and the stream flow remains relatively constant from year to year, even the head pond storage will not be enough and the electricity service must be suspended all morning and early afternoon during the dry season to allow the plant to generate for one or two hours of peak demand with the small water reserve that is available.

With the above in mind, when in 2003 the opportunity arose to finance the 914 kW El Bote SHP facility, ATDER-BL designed the plant to be intertied to the national grid rather than as an Island SHP. This required building a 30 km, 24.9 kV three-phase line to interconnect from El Cuá to the nearest circuit of the national grid. This extra investment has been worth it. The intertie to the national grid allows the El Bote SHP to sell its excess hydroelectricity generation to the national system during the rainy season, whilst enabling the purchase of additional energy that customers require and that cannot be covered by the SHP due to water shortage during the dry season.

Similarly in 2007, ATDER-BL also built an additional 22 km of a three-phase medium-voltage line further to the north to intertie the Bocay SHP, enabling it to sell a small amount of excess hydroelectricity generation during the rainy season and purchase much needed electricity during the dry season, eliminating dry-season energy rationing in Bocay municipality.

Importantly, in 2001 the Nicaraguan Government mandated the distribution companies operating the national grid to purchase electricity generated by SHPs at stable prices fixed by the Energy Board of the national legislative body. Though lower than the overall national energy purchase price, they are high enough for project viability.

During the first five years of El Bote SHP operation, approximately 25 per cent of the annual generation was consumed by local customers in El Cuá municipality, whilst 75 per cent was sold as excess generation to the national grid. However local demand has grown rapidly and in recent years 80 per cent of El Bote generation is consumed locally and only 20 per cent is sold to the national grid. During the entire period of operation of El Bote to date (2007–2019), the sale of excess hydroelectricity to the national grid has provided the project with a second income, above and beyond the sales to local consumers.

The intertie to the national grid is not perfect. The remote rural circuits of the national grid in Nicaragua tend to be poorly maintained, too long and a service quality standard does not exist. Frequent blackouts of variable duration are common, especially during the rainy season – voltage sags, over-voltage peaks due to re-closures at the distant substation, poor voltage regulation over the 24-hour cycle and phase imbalance from the national grid, are all part of life. Nonetheless the tremendous advantages of having an outlet for all excess hydropower generation and being able to purchase from the grid any electricity that customers require that the SHPs are unable to generate, far outweigh the difficulties with the intertie.

'Island SHPs built for the purpose of rural electrification should be intertied to the national grid – doing so will promote local economic development, increase rural electrification, while also supplying the grid with inexpensive renewable energy.'

Overall, it is strongly recommended that all Island SHPs built for the purpose of rural electrification should be intertied to the national grid as soon as possible. Doing so will promote local economic development, increase rural electrification while also supplying the grid with inexpensive renewable electricity.

Lesson 2: Run-of-river versus daily reservoir

For an SHP that serves a local domestic load with a significant load peak, a strictly run-of-river hydropower plant based on a small stream will not provide satisfactory service in a climate with a rainy season-dry season weather pattern. This is due to a shortage of water during the dry season. In hilly terrain with high heads available, it is usually not difficult to choose a dam site that permits building a low dam (2-4-metre-tall) that will impound water with a storage capacity sufficient for daily flow regulation during the dry season and the transition months. It is recommended to incorporate daily storage capacity in a head pond whenever possible, both when the SHP operates as an Island plant and when it is intertied. In the case of the latter, daily water flow regulation permits the plant to follow the local demand cycle, thereby reducing the need to purchase electricity from the national grid (which is more expensive) to cover the peak hour demand.

A 2008 inspection carried out on the Bocay SHP and the El Bote SHP by a watershed biologist indicated that the presence of the head pond, the daily regime of water usage and the periodic purges of the sediment from the head pond once or twice a year were not damaging the health of the streams. Moreover, the flora and fauna in the stream bed and along the edges of both streams was found to be identical upstream and downstream of the head pond and in good health.[3]

Note: *The authors would like to express their gratitude to all of the Nicaraguan and International organizations that provided funding to get the projects started, and special thanks to the volunteers from Tecnica-USA and Canadian civil engineering collaborators whose contributions in the early stages established the technical foundations for the work that followed.*

[3] As Nicaragua does not have species of fish or other aquatic animals that swim upstream to spawn, the low dams do not cause a barrier of any environmental or natural significance.

3. THE 700 KW ZENGAMINA SMALL HYDROPOWER PLANT AND MINI-GRID: BUILDING ON 12 YEARS OF OPERATIONAL SUCCESS IN ZAMBIA

Bernard Moulins, Laurent Nahmias-Léonard, Nicola Yurkoski, Virunga Power; Daniel Rea, Zengamina Power Ltd.

In a remote district of Zambia's North-Western Province, the Zengamina small hydropower plant (SHP) harnesses the power of Africa's fourth largest river, the Zambezi. Developed by local stakeholders, the SHP project and mini-grid have been providing access to electricity in this energy-deprived area for over a decade, improving local living conditions and helping to promote social and community development.

The 700 kW Zengamina Power SHP (Figures 1 and 2) project and mini-grid are located in the Ikelenge District in Zambia's North-Western Province and are close to the country's intersection with the Democratic Republic of the Congo (DRC) and Angola. Traversed by the Zambezi River, historically access to electricity in this area has been very low with the Ikelenge District over 250 kilometres away from the Zambia Electricity Supply Corporation (ZESCO)-operated national grid. Traditionally, locals have relied on wood or kerosene for cooking and heating and there is a prevalence of unsustainable slash and burn subsistence farming. In general, the lack of reliable energy has perpetuated a cycle of poverty across the region.

The completion of the Zengamina Power SHP scheme in 2007, a run-of-river SHP (Box 1) which harnesses the power of the fast-moving Zambezi River, has had a significant positive impact on local development. As well as providing clean, reliable and affordable electricity to the local hospital, schools, businesses and access to electricity for local households, it has promoted wider sustainable development of the rural community. More specifically, over the last decade the SHP development has created hundreds of new direct and indirect jobs in the community, triggering massive investment in social institutions by the Zambian Government and raising the region's living and working standards.

The origins, development and expansion of the Zengamina SHP initiative

The project dates from 2001 and recognized that there was a critical need for a reliable and affordable alternative to diesel to power the 100-year-old Kalene Mission hospital, which offers critical care to patients from three countries – Zambia, the DRC and Angola. In response, a group of local stakeholders set up the non-profit North West Zambia Development Trust

(NWZDT) to raise funds for the Zengamina SHP development. Early funding came from several British charities, churches and private individuals.

Construction of the Zengamina SHP, which was named after a local Chief, began in March 2004. Taking advantage of the Zambezi River as a huge natural resource, the SHP plant officially opened in July 2007 and began supplying electricity to Kalene Hospital, as well as local clinics, schools, an orphanage and local households. The original project costs were US$ 3 million – approximately US$ 2 million for the SHP itself and US$ 1 million for the distribution network. As well as NWZDT, a sister company, Hydro Electric Power Ltd (HEP), was later established to further develop the initiative and build and operate similar SHP schemes based on the experience of the Zengamina SHP.

Today the grid covers 30 km, while over 30,000 people benefit from the connections provided to schools, healthcare institutions, houses, small and large businesses and mobile phone towers. Despite the great positive impact, limited resources have reduced the scheme's potential, which has excess capacity and unmet customer demand. To address this, HEP has recently established a partnership with Virunga Power (Box 2) to gain strategic support and help optimize mini-grid operations and facilitate the Zengamina's expansion with a view to providing electricity access and associated economic benefits to more people in the area.

The joint venture between Virunga Power and HEP will expand the generation capacity of the Zengamina Power SHP to 1.4 MW. Moreover, the joint venture will hybridize the generation assets by adding solar power of up to 1 MW. Alongside the generation expansion, Virunga Power will extend the existing Zengamina distribution network leading to a total reach of over 2,500 connections or local rural households. In conjunction with the expansion, the partners will seek to achieve an optimal level of tariff for long-term financial success, formulate strategies to continue stimulating productive uses of energy through partnerships with NGOs and local businesses, and introduce new technology and build an effective team with local expertise to enhance the operational excellence of the grid. Longer-term, the partners plan to develop a Zengamina Cascade by adding several small hydropower generation projects upstream from Zengamina and further extending the mini-grid.

Box 1. Technical Information

A run-of-river project, Zengamina Power SHP utilizes the fast-moving Zambezi River, Africa's fourth largest river, to generate electricity for the local area. The Zambezi at this location drops 17 metres (56 ft) over a 350-metre (1,150 ft) length of rapids. The facility includes a 100-metre-wide weir, 400-metre canal, 70-metre penstock, powerhouse and tailrace – and installation of an Ossberger cross-flow turbine, step-up transformer and substation, and 35 km of 33 kV line as the backbone and 10 km of low-voltage line. The 700 kW SHP is built to allow easy expansion to 1.4 MW. Construction on the project began in March 2004 and it was officially opened on 14 July 2007.

Box 2. Virunga Power

Virunga Power is an owner, investor, developer and operator of SHP-based mini-grids in Kenya, Tanzania, Burundi and Zambia. It has a strong focus on SHP, such as the Zengamina project, given the technological and scaling advantages. SHP is a proven and durable technology that leverages an abundant and familiar resource in Eastern and Southern Africa to create long-standing energy infrastructure. Moreover, SHP provides base load energy generation that can operate without storage and eventually serve as an ideal complement to other intermittent renewable energy sources, such as solar and wind power. Additionally, it supports larger-scale projects that enable improved customer services as well as significant cost savings that are passed to end-users as grid parity costs of energy. Virunga Power also promotes the use of a 'grid-as-anchor' model that bridges on-grid and off-grid areas by simultaneously distributing power to new rural areas and selling any excess power into the national grid. This allows developers to optimize projects based on resources rather than anticipated demand and provide affordable end-user tariffs – a strategy HEP and Virunga Power plan to employ in the expansion of the Zengamina Power SHP initiative.

The benefits of the Zengamina Power SHP: promoting community development, economic growth and supporting the United Nations Sustainable Development Goals

The Zengamina SHP project has transformed the Ikelenge District by providing the electricity needed to build a self sustaining local economy. It has provided access to clean, reliable, renewable electricity to thousands of people who previously had no access or who were dependent on expensive, unreliable electricity from polluting diesel generators.

This has had a positive impact on the standard of public service provision in the hospital, clinics and many schools, improving the overall health and education of the local population. Public institutions have been renovated and many new buildings constructed, with US$ 30 million worth of contracts awarded for public works. Furthermore, these institutions are now fully staffed. Previously the hospital and schools typically had half the number of nurses and teachers required as qualified professionals often avoided "hardship rural postings", which offered none of the modern conveniences taken for granted with electricity access.

Beyond improved living conditions, this project provides continuous electricity supply needed for medical equipment in the hospital, computers for businesses and schools, and other appliances previously limited by power restrictions. Furthermore, the project created direct jobs and life skills through construction and maintenance of the SHP (Box 3).

The new access to electricity also stimulated indirect jobs by enabling the growth of small businesses in the area, creating a more dynamic local economy. In fact, the initiative proactively partnered with a number of local businesses to create jobs and increase energy demand through income-generating productive uses of energy. The development of a new pineapple processing plant was supported as was the development of new stone crushing and block making factories. This work led to both increased income generation in the local community and higher energy usage which helped to pay back the infrastructure development costs of the project. In an area where unemployment rates were nearly 80 per cent, these local jobs were extremely important. Overall, this project has transformed opportunities and living standards in this rural community and there is still potential for further development.

Box 3. Creating jobs and skills through Zengamina Power SHP

"Over 400 local people helped with the original construction and up to 40 per cent of the workforce were women. We also worked hard to successfully transfer operations and maintenance of the plant from international experts who helped us establish, to a local team who now manage the generation and transmission infrastructure. In our operational team we have individuals who were born before there was power in this remote area, went to school, then college, had work experience with us, and are now on staff. That is something we are proud of, and shows the changes brought about within a generation."

–Dan Rea, social entrepreneur involved in the construction of the Zengamina Power SHP

The recently established partnership between Virunga Power and HEP will drive the expansion of these positive economic and environmental impacts to the broader area. In addition to expanding the capacity and distribution of the project, HEP and Virunga Power are proactively identifying additional productive use partners for the area.

The Zengamina project and HEP and Virunga Power's mini-grid projects more broadly address several of the United Nations Sustainable Development Goals (SDGs) including SDG 1 "No Poverty", SDG 7 "Affordable Clean Energy", SDG 8 "Decent Work and Economic Growth", SDG 9 "Industry Innovation and Infrastructure" and SDG 13 "Climate Action". Most notably, this project addresses SDG 7 by expanding access to an affordable, reliable, and renewable energy service in a rural area.

Lessons for future SHP development

Over the past decade, the Zengamina initiative has become a prime example of a successful SHP and mini-grid development in Sub-Saharan Africa. The NWZDT team has several recommendations for other SHP developers and mini-grid operators based on the specific experience gained during project development and operation.

Figure 1. Zengamina SHP

Source: Google Maps

Figure 2. Zengamina SHP on the map of Zambia

Figure 3. Connection of new customers to the grid

Figure 4. Signing up for electricity connection

Figure 5. New small businesses

Figure 6. New equipment in the hospital

Figure 7. Community consultation with the chief and local leaders

Lesson 1: Set tariffs at the optimal price point from the start of the project

Rural electrification typically requires a subsidy for development and early operations given the low income and energy usage of rural customers. To ensure electricity was affordable for impoverished customers in the Ikelenge District, the team set the basic Zengamina tariff for individual households at only US$ 5–8 per month. They assumed that the high growth of usage in the area (usage per household and number of households connected) would compensate for this low price point. However, it was soon clear that a higher tariff was necessary for long-term financial sustainability and that the early focus should be on connecting higher users of power. Even with a capital subsidy, the service of low density, low-usage customers is uneconomic, certainly at lower tariffs. The lowest users may be better served by home solar power units.

According to the Energy and Extractives Global Practice, World Bank Group, studies indicate that consumers in developing countries are willing to pay significantly more than existing tariffs if provided with an improved electricity service. Committing to a high service delivery standard and setting the optimal tariff from the onset of a project are essential to ensuring long-term operational sustainability. When combined, they can create a virtuous circle of operational improvement.

Lesson 2: Focus on productive use stimulation over simply increasing the number of connections

Many project developers focus on the number of new household connections as the key metric of success, often driven by funder Key Performance Indicators (KPIs). However, household connections alone will not drive substantial energy usage for a project – especially in the early stages. It is critical for developers to also identify types of businesses that will be successful in the region and partner with them to drive productive energy use. Despite Zengamina's emphasis on productive use activities, only 30 per cent of the generation capacity is being used over a 24-hour period, while the relatively short, domestic driven evening peak is now close to capacity. It is advisable to engage with other partners during the project's early stages to help drive a variety of productive uses of power from the very beginning. HEP and Virunga Power are striving to establish partnerships with NGOs and local companies in parallel with the expansion of Zengamina to ensure productive uses in the area.

Lesson 3: Embed dedicated local community members within the project team

Regardless of the financial and technical expertise of a development team, it is critical to recruit one or more local community members to help lead and champion the project. This dedicated local team member is necessary to ensure community awareness and involvement from the outset. A deep understanding of the site, local businesses and community preferences can ensure that the project succeeds and meets its potential for providing electricity and simultaneously stimulating productive uses of electricity in the area. As companies such as HEP and Virunga Power expand operations to other areas of Zambia and beyond, the need for a local teammate becomes even more important. Every project comes with a unique set of political, cultural and physical circumstances that only a local community member can effectively address and incorporate into the projects long-term strategy and implementation.

Overall, the Zengamina Power project is a pioneering example of the impact that SHP and mini-grid infrastructure can have on rural communities. Renewable SHP can provide durable, reliable and affordable electricity to areas not covered by the national grid – leading to transformative economic opportunities in rural communities. HEP and Virunga Power are excited to build on the success of this project by expanding its reach to more communities in the region.

4. 200 KW BASID SMALL HYDROPOWER PLANT: INCREASING RESILIENCE IN THE TAJIK PAMIR

Thomas Gross, HYCON GmbH

In the isolated village of Basid in the Tajik Pamir Mountains, the rehabilitation of a small hydropower plant (SHP) has provided a firm basis for community development and economic progression. It has also helped protect the local environment, reducing deforestation and on-going soil degradation, which in turn has mitigated the threat from natural hazards.

The Tajik Pamir Mountains are amongst the most remote and poverty-stricken areas of the world and at an altitude of 2,000–7,500 metres above sea level extremely cold and harsh winters are the norm. Many of the region's villages suffer extremely poor access to electricity. Moreover, the ongoing impoverishment of communities is coupled with an unhindered degradation of natural resources including the soils and vegetation on which local people directly depend, with shrubs and local biomass fuels a primary source of energy. Although some SHP projects have been developed at village level, electricity is often produced by locally built, ineffective micro-hydropower plants (MHPs), which often generate supply sufficient for lighting only.

'With no connection to the regional electricity grid, sustainable business development in Basid has historically been out of reach for villagers, contributing to a lack of economic progression and community development.'

Basid, a remote community in the upper Bartang valley, is a case in point. Built at 2,400 metres, it is a five-hour drive from Khorog, the provincial capital, if the road is accessible. The village is home to around 600 people across approximately 100 self-sufficient households, with most locals working in subsistence agriculture, although there are a few skilled craftspeople. With no connection to the regional electricity grid, sustainable business development in Basid has historically been out of reach for villagers, contributing to a lack of economic progression and community development. Public infrastructure is limited to a school and medical point. Like many communities in the region, Basid's population has been largely dependent on burning firewood, shrubs and dung for cooking and heating. In fact, it is estimated that up until recently Basid households burned around 800 tons of firewood each year, including wood sourced from local forests. This led to deforestation and soil degradation in the local area already prone to natural hazards, such as landslides and avalanches.

Tackling local energy issues through rehabilitation of the 200 kW Basid SHP

The local community in Basid laid the foundations to resolve its own energy crisis by building the original Basid SHP and by purchasing a generator – though due to a lack of technical knowledge, the electricity supply proved unreliable and inefficient. Following thorough assessment and consultation, a Swiss-based non-governmental organization (NGO) PamirLink (Box 1) agreed to facilitate and support rehabilitation of the existing Basid SHP installation (Figures 1 and 2). As part of the SHP project, PamirLink provided technical expertise from Switzerland as well as European-manufactured electro-mechanical equipment to help develop a more efficient run-of-river scheme (Box 2). Given the commitment to reducing local consumption of natural resources, the rehabilitation project successfully achieved a design output of 200 kW, which, according to a baseline survey, was the capacity needed to substitute biomass fuel for the Basid community's cooking and heating needs. It also allowed for productive use of electricity during day time. The project set a minimal supply of 1.5 kW per household as a target.

Source: Wikimedia Commons

Figure 2. Basid on the map of Tajikistan

Figure 1. Basid SHP

Box 1. PamirLink

PamirLink is a Swiss-based NGO which offers support to rural communities in Tajikistan's Pamirs Mountains. The organization has particular focus on sustainable tourism and renewable energy to improve livelihoods – the rationale being that by providing access to a sustainable and renewable energy for domestic and productive use, the consumption of natural resources (shrubs, wood, dung) for heating and cooking is reduced. In this way, project activities also help to reduce deforestation and soil degradation, while preserving dung as agricultural fertilizer. A further productive end-use of SHP energy is generating an important additional source of income for local communities.

Box 2. Technical Information for 200 kW Basid SHP

Providing know-how and expertise from Switzerland and European-manufactured electro-mechanical equipment was the cornerstone of this sustainable rural electrification project. For the 200 kW SHP run-of-river scheme, water is diverted by a temporary weir from a side stream of the Bartang River. The water follows a 750-metre-long channel, which is partly made from concrete. From the forebay, the Gross Head of 27 metres is maintained with a penstock (DN 700 mm). For electricity generation, a cross-flow turbine is installed. The turbine is coupled directly to a 240 kVA synchronous generator with a rated speed of 600 min-1. To govern the SHP, an automated hydraulic system was installed. The cross-flow turbine, the generator and the governing system were all manufactured in Europe.

Community involvement was a key success factor in generating the necessary local ownership, and the local people contributed labour and building materials such as stones to the project. In the implementation phase, the hydropower station was handed over to the community, which established a village organization to act as a council for the management and operation of the Basid SHP facility. The village organization currently collects electricity fees and sets the electricity tariff, including subsidies for less well-off households. The electricity revenues finance four full-time jobs for operators who have been recruited from the village population. PamirLink maintains regular contact with the village organization, providing and exchanging information and technical know-how related to the project on a monthly basis.

Financing the project proved challenging and community contribution aside project costs totalled around US$ 300,000. The Swiss Government contributed about half of the budget through the Renewable Energy and Energy Efficiency Promotion in International Cooperation (REPIC) initiative. The remainder was collected through a crowd funding campaign led by PamirLink and from other donations

Improving overall resilience and promoting community development

Rehabilitation of the Basid SHP improved the overall resilience of the Basid community. Importantly, access to electricity has improved the economic situation with the local people increasing their income level. For example, the local carpenter has increased productivity and reduced costs by permanently using electrical appliances rather than relying on a costly fuel-powered generator; while the local shop has increased its capacity and productivity by using electrical appliances such as a refrigerator and electric cook stoves.

The reduced consumption of firewood also has an economic impact. With an average price of over US$ 5 per m^3 of firewood, saving 670 m^3 of firewood means making available US$ 4,000 per year for other purposes or reducing household expenditure by US$ 30–40. Villagers have also reduced the time spent collecting locally grown wood, shrubs or dung, which has enabled them to invest their energy in other income-generating activities. Moreover, as less dung is used as a fuel source for cooking and heating more is available as fertilizer, in turn reducing the costs of farming and improving local incomes.

Replacing biomass fuels not only improves local income but also has a significant impact in improving health, especially for local women. Access to clean energy and the reduction in firewood or dung usage for cooking reduces smoke emissions, CO_2 and particles in the air, with clear benefits for respiratory health.

In providing access to reliable and affordable energy for villagers, the project has also improved quality of life and allowed a degree of community planning for the future. Following rehabilitation, the plant achieved an average output of 175 kW which meets the village's energy needs with domestic consumption currently at 100 kWh per month. To enable social development, the energy also needs to be affordable. Currently, the tariff is set at US$ 0.015 per kWh. On average Basid households pay US$ 1.50 per month for electrical energy. With this tariff, the Basid village organization is able to save approximately US$ 900 per year for future investment in value retention and rehabilitation.

Furthermore, villagers have also started to develop coping measures for natural hazards. Becoming an owner of the SHP has encouraged the local population to take care of their investment and the basis for their improved livelihoods. This has led to an increased awareness of natural hazards such as floods, mudflows and landslides, rock falls and avalanches. Parts of the SHP, including the headrace channel, are exposed to such hazards, and the diversion weir was built as a temporary structure in view of the annual floods caused by snowmelt. To cope with such threats, the local community constantly maintains the infrastructure, has improved preventative measures and adjusts the layout where needed, with a view to keeping the installation running for as many hours per year as possible.

Importantly, the rehabilitation has had the key effect of protecting natural resources in the area. With the power plant in operation, consumption of wood and similar fuels has reduced. This has lessened the pressure on the sparse local natural resources. Reducing the consumption of firewood in particular has a major impact, with local deforestation reduced to a minimum. Moreover, existing and newly growing trees and bushes help to stop soil degradation and prevent future landslides or avalanches, and their protection can be considered an effective Disaster Risk Reduction (DRR) measure.

Access to sustainable energy – aiming at the UN Sustainable Development Goals (SDGs)

As a renewable energy project, the 200 kW Basid SHP supports several UN SDGs including SDG 7 Target 1 which aims to ensure universal access to affordable, reliable and modern energy services by 2030. Specifically this SHP initiative provides 650 villagers access to reliable and clean energy, where previously only a handful of locals had access to electricity via fuel or diesel generators.

Gaining access to a reliable energy supply also helps generate additional income and productive usage of electrical energy equates to around US$ 1.50–3.00 per kWh, contributing to the country's gross domestic product (GDP). With an average annual consumption of a small enterprise in these rural areas of about 300 kWh, the economic impact is approximately US$ 500 per year per business. In this way the project clearly augments GDP in rural Tajikistan in support of SDG 8, to 'promote sustained, inclusive and sustainable economic growth', and is in line with indicators regarding the annual growth rate of GDP per capita and per employed person (Indicators 8.1.1 and 8.2.1). Values given for the Basid SHP are comparable with other renewable energy and energy efficiency projects in Tajikistan. Moreover, the productive end-use of clean energy is key for sustainable development and the primary way to increasing income in Basid and the surrounding hamlets. Higher household income further enables villagers to increase their consumption which again fuels small businesses. By providing energy we therefore initiate a positively amplifying process.

The third major impact is the reduction in soil degradation and protection of forest areas, which supports SDG 15 (15.1–15.3) on the sustainable usage of natural resources, mainly forests. The Basid SHP renovation, and subsequent reduction in firewood consumption, means sustainably managed forest areas are increasing and the local degradation of soil is being reduced. In fact, the SHP substitutes at least 50 per cent of the consumed biomass fuel. Reducing wood consumption by 400 tons per year equates to 670 m^3 of wood or what is being naturally regrown on 330 ha of forest per year.[1] This reduction in the consumption of biomass fuel also has an impact on greenhouse gas emissions and substituting 400 tons of firewood per year means eliminating 130 tons of CO_2 emissions per year in the Basid area.

Lessons for future rural electrification projects

Lesson 1: The importance of community involvement for sustainability

The Basid local community has taken ownership of the SHP project, maintaining the system and investing in the power plant which helps to ensure project sustainability. More specifically, the local community mutually agrees the electricity tariff, which includes subsidies for economically less well-off households. The collected income pays for trained operators and the surplus is saved for future investments. The necessity of saving money was evident when the local operators together with the manufacturer of the turbine made a first in-depth inspection and annual revision of the turbine. The extra cost of this major maintenance encouraged the Basidis to learn how to maintain the facility themselves, which in turn increases the lifespan of the power plant.

Lesson 2: Take a wider or more holistic approach

The project's main aim was not simply the installation of a hydropower plant but rather to improve the overall resilience of the village and to protect natural resources. By providing access to SHP electricity in sufficient quantities, the project enabled the people of Basid to substitute biomass fuel for clean, renewable energy even during wintertime. This has several wider benefits. For example, it has improved livelihoods freeing up the local workforce that previously spent much time collecting wood and there has been an economic impact on the households with electricity facilitating new opportunities for income generation. Environmentally the project saves biomass or wood equivalent to the annual growth of 330 ha of forest, preventing some 130 tons of CO_2 emissions, and biomass reduction has a positive impact on respiratory health amongst local residents.

Lesson 3: Projects can raise awareness of potential for natural disasters in disaster-prone areas.

A welcome project side benefit is that it has raised awareness amongst the local community of the potential for natural disasters. Moreover, local residents are beginning to take preventative measures to ensure a maximum availability of their source of energy. Nevertheless, the fact remains that the Basid SHP is a power plant in the Pamir Mountains which is a challenging environment, particularly during winter. A still unresolved problem is the icing up of the intake and the channel and the ice is too thick to be removed manually. When this occurs the power plant is taken off-grid during a season when the energy is most needed.

Source: Tobias Hoeck

Figure 3. Villagers collecting shrubs

[1] Mean annual increment: 2 m^3/ha/year; source: Food and Agriculture Organization (FAO).

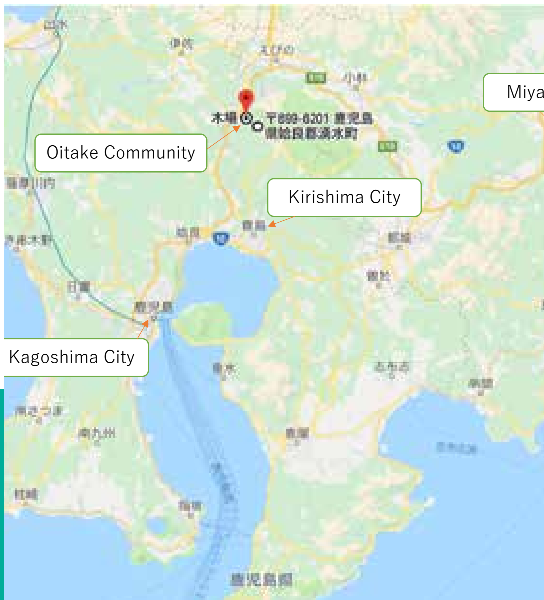
Lesson 4: Possibility of a 'snowball effect' in other villages

The successful development of the project has been reported locally leading to requests from nearby villages and hamlets around Basid to be connected to the SHP or for them to benefit from their own SHP initiatives. PamirLink is currently planning to extend the grid to Dorj, a nearby hamlet. This requires approximately another 4 kilometres of transmission line and will allow for about a dozen of households to access the grid.

Lesson 5: The need for thorough assessment and continued support

This project shows that rural electrification projects need to have a thorough assessment of the situation of a village to identify the various dimensions of impacts of such interventions. Although the main aim is to enable local communities to run their own power plant independently and sustainably, the rural communities also need to be supported during and after the project cycle to enable them to secure the envisaged benefits. In the case of the Basid SHP, PamirLink is still in regular contact with beneficiaries with information and technical know-how exchanged on monthly basis.

5. 30 KW OITAKE SMALL HYDROPOWER PLANT IN KAGOSHIMA PREFECTURE, JAPAN



Source: Google Maps

Yoshinobu Watanabe, Zafar Alam, Raditya Rahmanhuda Rusmiputro, Nakayama Iron Works Co. Ltd.; Keijiro Okajima, Shigenori Yamamoto, Seiko Service and Engineering Co. Ltd.; Faisal Rahadian, Asosiasi Hidro Bandung; Arun Kumar, Indian Institute of Technology — Roorkee; Tokihiko Fujimoto, Shizuoka University

Small hydropower (SHP) is seeing unprecedented growth in Japan as the Government and private sector commit to a greater utilization of this abundant natural energy source to help boost economic and social development, particularly in rural areas. One such example is the Oitake SHP in Kagoshima prefecture, which uses a pre-existing irrigation canal to generate clean SHP energy locally. It also has an innovative design; the project re-working a common shipping container as the plant's powerhouse.

In Japan, SHP is considered a reliable and sustainable source of electricity, which resulted in its development and adoption whenever there is an adequate quantity of unused flowing water at the local level. Moreover, in recent years the Japanese Government has simplified the water rights application system, while also setting targets to initiate thousands of SHP projects across the country.

Overall, Japan has abundance of small streams, particularly in mountainous regions, and in the past many small channels have been created for irrigation purposes. Some of these irrigation channels continue to be used today. Others, though in good condition, remain unused. Increasingly these channels are being utilized to produce SHP electricity to promote local development. This is particularly important for rural Japan, which has suffered from rapid depopulation due to a combination of an aging population and urban migration.

The 30 kW Oitake SHP, in Kagoshima prefecture, is one such example of using SHP as a strategy for rural development. A key aim of this project was to use available water in a rural area to produce clean energy and to stimulate the local economy. The Government's electricity tariff system and the availability of cheap rural land helped with project establishment.

Developing and implementing the 30 kW Oitake SHP project

A compact hydropower initiative, the 30 kW Oitake SHP project (Boxes 1 and 2) is located in Kagoshima prefecture, south-western Japan. Specifically, the project site is in Oitake community in the mountainous Aira District, 10 km west of Kirishima City. With strong agricultural roots, well-known Kagoshima exports include green tea, sweet potato, radish and Pongee rice.

'The Oitake SHP uses a common shipping container as a powerhouse, with all mechanical electrical control equipment pre-installed in a factory, significantly reducing the costs and the length of time needed for project implementation.'

Uniquely for SHP projects of this type, the Oitake SHP uses a common shipping container as a powerhouse, with all mechanical, electrical control equipment pre-installed in a factory (Box 3, Figures 2 and 3). This has the effect of significantly reducing the costs and the length of time needed for design and project implementation, in particular in relation to civil engineering and the fact that there is no need to design and construct the powerhouse.

In terms of output, the plant started generating electricity in May 2018 and currently has a capacity of 30 kW. At the site, a small stream of water has been diverted from an existing irrigation canal used to irrigate local paddy fields in the village – and in this way the project utilizes local water resources prior to agricultural usage. Diverted water is first stored in a small 6 m^3 steel water tank before being carried through the penstock to rotate the turbine. The generated electricity is sold to the nearby electricity grid benefiting from the feed-in tariff (FIT) offered by the Government of Japan.

One implementation challenge was the selection of a suitable turbine as SHP turbines under 50 kW have limited availability in Japan. To ensure proper planning and follow-up of this small community-based SHP project and to provide the appropriate electromechanical equipment, a professional hydropower consultant was employed. Subsequently, a cross-flow T-15 turbine, manufactured by Asisiasi Hidro Bandung in Indonesia, was selected for this compact hydropower system, while other electric and control equipment was manufactured in and sourced from Japan.

The compact hydropower system, which is a new concept in SHP technology in that it replaces the need for building a powerhouse, was co-developed by Nakayama Iron Works CO Ltd (Saga, Japan) and Sieko Sevice Engineering Co. Ltd (Fukooak, Japan). The project civil works were undertaken by the developer, which is a civil engineering company, Shigekazu Co. Ltd (Kagoshima, Japan), operating in the local area. The project, which was started in June 2017, required a total investment of approximately US$ 460,000 and is fully self-financed by the developer.

The benefits of the Oitake SHP: developing rural areas and supporting the United Nations Sustainable Development Goals

The installation of the Oitake SHP has several distinct benefits, which include helping the Government to achieve its sustainable development goals from the local level, and helping to support and promote development in a rural area.

More specifically, the project has boosted rural growth and the growth of a local company, with the developer, a civil engineering company, financially benefitting from the FIT offered by the Government. This FIT applies to all renewable energy resources including SHP. The official buying price offered by the Japanese Government for electricity generated from the Oitake SHP is JPY 34 per kWh (US$ 0.31 per kWh; under 200 kW), which means that the developer will receive approximately JPY 7.3 million per year (US$ 67,500). It is envisaged that the local developer will break even on its investment within seven years, while earning a profit over the 20-year lifespan of this SHP project. Importantly, the relatively high FIT means the developer was able to plan financing of the Oitake SHP scheme.

From an environmental perspective, the Oitake SHP initiative contributes to the Government's efforts to promote clean energy sources and to achieve its wider sustainable development goals and agenda, the project promoting renewable energy generation by converting unused available water into a useful product without consuming or affecting it. In terms of specific United Nations Sustainable Development Goals (SDG), the Oitake SHP supports SDG 7, to "Ensure access to affordable, reliable, sustainable, and modern

'The project has boosted rural growth and the growth of a local company...it is envisaged that the local developer will break even on its investment within seven years, while earning a profit over the 20-year lifespan of this SHP project.'

energy for all", and SDG 8, to "Promote sustained, inclusive and sustainable economic growth, full and productive employment and decent work for all".

The Oitake SHP project also contributes to SDG 13, to "Take urgent action to tackle climate change and its impacts by regulation emissions and promoting developments in renewable energy". In terms of reducing CO_2 emissions, as each kWh of electricity generated from a renewable energy source is the equivalent of 0.555 kg CO_2, the 180 MWh of electricity generated annually by the Oitake SHP will lead to an estimated reduction of 100 tons of CO_2 per year.

It also contributes to social and community development by boosting a local company in a rural area. Like many rural areas in Japan, there has been a strong trend towards urbanization across Kagoshima prefecture for more than half a century, largely due to lack of jobs and facilities in rural villages. Furthermore, industrial growth remains low. SHP development is considered as an attractive option for this area particularly in that it can help to increase local employment and stimulate local business. In the case of the Oitake SHP, the project developer and owner runs a local civil engineering company close to the project site. All civil engineering works were done in-house and the company gained valuable technical know-how in the construction of the SHP system. The company also worked on the development stage of the project for over a year and gained new business in maintaining the system and managing the SHP facility. Moreover, the project has created local employment linked to maintenance of the SHP plant for a minimum of 20 years.

Figure 1. The head tank from the intake

Note: *The head tank from the intake; made up of steel, it is 3 metre long, 2 metre deep and 1 metre wide. This tank stores water for 1.5 minutes and its main purpose is to stabilize the head at the site and to provide a continuous and constant flow.*

Lessons for future SHP development

Lesson 1: There are major benefits of using a compact hydropower system which houses the powerhouse in a shipping container

The uniqueness of this compact hydropower system is the use of a shipping container as a powerhouse. This design concept significantly reduced the cost of civil engineering and the amount of time required to construct the powerhouse. Containers similar to the one used in the Oitake SHP are cheap and easily available around the world. All mechanical, electrical and control equipment is installed in the factory (to factory standards) and the finished product can be simply put on the site with the help of a local civil engineering company. Utilizing local industry makes the installation of the SHP system even cheaper and faster. Furthermore, this compact hydropower system is very easy to move and install, which potentially will make it of interest to developers in other countries.

Lesson 2: SHP can benefit local communities and companies while helping countries meet their SDG goals

Installing this kind of SHP can benefit rural areas by promoting economic and community development and help companies in terms of technical know-how and increased business. They can also help governments meet the UN SDGs. One obstacle to implementing this kind of project is the difficulty in sourcing electromechanical machines and the total project investment costs, though the FIT system provides a degree of financial security for the SHP developers and investors.

Figure 2. The powerhouse

Note: *The powerhouse is actually a container used in shipping industries and in the case of the Oitake SHP it was ordered from a Korean company. All electrical and mechanical equipment has been installed inside this container, in what has been called a compact hydropower system.*

Box 1. Technical details of the 30 kW Oitake SHP project

Items	Values	Remarks
Turbine output	33 kW	Cross-flow
Total output	30 kW	
Electricity generation per year	215 MWh	Estimated
Total investment	JPY 50 million (US$ 460,000)	Approximate
FIT	34 JPY/kWh (US$ 0.31/kWh)	
Expected income per year	JPY 7.3 million (US$ 67,500)	Approximate
Present output	30 kW	

Box 2. SHP energy generation and income

Site condition and parameters of the SHP:

Effective head – 63 metres

Design discharge – 0.07 m3/sec

Turbine – Cross-flow T14 (D225, B55) from Asosiasi Hidro Bandung (Indonesia)

Efficiency of turbine – 76 per cent

Type of generator – IPM generator from Yasukawa Electronics (Fukuoka, Japan)

Generator spec – 1,450 rpm, 37 kW

Generator + GD + DC efficiency = ~94/95/95 per cent

Concept design of compact hydropower – Nakayama Iron Works Co. Ltd (Japan)

and Seiko Service and Engineering Co. Ltd (Japan)

Civil Engineering, consultant and owner – Shigekazu co. Ltd (Local, Japan)

Box 3. Concept design – using a shipping container to house the installation

A unique aspect of the 30 kW Oitake SHP is that it utilizes a 12-feet shipping container to house the powerhouse. This design concept offers several major benefits. The container acts as a strong shelter to protect the plants mechanical and electrical equipment. Moreover, this compact hydropower system is easy to carry and install, and reduces the time for construction and civil works, lowering costs and shortening overall delivery time with no requirements for assembly work or other precision work on site. With the system assembled and tested in a factory, the quality level, such as the finished wiring work, is very high. This compact hydropower system is also very easy to maintain – as the whole system can be lifted by crane and taken directly to the factory for testing, repair and general maintenance.

Figure 3. Equipment of the power plant

Note: *Equipment installed inside the container; the equipment in yellow is the cross-flow turbine which is connected to a grey generator. The equipment in three boxes is the control panel, behind which the resistor and transformer are installed.*

6. MUTWANGA SMALL HYDROPOWER PLANT IN THE DEMOCRATIC REPUBLIC OF THE CONGO: VIRUNGA'S BOLD HYDROPOWER PLAN, TRANSFORMING LIVES IN A CONFLICT AREA

The European Union Delegation in the Democratic Republic of the Congo; Virunga National Park

Investment in hydropower infrastructure, as a way of promoting community development, is an innovative approach for a national park, especially in a conflict-torn region in one of the poorest countries in the world. With the European Union assistance, Virunga National Park in the Democratic Republic of the Congo (DRC) is becoming the economic drive for the entire North Kivu region, pushing forward a bold hydropower plan for rural electrification, amidst illicit activities and armed groups, in a far from stable state.

In eastern DRC, rural electrification is being promoted by the oldest national park on the continent as a pathway to security and community development in a region marked by poverty and conflict. Virunga National Park is part of both the Nile and the Congo basins – the largest watershed in Africa and the second largest in the world. As such, Virunga sustains a system of lakes and rivers that contain a considerable amount of harnessable energy, which the park is using to revitalize the local economy in the form of sustainable hydropower.

By constructing low impact, run-of-river hydropower plants outside Virunga National Park's boundaries, the aim is to supply reliable and affordable electricity to households and the local economy, which will reach 4 million people who live around the park.

Virunga National Park and development through the Virunga Alliance

Virunga National Park (Figure 1), if badly managed, can become an economic burden for the people of North Kivu. Protection of 2 million acres of park land represents an opportunity cost of over US$ 250 million per year to the local economy if there is no alternative industry, such as tourism, to offset the cost.

As it stands, up to US$ 100 million in illegal revenue is generated from the park, which includes an estimated US$ 34 million in illegal charcoal, US$ 42 million in illicit fishing and tens of millions in illegal land grabs. Worryingly, these trafficking networks provide the main source of income for armed groups and weaken the Congolese state through associated corruption. Together, they contribute to a conflict economy that feeds on widespread unemployment, which, in turn, drives people to join the armed groups. This conflict economy also perpetuates poverty by preventing a secure environment in which a legitimate economy can thrive.

In response to these challenges, in 2013 Virunga National Park launched the Virunga Alliance, which brings together public authorities, civil society and the private sector in North Kivu around a shared vision of development. The organization has three main goals –conservation of natural resources, reduction of poverty and promotion of peace. A key role is played by rangers, who represent the state and apply the law in the territory of the park and, with some restrictions, in its periphery. The rangers patrol, seize illegal shipments, prosecute members of armed groups, arrest suspects and bring violations of the law to justice. Beyond the protection of the flora and fauna, their action is essential to the stabilization of the entire region.

In addition to its sovereign missions, the park is also an economic operator with a development agenda extending across North Kivu. It articulates its interventions around three pillars – tourism, sustainable energy and support for entrepreneurship and agricultural transformation. Overall, the plan's centrepiece is the rural electrification programme, which makes reliable, lower-cost electricity available to approximately 4 million people living around the park. It also aims to help thousands of small businesses to grow, thereby stimulating regional employment, which, in turn, boosts local empowerment and community development.

As Emmanuel de Merode, the Director of Virunga National Park, explains, "Every MW of electricity generated empowers the community by creating around 1,000 jobs, 5–10 per cent of which go to ex-combatants. When people are empowered they have the choice to control their future and move into productive society, and away from armed groups."

Figure 1. Virunga National Park

Note: *Managed by DRC's national parks authority, the Institute Congolais pour la Conservation de la Nature (ICCN), Virunga National Park is emerging as a regional leader by engaging in the implementation of community development projects in North Kivu. Its bold rural electrification plan is based on investments in hydropower.*

Hydropower in Virunga: SHP Mutwanga I and II

The small hydropower plant (SHP) Muwanga I, Virunga National Park's first SHP project, was launched in 2012 at the town of Mutwanga, which is in the Beni territory in the North Kivu province, about 40 kilometres by road from the Kasindi border crossing into Uganda. Just outside the border of Virunga National Park, Mutawanga sits at the base of the western slopes of the Rwenzori Mountains and the area has 42,000 inhabitants living across some 6,400 households.

The Mutwanga I SHP (Figures 2 and 3) runs with water from the Butahu River, flowing down Mount Rwenzori. The plant is a run-of-river station and is based on the diversion of river waters for just a few hundred metres. This creates a lower environmental impact than setups that require dams or flooding.

Figure 2. Mutwanga SHP

Note: *Water feeding the Mutwanga II turbine is taken from the Butahu River, as Mutwanga I, but higher up. This allows for a higher fall and more power production.*

Figure 3. The powerhouse of the Mutwanga SHP

Note: *A plaque outside the Mutwanga SHP, which houses both turbines, commemorates the launch of the plant in December 2012, with assistance from the European Union's 9th European Development Fund (EDF).*

The SHP initiative has a capacity of about 400 kW servicing over 600 homes, 43 businesses and two industrial investments. It also provides free electricity to schools and hospitals. Following the impressive societal benefits of the plant, an additional turbine, adding another 1 MW to Mutwanga I, was installed in early 2019 this year (Box 1). With the commissioning of Mutwanga II, 600 additional households will be connected in phase 1 which started in March 2019. Currently, phase 1 is in progress with 121 new clients connected and 283 clients expected to be connected by June 2019.

The overall aim of the upgrade was to further boost the local economy, in particular, by providing additional energy to power the SICOVIR soap factory which consumes a growing part of the local farm production. It also allowed more small- and medium-sized enterprises (SME's) and households to be connected to the grid. It is important to note that no other power supply is available in the region. While there is some household and business electricity connectivity via public and private generators or small solar panels, the vast majority of the population has not had access to electricity.

Box 1. Technical specifications of SHP Mutwanga I and II

A run-of-river hydropower plant, the SHP Mutwanga I has an installed capacity of 380 kW. A concrete dam directs part of the water through a 172-metre-long channel towards the forebay. Water flows through a penstock and drops 18 metres to feed a cross-flow turbine. A small gearbox allows running the alternator at the right speed.

Mutwanga II was completed in 2019. This second run-of-river hydropower plant was built to increase the power capacity to 1.35 MW. The turbine was installed in the building housing the Mutwanga I turbine, so as to reduce construction costs.

Mutwanga II collects its water through a small concrete dam. Due to the steep terrain, water is then conveyed through a 1,050-meter-long pipe along the cliff and a 1,180-meter-long channel to the forebay. Water drops 211 metres to reach a Pelton turbine which has two injectors. The high head makes it possible to reach 1.35 MW even with limited water flow rates. In terms of distribution, 6 kilometres of medium-voltage network and 24 kilometres of low-voltage network has been built and is currently in operation.

The benefits of SHP — transforming lives and local communities

The arrival of electricity has led to a complete transformation of life in the villages around the park. Specifically, the hydropower plants generate electricity for some 600 clients, including approximately 400 households and 200 businesses, as well as a hospital, four schools, an administrative building, a military camp, an orphanage, and the local radio station. The SHP initiatives also power over 60 street lamps.

> **'Apart from the electricity produced, the plants themselves will have significant impacts on livelihoods and contribute to agricultural transformation in the region.'**
>
> ***–Emmanuel de Merode, Park Director***

The park has set up an energy company, which is building the grid system, and has also initiated a small loans scheme linked to electricity consumption. Households that are connected to the grid are given a small electric cooker, which in itself implies local health benefits as it reduces charcoal use and the associated smoke-induced respiratory illnesses. In practice, households use electricity mainly for lighting. This has enabled children to study at home and home-based professionals, such as tailors (Figure 4), to work longer hours and work later in the evening. SHP-generated electricity has also improved access to infotainment and is used for powering radios and televisions and for charging mobile phones.

The conservation implications of this development are far reaching. Traditionally, most households in the periphery of Virunga National Park rely on wood or charcoal to meet their energy needs. This has led to deforestation and habitat destruction in the park. The clean energy provided through the hydropower investments is an alternative to illegal charcoal, which is also an important source of revenue for the armed groups.

The high demand for electricity by both pre-existing and start-up businesses helped to guarantee a client base ready to consume as much electricity as the hydropower plants are able to produce. Moreover, from an economic perspective, there has already been an increase in entrepreneurial ventures from palm oil processing plants to artisanal corn mills. For example, two industrial facilities, the SICOVIR soap factory (Box 2) and V Enzymes have been set up since the launch of the hydropower plants; while at least two others are currently being installed, including a chocolate factory and a chia seed processing plant.

In terms of employment, the Mutwanga I and II hydropower plants have contributed to the creation of 160 direct jobs in the two industrial facilities, as well as some 3,000 indirect jobs along the peasants' palm oil value chain (2018 figures). Furthermore, hydropower development has also benefitted the fishing industry around Lake Edward by enabling investment in refrigeration along the supply chain, thus increasing the size of the market.

Figure 4. A woman working as an apprentice in a tailor's shop connected to the hydroelectric grid

Note: *Electricity allows the tailors to utilize electric sewing machines and to work later into the evenings, increasing their productivity and weekly income.*

Figure 5. Working in the palm oil sector

Note: *Palm kernels purchased from local growers are processed into oil then sold to aggregators, who in turn sell it to the SICOVIR soap factory.*

Box 2. Agricultural transformation and the SICOVIR soap factory

The SICOVIR soap factory, the largest factory of its type in the eastern DRC, was only made operational as a result of the electricity generated by the Mutwanga SHP plants. Located on the edge of Mutwanga, construction of the SICOVIR facility began in September 2013 with operations starting in spring 2016. SICOVIR continues to provide much needed employment to the local community through permanent skilled jobs as well as short-term, low-skilled jobs. A large part of the soap factory was installed following the SHP development and it is estimated that 157–188 jobs per month can be directly attributed to electrification – job creation corresponding to a conservative ration of 337–449 jobs per MW of installed capacity. The factory also purchases crude palm oil, palm kernels and palm kernel oil from local producers via local depots and buys other agricultural goods, including wood, beans and rice, directly from local producers. Given that the majority of people in the Mutwanga area are supported by agriculture and by cultivating palm for sale, there is a significant potential for positive economic impacts across a broad population base through these agricultural purchases.

Box 3. Revitalizing the palm oil sector

According to 2018 figures, the Mutwanga I and II hydropower plants have contributed to the creation of some 3,000 indirect jobs along the palm oil value chain.

Moreover, SICOVIR guarantees farmers with an almost unlimited market for their production of oil palm fruit if the quality standard is met. Currently, the soap factory is obliged to buy up to 150 tons of palm oil per month from the Kisangani region to ensure its operations – limited palm kernel production in the region, coupled with artisanal extraction of oil severely affects availability and oil quality. Furthermore, through the 'Palm trees of Kivu' project, SICOVIR is now collaborating with the Virunga Foundation and an international network of organizations specialized in the development of agricultural sectors to boost the recovery of the palm oil sector in the Mutwanga region. Funded by the European Union, the project is helping to revitalize palm cultivation and palm oil processing in this area of the park and some 3,165 farmers in the area will be involved in the project, with more than 18,000 people benefitting from improved well-being of households. Virunga National Park will learn from this pilot with a view to launching similar projects in other areas of the park and for other agricultural sectors such as coffee, cocoa and maize.

Lessons for future SHP development

Lesson 1: Progress can be made even during times of conflict with the right support

Economic development in rural communities, in particular, communities in conflict, such as those in the eastern DRC, is a complex and challenging goal. The list of Virunga's complex challenges is long and includes illegal trafficking of charcoal and fish, corruption, political instability, rebels, armed conflict and violence. However, the payoffs of rural electrification in this particular case study are promising. A main take-away has been that substantial progress can be made even during times of conflict, as long as the right support is in place. As Emmanuel de Merode, Parks Director, indicates:

'The construction of the second hydroelectric plant started under artillery fire during the M23 conflict, but we had a motivated team and the plant was built within the specified deadlines and within budget. The lesson is that it is possible with the right approach and commitment. Fortunately for us the EU, our main donor, has been very understanding of that need. It is when the risks are highest that we need the most support. This explains, more than anything else, the success of the programme's continuity.'

Progress is still going strong and investment has been growing as the societal benefits are becoming visible. In 2015, a larger hydropower plant of 13.5 MW was completed at Matebe, and a network of distribution lines was constructed to take electricity out to nearby communities. Over 3,000 households and 125 SMEs are connected to this network, with new connections taking place at a rate of 25 per day. Some 15 villages have received free street lighting, which has had a major impact on the social lives and physical security of their inhabitants and this will be rolled out for many villages in the near future. Furthermore, the construction of an additional hydropower plant, a 15 MW SHP in Luviro, was started in 2017 and this plant is scheduled to go online by March 2020.

There are the day-to-day challenges of running power plants in the environment of instability, poverty and corruption. The two case study plants offer the administration lessons in trial and error. The challenging next steps will be for practitioners and researchers to show whether the impacts of the Mutwanga case study are scalable across larger hydropower projects, whether or not this economic development can help reduce violent conflict and armed group participation in the region and whether these sorts of projects ultimately benefit both local communities and conservation efforts.

7. SMALL HYDROPOWER DRIVING LOCAL DEVELOPMENT: TAKING XINGSHAN COUNTY, HUBEI PROVINCE, CHINA AS AN EXAMPLE

Source: NordNordWest/Wikipedia, https://creativecommons.org/licenses/by-sa/3.0/de/legalcode

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Considered a "starting pillar industry", SHP has underpinned the rapid development of Xingshan County, promoting industrial production and development, attracting investment and significantly boosting GDP. It has also helped to promote social and community development, increasing local incomes, alleviating poverty and helping to meet basic public needs.

Xingshan County is located in Hubei Province in the mountainous north-western corner of Yichang prefecture, China. The county, which is affiliated to Yichang City, has an area of 2,327 km^2 and a total population of 260,000. Overall, it boasts of 156 streams which form two major river systems, the Xiangxi River and the Liangtai River. With a total annual runoff of 2,096 million m^3, the county's theoretical hydropower potential amounts to 318 MW and the developable potential capacity is 242 MW.

SHP is arguably Xingshan's most famous brand and the county has long identified hydropower construction as a "starting pillar industry", while formulating a national economic development strategy of "hydropower industry starts, mineral industry makes breakthroughs, and forestry and fruit industry booms" (Box 1). One of the first 100 pilot counties to achieve rural primary electrification, Xingshan County was also listed as one of the 400 rural electrification counties in China during the 10th Five-Year Plan period (2001–2005).

Over the last 50 years, Xingshan has developed and built 84 hydropower stations with a total installed capacity of 220 MW, an annual power generation of 650–690 GWh and a per capita installed capacity of 1.3 kW. Xingshan County forms an electric power industry system integrating construction, generation, supply, utilization and management. Besides improving life quality, SHP development has significantly increased local fiscal revenue and promoted economic development across multiple sectors including local industry, agriculture, commerce and trade.

The benefits of SHP – improving life quality, promoting industrial production and development and attracting investment

The benefits of SHP development have been wide-ranging. SHP has improved life quality in rural areas in particular by solving the issue of poor rural illumination. Before the exploitation of SHP, rural areas in Xingshan County were mainly illuminated by burning pine torches and kerosene lamps. Continuous SHP development has powered rural lighting while also achieving self-sufficiency and delivering large amounts of electricity to the state grid. Electricity access has also meant washing machines and rice cookers now feature in many family homes.

SHP has also enabled electrical processing in rural areas. Traditional workshops, which depended on manpower and animal power in rice and noodle processing, oil extraction threshing, have been replaced by modern electric machinery that has significantly improved production efficiency. Over the last 30 years, the annual output value has increased from US$ 10.8 million to US$ 32.4 million, resulting in the creation of 1,520 jobs.

The county's long-term SHP commitment has also promoted industrial development. While solving the problem of daily electricity consumption in urban areas, Xingshan County used a large amount of surplus electricity to develop industrial production with a particular focus on mining and mineral and agricultural products processing – enabling a significant structural shift from agriculture-oriented to industry-oriented production.

Overall, SHP enterprises provide 1,500 jobs per year. Mining enterprises, accelerated by SHP projects, have an annual mining capacity of over 2 million tons and have created more than 1,000 jobs. Similarly, the Xingfa Group, a leading enterprise, which is mainly engaged in mineral product processing, has established two chemical parks in the county and is a major employer, achieving annual sales revenue of more than US$ 150 million.

'Xingshan County used a large amount of surplus electricity to develop industrial production... enabling a significant structural shift from agriculture-orientated to industry-orientated production.'

SHP has also stimulated investment and promoted cooperation in Xingshan. Due to its abundant SHP resources, Xingshan County has been able to absorb social capital to participate in SHP exploitation. The county has 21 state-owned hydropower stations, 54 installed units, 145,050 kW of installed capacity and a designed annual power generation of 546.67 GWh. It also has 61 hydropower stations developed with private capital, with 123 installed units, a capacity of 75,395 kW and the designed annual power generation of 294.41 GWh.

Since 2011, Xingshan County has also established an industrial park in Pingyikou and attracted a number of new industries with high technology content, good economic returns, low resource consumption and low environmental pollution. So far, eight enterprises have settled in the park, providing over 600 jobs. Annual sales revenue has increased by nearly US$ 1,500 million and total taxes exceed US$ 150 million.

Meanwhile, the agricultural product processing industry has been vigorously developed. Projects include the production of Gegen (kudzu vine root) vinegar and base wine, tea processing, ecotourism and sightseeing, undergrowth cultivation, and biological organic and inorganic compound fertilizer production. In the tourism logistics industry, five logistics transportation enterprises and 10 commercial enterprises have also been introduced, and planning and investment have supported Nanyang Hot Spring and Longmen River tourism in the county. Moreover, Xingshan Gaolan River Water Conservancy Scenic Area, Gufu River Water Conservancy Scenic Area and Nanyang River Water Conservancy Scenic Area have been successfully branded as "Hubei Provincial Water Conservancy Scenic Areas" by Hubei Province.

Figure 1. The powerhouse of the Mantianting SHP

Using SHP to stimulate economic development and social consumption, increase personal income and taxation, and help meet basic public needs

SHP has driven economic development and boosted the GDP growth in Xingshan County which was low in part due to the lack of access to electricity. For example, in 1978, there were less than 20 industrial enterprises in the county and an industrial output value of only US$ 1.7 million, accounting for only 28 per cent of the total industrial and agricultural output value. By 1994, the number of industrial enterprises had increased to over 4,000 and the industrial output value reached US$ 77 million.

In terms of the county's industrial economy, resource development enterprises and resource transformation enterprises in chemicals, electronics, machinery, building materials, papermaking and processing have all developed rapidly. While the output value per kWh of electricity reached US$ 0.21, the power consumption and conversion rates were the highest in the province. In 2016, the county's GDP was over US$ 1.5 billion, around 19 times that of 2011.

SHP has also effectively promoted the rapid growth of social consumption in Xingshan County. By 1994, around 95 per cent of rural households used electricity, with 31 per cent replacing firewood with electricity. Overall, the average annual electricity consumption reached 410 kWh, driving the consumption of power and related products. Further, SHP development has significantly increased personal income, the monthly per capita disposable income of local people increasing from US$ 71.6 in 1990 to US$ 1,630 in 2017.

'In 2016, the county's GDP was over US$ 1.5 billion, around 19 times that of 2011. Further, SHP development has significantly increased personal incomes, the monthly per capita disposable income of local people increasing from US$ 71.6 in 1990 to US$ 1,630 in 2017.'

The amount of local taxes raised has also increased, and the county is no longer dominated by the traditional agricultural economy nor characterized by insufficient tax sources and long-term national financial subsidies. Similarly, the proportion of industrial economy in Xingshan County has gone up continuously over the last 30 years of development, while the SHP industry still accounts for a considerable proportion of the county's fiscal revenue.

SHP has also helped in the development of other sectors including local building materials, transportation, catering, commerce, construction, tourism, agricultural and other product supply and other service industries. This has provided a large number of indirect employment opportunities and accelerated the development of the county's mines, industrial park construction and urban construction, and contributed to meeting the county's industrial demand for water. Meanwhile, sufficient electric power has boosted Xingshan's tourist industry, with Zhaojun Village Scenic Area now gaining popularity among tourists, the Gufu River project proving a major attraction, and rural tourism and farmhouse tourism developing rapidly to become important channels to increase farmers' income.

Moreover, SHP helped with water supply engineering to satisfy basic electricity and water needs of urban areas and industries. The county has eight townships and some village committees have implemented unified water supply from the water supply company. SHP has also been used to address long-term water shortages caused by geographical and environmental factors as is the case in Huanglian Town, which used SHP-generated electricity for cascade water diversion.

By utilizing power to implement artificial water diversion, the irrigation needs for various economic crops such as citrus, tobacco and vegetables have been effectively met; and reservoirs, such as Gudongkou and Qinglongzhai, play an important role in flood control and crop irrigation. At the same time, the development of SHP projects has led to the construction of many rural roads across the county.

SHP and social responsibility – poverty alleviation, assisting migrant groups and supporting local education

The Xingfa Group assisted both Shukongping Village and Maocao Village of Shuiyuesi Town in Xingshan County to alleviate poverty. Specific measures, which are directed at areas with an average monthly income per capita lower than US$ 581, were adapted to local conditions and often creatively combined national green hydropower with New Countryside Construction. Poverty alleviation methods were employed along with infrastructural improvement. In the two villages assisted, a total of 97 households were lifted out of poverty.

The Xingfa Group also engaged in poverty alleviation and relocation for residents of areas affected by hydropower, and this has focused in particular on the construction of three migrant resettlement communities – Maocaoping Community, Guanzikou Community and Gaolan Community. The Maocaoping Community has already been built and 30 migrant families have been resettled in a development, which has undergone a significant improvement in living conditions and environment, and access to facilities, utilities and transport.

The Xingfa Group also implements a fundraising policy for company employees' children, who are admitted to universities, thereby reducing economic stress; and it assists employees in need and provides assistance to employees with special difficulties or suffering from major illnesses to help prevent impoverishment of workers' families.

Lessons for future SHP development

Lesson 1: SHP can promote the coordinated development of the regional economy

SHP has brought prosperity to all industries and the development of SHP projects has enabled effective utilization and availability of resources in different regions. It has also facilitated the synchronous advancement between developed and less developed regions, between industry, agriculture and tertiary sectors, and between county and village households. Moreover, it has contributed to narrowing the gap between regions and industries, and promoted the coordination of economic development.

Figure 2. Drifting in the Basin of Chaotianhou SHP

Lesson 2: The importance of building public infrastructure to support SHP-inspired economic development

For many years, high traffic levels restricted Xingshan's agricultural products and farmers' income. In order to fully benefit from SHP-related economic development, it was necessary to support the construction of transportation infrastructure including highways, ports and piers, and rural ferries. The construction of these projects has optimized the road network in the county and has laid the foundation for regional economic development and poverty alleviation.

Lesson 3: The importance of green SHP construction

SHPs with a small installed capacity, ageing equipment and low efficiency have been phased out with a view to protect the natural environment. In 2017, the Gengjiahe hydropower station, which was built in the 1960s, and the Jiangjunzhu hydropower station built in the 1980s, were both dismantled. Moreover, from 2017, ecological water discharge projects were fully implemented by 28 hydropower stations in the Gaolan, Nanyang and Gufu river basins to ensure continuous water flow throughout the year.

Lesson 4: The need to guarantee future development

Xingshan County is rich in SHP resources. In future, it will make better use of these resources and will actively engage in scientific development to improve SHP efficiency and usage with a view to protect the ecological environment. Through scientific and technological progress, the county will oversee the mechanization, automation and intelligent transformation of existing SHP stations to enhance the efficiency of power generation and supply. It will also make use of SHP and other power resources to accelerate the extensive use of electric machinery, production equipment, automobile and other sectors. It will also strive to reduce the application of gasoline and diesel engines, and contribute to reduce air pollution and protect the natural environment.

Lesson 5: GEF value-added services

During the 12th Five-Year Plan period (2011–2015), Xingshan County engaged the Xingfa Group as a leading enterprise and actively sought policy support from the joint project of ICSHP and the Global Environment Facility (GEF). The Xingfa Group implemented central and provincial financial support, gaining over US$ 10.7 million in self-raised and subsidy funds from central and provincial governments, and carried out efficiency improvements, capacity expansion and the transformation of the Houzibao, Cangpinghe, Jiuchonghe and Nanyang hydropower plants in the Nanyang River Basin. In 2017, Xingshan County launched an initiative aiming to increase the efficiency and expand the capacity of SHP projects on the Gaolan River and Gufu River.

Box 1. Xingshan's booming forestry and fruit industry

Before the 1980s, agricultural production in Xingshan County was dominated by grains with a low proportion of cash crops. From 1986 to 2005, taking advantage of the mountainous terrain, Xingshan County established its new economic development strategy, "hydropower industry starts, mineral industry makes breakthroughs, and forestry and fruit industry booms".

The county's lower-altitude areas focused on four kinds of oranges – navel orange, Jincheng orange, summer orange, blood orange and a kind of tung tree; the mid-altitude mountainous areas focused on four fruits and two leaves, which included walnut, chestnut, hawthorn, ginkgo, tea and flue-cured tobacco; while the high-altitude areas focused on two forest projects and one grass project, which included artificial forestation and hillside enclosure for forestation and forage.

During the 11th Five-Year Plan period (2006–2010) and based on the idea of "mountain exploitation, cultivated land remediation and base construction", the county focused on the "three specialities" of building a professional village, professional farms and specialized households. It also focused on three modernizations of projectization, standardization and commercialization, and prioritized the development of five big industries – livestock, fruit and tea, tobacco, vegetables and medicinal herbs.

In 2018, the total agricultural output value of the whole county reached US$ 343 million, 18 times higher than in 1989 and the annual per capita disposable income of rural residents was US$ 1,779. In terms of specific products, the citrus yield of the entire county totalled 96,918 tons, a 112-fold increase in less than 30 years, and 2,341 tons of tea was produced, up by 26.5 per cent. Meanwhile, some 251,000 tons of vegetables were grown increasing the self-cultivation and self-sufficiency of farming communities and the tobacco yield reached 1,992 tons, up by 35.6 per cent, while the output of traditional Chinese medicinal products was up over a quarter reaching 4,782 tons. Moreover, the local farm industry had a total of 288,900 pigs and 184,200 goats, a significant increase from previous years.

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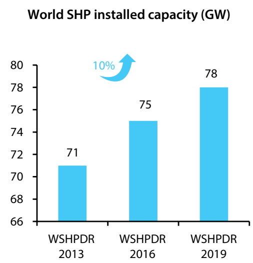
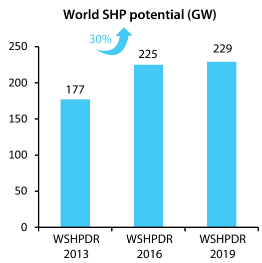
World Small Hydropower Development Report

The *World Small Hydropower Development Report (WSHPDR) 2019* is an update of the Report's first two editions in 2013 and 2016. The *WSHPDR 2019* contains **166** national reports and **20** regional reports, with 21 new countries added since its first edition.





- The Report is available on **www.smallhydroworld.org**;
- More than 230 experts and organizations have been involved;
- Every country report provides information on:
  a. Electricity sector;
  b. Small hydropower sector;
  c. Renewable energy policy and;
  d. Barriers to small hydropower development.

A special report with **Case Studies** is added to the *WSHPDR 2019*, showing the different roles small hydropower can play in achieving the SDGs.

- SHP for productive use
- SHP for social and community development
- SHP financing
- Technology, innovation and smart SHP
- Incentive policies for SHP development
- Green SHP

Small hydropower for a better world

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