PEREZ-GUERRERO TRUST FUND FOR ECONOMIC AND TECHNICAL COOPERATION AMONG DEVELOPING COUNTRIES

Final Report on

Micro Hydropower Plant Development on Existing Irrigation Canals for Sustainable Socioeconomic Development of Rural Areas: Pilot Projects in Selected Developing Countries

International Center on Small Hydro Power

July 2019, Hangzhou, China

Ⅰ. Project Overview

1. **Project Title:** Hydropower Plant Development on Existing Irrigation Canals for Sustainable Socioeconomic Development of Rural Areas: Pilot Projects in Selected Developing Countries

2. **Abstract:** This project is planning to utilize the otherwise wasted existing water flow drop energy from multipurpose water canals, mostly used for irrigation proposes. It provides low-cost solutions for areas where the extension of a grid system is uneconomical. By using existing irrigation canals there are fewer civil works involved, making the projects cheaper, faster to implement and even more environmentally friendly. The greatest advantage for hydropower generation at the canal drops is continuous operation at maximum efficiency under constant head and discharge for a unit, so it is easy to connect the plant to the national grid if a connection is desired. Micro-hydropower is easy to operate and there is no need for rigorous maintenance. ICSHP plans to tap this energy and promote rural development by using pilot projects to create standardized technology for implementing it afterwards all over the developing world.

3. **Background Analysis:** There is great untapped energy potential and increasing energy need especially in remote rural areas. This project is planning to develop micro hydropower plants on existing irrigation canals by adapting water drop rather than constructing dams to change the flow, which provides low-cost solution for remote and hilly areas. Besides much cheaper and more environmentally friendly, the greatest advantage for hydropower generation at the canal drops is operation at maximum efficiency under constant head and discharge for a unit. Micro hydropower is easy to operate and there is no need for rigorous maintenance. The micro-hydro system also can provide job opportunities for the civil works which promotes the rural employment. Power would bring major socioeconomic development to villages. Micro-projects provide power for: battery charging, welding workshop, crop processing, grain milling, home electrification, faming, street lighting, fishing industry, and other small business. Remote communities gain using micro-hydro electric systems such benefits as, refrigeration for health clinics, computers and radio for schools, internet access and mobile phone charging. Also, these beautiful hilly areas could become attractive spot for tourists due to the availability of power.

   However, the energy of the falling water at the irrigation canal drops are often wasted through special energy dissipating devices. This project proposes to tap this energy and promote rural development by developing pilot projects to create standardized technology for implementing them all over developing world.

   The selected pilot project countries possess an enabling policy framework on renewable energy but still with barriers. Nigeria’s National Renewable Energy and

Energy Efficiency Policy (NREEP) indicates hydropower as the most important renewable energy sources that national aims to harness to its full potential. India is constantly planning to reduce the carbon emission to meet the electricity demand for economic development. The renewable energy, especially the hydropower, will be listed at the top for development. India has been active in developed small hydropower on its existing irrigation dams and irrigation canal falls. Ethiopia's major objective for the energy sector is to provide sufficient and reliable power sources at all time for economic and social development as well as for irrigation activities, to accelerate and complete the construction of the ongoing hydropower electric generation projects. Madagascar's new policy on renewable energy is expected to strengthen the governance framework and encourage the predominance of renewable sources in the energy mix.

China has many successful experiences on rural small hydropower and micro hydropower electrification, demonstrating that the decentralized development of SHP could be an effective approach for rural energy supply and poverty mitigation. Within the South-South cooperation framework, China's practice and experience in SHP have been widely spread worldwide.

Ⅱ. Implementation

The implementation of this project is divided into four distinct stages, but only first three stages are involved in current project report. The remaining stage is a future strategy, in order to further provide relevant technical assistance for target countries.

- **The first stage** is to take technical consultation on potential canal drop hydropower sites selection for the target countries. ICSHP invited experienced experts from our members to provide technical assistance for potential site selection in India, Nigeria and Ethiopia, technically analyzing the comprehensive conditions of the potential locations.
- In **the second stage**, ICSHP organized expert teams to India, Nigeria and Ethiopia to provide on-site technical guidance and relevant training to the local engineers on canal drop development to enhance in-house capacity. The on-site investigation selected the potential sites and data for future feasibility studies. Meanwhile, ICSHP also invited officials and experts from target countries to visit the sites in China.
- **The third stage** is to produce one technical and business proposal for further construction of the canal drop hydropower plant in one of the target countries, including all the technical data which provide technical reference for the local technicians to prepare the prefeasibility studies and even the design report.
- As planned ongoing strategies, ICSHP will strengthen cooperation with target countries. ICSHP will provide more opportunities for local investors and hydropower owners in target countries to explore the new business model for the canal water development.

Beneficiaries:

The first to benefit from this project will be local technicians/experts as well as SHP/MHP investors in India, Nigeria, Ethiopia and Madagascar. ICSHP will provide guidance and relevant training to achieve cheaper and more efficient way to utilize water drop energy from the existing irrigation canals, minimizing the total investment cost and time for project development. After implementation of canal drop micro hydropower plants the local rural communities around the plants will be the main beneficiaries. They will have access to affordable and green electricity what will bring substantial improvements to their quality of life and improve socioeconomic conditions. The successful tapping of irrigation canal energy will also serve as show case to the whole region of the target countries. This project will contribute to achieve global environmental sustainability by supporting green economy that brings prosperity to developing countries.

Ⅲ. Completed activities

Activity-1:

Time: September, 2017

Location: Hangzhou, China

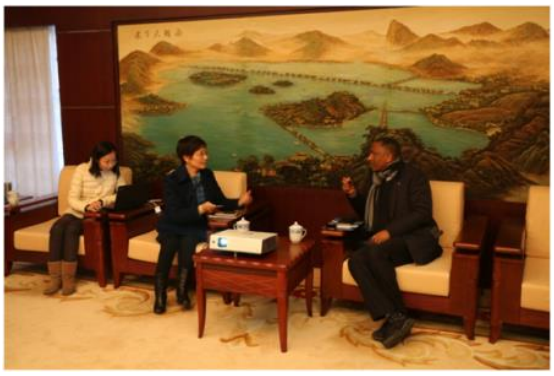
Implementation: ICSHP organized a training workshop for officials of small hydropower and energy from developing countries, including Ethiopia, Madagascar, Nigeria, Ghana, Kenya, Tanzania and Uganda. The experts from ICSHP and academic institutes gave the lectures covering SHP technology, planning, equipment, construction, management, financing, hydropower plant development on existing canals and international cooperation. The workshop also arranged the participants to visit equipment manufacturer, hydropower plants and technology company in Zhejiang

Province. At the end, the participants submitted country reports for exchange with local investors, and a certificate of completion was issued to every participant.

Activity-2:
Time: November, 2017
Location: Ethiopia and Nigeria

Implementation: ICSHP sent experts to visit Nigeria and Ethiopia to conduct site selection for existing irrigation canals. Experts visited Ministry of Water Resource of Nigeria and Ministry of Water, Irrigation and Electricity od Ethiopia to collect relevant data of existing potential sites. Experts visited 2 potential sites in Nigeria and Ethiopia respectively and gave on-site consultation for local technicians, engineers and officials

Activity-3：
Time: January, 2018
Location: Hangzhou, China



Implementation: Mr. Workneh Delegn, director of Ministry of Industry of Ethiopia visited ICSHP. He said the primary responsibility of Ministry of Industry of in future will be to develop the renewable energy especially small hydropower. Ethiopia has abundant hydropower resources and he hopes to introduce Chinese hydropower equipment, technology and capital to promote Ethiopia's hydropower development.

Activity-4:
Time: April, 2018
Location: Kerala of India




Implementation: ICSHP sent experts to visit Kerala of India to conduct site investigation for an existing irrigation canal. They held a meeting with the project owners Bekal Resorts Development Corporation Ltd (BRDCL) and Energy Management Centre (EMC) under Department of Power of Kerala, giving on-site consultation for local technicians and plant owners. They also collected all the relevant

data for preparation of the proposal for hydropower plant development on existing irrigation canal.

Ⅳ. Activities costs

Activities costs of this project were strictly based on the financial budget. IC-SHP referred specialized accountants to manage the economic evaluation and review for this project. Project leaders were also responsible for monitoring of cost for each activities regarding to the project and required for submission of periodical report to the Director General of IC-SHP for processing and stage of the project. Details are shown below:

No.	Items	PGTF Fund	ICSHP Fund	Total
1	International travel	17,000 USD	20,000 USD	37,000 USD
2	International consultants	5,000 USD	5,000 USD	10,000 USD
3	National experts	5,000 USD	5,000 USD	10,000 USD
4	Workshop organization	3,000 USD	10,000 USD	13,000 USD
5	One technical and business proposal	3,000 USD	5,000 USD	8,000 USD
6	Domestic travels	0 USD	5,000 USD	5,000 USD
	Total	**33,000USD**	**50,000 USD**	**83,000USD**

Ⅴ. Project management arrangements

The project is implemented by the International Center on Small Hydropower (IC-SHP). IC-SHP has appointed a project coordinator. All project staff is appointed by IC-SHP. IC-SHP is responsible for producing and submitting a report to the UNDP China Office following allocation of 90% of the budget resources. The IC-SHP Director General (DG) bears the ultimate responsibility for overall management of the project.

IC-SHP has executed the project under UNDP National Execution modality (NEX). As executing agent for the project, IC-SHP is responsible for the reporting and financial requirement foreseen under the UNDP's national execution procedures and guidelines.

Progress monitoring is mastered by the China International Center for Economic and Technical Exchange, Ministry of Commerce. However, any staff from the UNDP or Perez-Guerrero Trust Fund undertakes monitoring activities in line with managerial roles above. All lessons learned will be written into a report after the project has been implemented.

Ⅵ. Appendix

The list of participants and schedules of the training workshops held in Hangzhou and in Hangzhou are collected as appendixes shown as following:

Appendix-1

Participant list of the training workshop in China

No.	Name	Country	Gender	Position	organization
1.	Tsigereda Atnafu MAKONNEN	Ethiopia	Female	Project coordinator	Ministry of Water, Irrigation and Energy of Ethiopia
2.	Hery Tiana RAKOTONDRAMIARANA	Madagascar	Male	Associate professor	University of Tananarive
3.	Tovoniaina RAMANANTSOA ANDRIAMPANIRY	Madagascar	Male	Technical Advisor of the Director General of Energy	Ministry of Energy, Water and Hydrocarbons
4.	Isa BUBA	Nigeria	Male	Assistant to director	Ministry of Science and Technology
5.	Emma Bambo Onoriode ISHARUFE	Nigeria	Male	Project officer	Ministry of Science and Technology
6.	Abbas GUMMI	Nigeria	Male	Director	Ministry of Science and Technology
7.	Faith Ebere Martina UDEH	Nigeria	Female	Senior Officer	Ministry of Science and Technology
8.	Khalilat NAIBI USMAN	Nigeria	Female	Assistant	Ministry of Science and Technology
9.	Sulaiman Abubakar ADAMU	Nigeria	Male	Assistant to Director	Ministry of Science and Technology
10.	Zahrau Kasim YAHAYA	Nigeria	Female	Technical Officer	Ministry of Science and Technology
11.	Toto Zedekia KISINZA	Tanzania	Male	Manger	TAMESCO
12.	Adolph Joseph KIGOMBOLA	Tanzania	Male	Engineer	TAMESCO
13.	Mkufu Shabani TINDI	Tanzania	Female	Senior Engineer	TAMESCO

14.	Nana Akua Ampomaah AGYAPONG	Ghana	Female	Appraiser	Ghana President Special Initiatives
15.	Maxwell Arko Ofosu	Ghana	Male	Appraiser	Ghana President Special Initiatives
16.	Eric GHANSAH	Ghana	Male	Project Manager	Ghana President Special Initiatives
17.	Rhoda Madey AGBESHIE	Ghana	Female	Analyst	Ghana President Special Initiatives
18.	Isaiah Kase OKUTHE	Kenya	Male	Senior Assistant to Director	Ministry of Energy and Petroleum of Kenya
19.	Peter Rimba Maneno RUWA	Kenya	Male	Engineer	Ministry of Energy and Petroleum of Kenya
20.	Robert Bonaya MIYESA	Kenya	Male	Manager	Ministry of Energy and Petroleum of Kenya
21.	Alan Yeseri LWABI	Uganda	Male	Senior Civil Engineer	Uganda Electricity Transmission Company Ltd.

Appendix-2

Schedule of the training workshop in China

Date	Time	Activities	Remark
9.13		Registration	
9.14	**Morning**	1. Opening 2. Lecture 1: China SHP Development ——Ms. Huang Yan	
	Afternoon	3. Lecture 2: SHP development, construction and management ——Prof. Liu Deyou	
9.15	**Morning**	4. Lecture 3: General situation of small hydropower development and rural electrification in China ——Ms. Cheng Xialei	
	Afternoon	5. Lecture 4: SHP equipment, investment and financing ——Mr. Tan Xiangqing	
9.16		City tour	
9.17	**Morning**	6. Site visit 1: Hangzhou Fuchunjiang Equipment Manufacturer	
	Afternoon	7. Site visit 2: Fuyang Yanshiling Cascade 2 hydropower plant	
9.18	**Morning**	8. Lecture 5: Hydropower plant development on the existing irrigation canal ——Mr. Li Zhiwu	
	Afternoon	9. Lecture 6: SHP international cooperation ——Mr. Dong Guofeng	
9.19	**Morning**	10. Site visit 3: Zhejiang Jinlun Hydropower Equipment Manufacturer	
	Afternoon	11. Lecture 7: SHP equipment manufacturing ——Mr. Wang Guowei	
9.20	**Morning**	12. Lecture 8: China SHP Standards ——Ms. Cheng Xialei	
	Afternoon	13. Lecture 9: Case study of SHP development ——Mr. Dong Guofeng	
9.21	**Morning**	14. Country reports presentations	
	Afternoon	15. Closing	
9.22		Departure	

Appendix-3
Technical and Business Proposal for Indian site.

PROPOSAL FOR BEKAL MINI HYDRO ELECTRIC PROJECT (3 x 170 kW)

Preamble:

It is proposed to implement a mini hydro power plant for power generation utilizing the discharge of the Kudumbur River and the head differential of the downstream of the existing Bangad check dam (weir). The project implementation is proposed as a consortium with Bekal Resorts Development Corporation Ltd (BRDCL) and Energy Management Centre (EMC) under Department of Power, Govt. of Kerala.

Installation of Archimedean Hydropower Screw type turbines of 170 kW capacity each is proposed for 510kW hydro power development as a run of river scheme at site located near the Bangad Check dam.

Introduction:

Archimedean Hydro Power Screws which can be used for generation of renewable energy using heads as low as 1 meter and flow as little as 1 m^3/second.

This renewable energy technology was introduced in Europe in early 2000 and is being greatly used to tap the full renewable energy potential from all the out lets of ETP/STP and fresh water falls of 1 m to 10 m by single screw.

This machine is the most efficient and viable option for low water fall and capacity sites, where, Pelton, Francis, Kaplan turbines do not technically suit. The range of performance is within 10 m^3/sec capacity at a head below 10 m, producing 500KW at mx. Flow and head.

Field of application for Hydro Power Screw Turbines:

- To use at run of river sites.
- To make use of treated water outlet of sewage plants.
- To make use of residual ecological flow passing over weirs at existing water intake.
- To replace derelict / unused water wheels.
- To extend the production of hydropower at existing Hydro Electric Installations.
- To replace small turbine plants requiring overhaul.

Site description:

This site is identified as a suitable one for Mini hydro energy generation up to 510 kW using 3 nos. of Archimedean Hydropower Screw. This site is located adjacent to the existing check dam on Kudumbur River. As per the topography of this location, a weir of 40meter wide is constructed across the river with more than 3 meters head available. Total weir height is of 5m. If we use 3 meters of available head with 8 cumecs flow by each turbine then around 172kW power generation is possible. With combination of 3 turbines total 510kW hydro power house can be proposed at this location.

We will extract 24 cumecs of water from the river and this water will be diverted to pass through 3 nos. of Screw turbines installed in parallel thus each taking 8 cumecs of water. After passing through the turbines this water will be discharged back to river after a distance of some 15-20 meters only.

Hence with utilizing this 3 meter of head and design discharge of 8 cumecs by each Screw, a mini hydro power project of capacity 3 x 170 i.e. 510kW is proposed at this location.

The Technology:

The Technology adopted here is Archimedean Hydro Power Screw, which can be installed easily with less civil work, long run & excellent reliability. Usually this system consists of one no. of screw turbine, couplings, Gear Box, Emergency brake, Alternator & control panel.

This screw shall be kept at inclination of around 22-25 deg from horizontal level and water will be made to pass through the screw and thus due to the water force, flights of screw will start rotating. This rotational speed through coupling will be transmitted to gear box. Gear box with its suitable gear ratio will increase the output rpm to 1500 and thus the alternator coupled to gear box will generate electricity.

Why Hydropower Screw?

Many technologies such as water wheel and Kaplan turbines are not that suitable for site mainly due to very low head and location non suitability, high wear & tear, less efficiency, costly maintenance and life. The other option is to go in for bulb type propeller turbines with large runner size for handling huge discharge due to low head of the scheme. This type of machine needs lot of excavation since the machine centre line will be below the tail water level to avoid cavitation. This type of construction near the existing check dam is risky, time consuming and costly due to continuous dewatering required during excavation and the subsequent mass concreting for the turbine installation and side protection with concrete walls to take care of the depth of foundation.

Whereas, Hydropower Screws are the best available technology in the world today to generate Micro/ Micro/ Mini power of this kind even with head of 1 meter and shall have the advantages listed below.

1. Speed as low as 25rpm resulting long lives, negligible wear & tear.

2. Good operating efficiency compared to conventional turbines & water wheels.

3. Fish Friendly.

4. No extensive civil engineering works required.

5. No noise pollution.

6. No cutting of trees, displacement of people

7. Negligible maintenance due to low rotation speed.

8. Operative life of over 30 years.

Site Conditions:

The water of the Kudumbur River has a drop at weir located near the weir. As a gradual fall of more than 3 meters is available after weir, can be used for power generation. If a hydro power house is built by tapping water flow with this unused head at this location, then, there will be a possibility of 510kW power generation and substantial revenue in terms of energy generation. Further, this green initiative will help not only in encouraging renewable energy but shall contribute in worldwide efforts to reduce the causes of Global Warming by reducing carbon emissions.

Proposed Hydropower Plant:

A 510kW hydro project based on 3 nos. of hydropower screws can be proposed at Kudumbur River where flow has a drop pf more than 3 meters at the existing weir located at Bangad. Location of screw turbine based MHP is at left bank of river both in the upstream and downstream areas of the existing check dam.

A raft of 300-400 mm height will be made to guide water towards in feed channel of screw turbines. At the cut point a trash rack is proposed to tackle large foreign particles.

Individual gates are proposed for each Screws in in feed channel for flow control.

Total three nos. of Hydropower Screws will be installed in parallel arrangement and the required quantity of controlled flow of discharge water i.e. 8 cumecs of water for each Screw will be allowed through the gates to pass through these Screws installed at 22-25 deg inclination. This will make the screw to rotate at a lower speed of less than 30 rpm which will be increased by speed increaser gear box to the rated speed of the generator which is coupled to gear box.

Another small length bypass channel is proposed from in feed channel to guide excess water to pass to the river directly. In case of maintenance of Screw, gate at in feed channel will be closed & water will pass through existing route.

In lean period when water flow is less, all the water will be accumulated in in feed channel because of raft provided and will pass through nos. of Screws depending on volume of flow and thus generating equivalent power as per available quantity of water. Hydropower Screw will be rigidly erected by grouting the mounting pedestal and fastening with the foundation bolts.

The powerhouse of around 16 x 10 meter will be constructed above of in feed channel and will house generator, gear box, grease pump assembly and the control panel. This powerhouse will be of RCC wall type structure with a canopy.

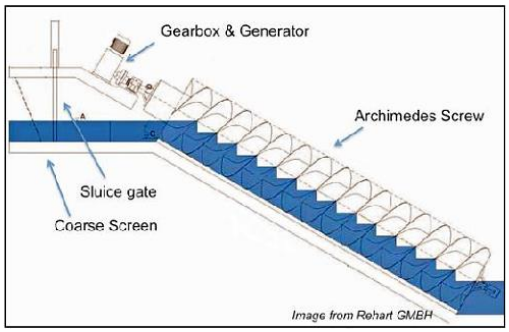
The above details of proposed MHP are tentative only and exact design of layout can be decided during detail engineering stage.

Determination of Power Potential:

Net Head: 03 m, Design Discharge: 3 x 8 m3/s

Power Generation: 170 x 3 kW Overall plant capacity: 510 kW

Typical Layout of Hydro Power Screw Plant



Some Installed Hydro Power Screw Plants

TECHNICAL DETAILS - Power Generation from Hydro Power Screw Turbine

Technical: Hydropower Screw c/w Steel Trough for casing

Net head: 3.0 m

Discharge Capacity: 24 m^3/sec (By 3 Screws)

Number of screws: 3

Electrical power: 3 x 170 KW i.e. 510 KW

Type: Inclined installed, fish friendly multiple winded Hydropower screw c/w trough

Upper bearing grease lubricated; Lower bearing grease lubricated

Gearbox and coupling: Flexible coupling between Hydropower screw and gearbox;

Synchronous/asynchronous generator

Nominal power – 210 kW, Voltage 415 V; Frequency 50 Hz; Protection IP 55

Emergency brake - Electric disk brake system;

Low-voltage control switchboard, Sluice gates— 1 no. for each screw, trash rack – 1 no.

Installation and Commissioning:

Technical Parameters:

1. Head Available : 5 mtrs
2. Head considered for power generation : 3 mtrs
3. Discharge through each Screw : 8.0 cumecs x 3
4. Rated Power Generation for Unit : 170 KW x 3
5. Quantity to be installed : 03 no.
6. Total Power Generation : 510 kW
7. Annual generation From Hydro Plant : 2 mU with 45% PLF
