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

Final Report on

Identify the New Business Model for African Small Hydropower Development through Technical Assistance

International Center on Small Hydro Power
July 2020, Hangzhou, China

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Ⅰ. Project Overview

1. **Project Title:** Identify the New Business Model for African Small Hydropower Development through Technical Assistance

2. **Abstract:** Small hydropower is a smart choice for African countries who need affordable decentralized energy. Although small hydropower has this potential to contribute greatly to enhancing renewable energy generation in most African countries, the barriers for its development are significant. This project is planning to provide technical assistance on small hydropower development for targeted African countries, in order to identify effective business models for SHP investment. Training course and study tour will be organized for those project owners, developers, investors, administers and technicians. Meanwhile, the project also intends to provide technical guidance for site selection and financing plan of the feasibility study. With China's successful business models on SHP investment, the project plans to promote the exploration of new business models in African countries.

3. **Background Analysis:** SHP systems have many economic and social benefits that make them suitable for meeting growing energy needs of rural areas in the developing countries. Moreover, small hydropower resource is available on a decentralized basis in abundance in most of the developing countries. Often, materials for civil works of SHP systems can be sourced locally, and it is easy to build local capacities for operational reliability. SHP systems can provide energy for development of remote areas through creation of job opportunities for both women and men through linkages with productive uses, and also provide social benefits such as energy for schools, health centers and Information Communication Technology (ICT) systems. Therefore, the development of small hydropower projects is expected to serve as a relevant tool to improve energy security and offer economic and social advantages to developing countries, especially African countries, where small hydropower can electrify rural areas for the first time. SHP can reduce dependence on fossil fuels, advancing energy access, and improving air quality while creating job opportunities for local people.

   The rural areas and poor cities and towns in Africa need affordable energy, and many do not rely on a large number of imports. Therefore, local production and distribution of renewable energy is a much more sustainable alternative if it can be made feasible. Africa Energy Outlook by International Energy Agency (IEA) suggests that by 2040 the generation from renewable energy can account for 45% of the total in the region. So far, only 10% of the technical potential of small hydropower in Africa has been developed and more than half of it is concentrated in central and eastern Africa. Although small hydropower has this potential to contribute greatly to enhancing renewable energy generation in most African countries, the barriers for its development are significant. In addition to natural issues depending on different regions, a dominant issue in Africa is the lack of a transparent, complete and accessible regulatory framework that encourages and facilitates the early stage risk of finance investment for small hydropower development. This can result in large upfront investment followed by a lack of technologies and management. Therefore, it is quite necessary to identify effective business models for African small hydropower development through technical assistance in order to make investment on small hydropower more efficient.

The selected countries are vigorously developing renewable energy, especially hydropower, and they possess an enabling policy framework on renewable energy, but barriers still remain. Nigeria has a renewed focus on rural electrification using renewable energy (RE), aiming to develop the potential of its RE resources and achieve the Millennium Development Goals and National Economic Empowerment Development Strategy targets. However, the main constraints to the rapid development and diffusion of technologies for the exploitation and utilization of RE resources in the country are the absence of market and the lack of appropriate policy, regulatory and institutional frameworks to stimulate demand and attract investors. Kenya is keen to increase the share of renewable energy sources in the country's generation mix. However, the lack of appropriate technical skills in the country is a barrier to investment in SHP, which has hindered both planned and existing SHP projects. Ethiopia Government issued energy policy with the objective of ensuring a reliable supply of energy at an affordable price in 1994. However, the absence of rules for decentralized energy production and management, and low FIT result in loss of interests for local and foreign investors.

Within the One Belt One Road Development Scheme and South-South Corporation framework, China will give more support on the infrastructure construction in developing countries, hydropower projects in particular. China's experiences in rural SHP electrification have successfully demonstrated that the decentralized development of SHP could be an effective approach for rural energy supply and poverty mitigation

Ⅱ. Implementation

To meet the objective of this project, it was implemented as the following three stages:

- **In the first stage,** ICSHP provided one training seminar on small hydropower sustainable development and investment in China for developing countries including three targeted countries of this project. The trainees mainly included project owners, developers, investors, administrators and technicians. During the training, ICSHP also organized several study tours to different sites, providing a platform for the trainees to communicate with Chinese design institutes, equipment manufacturers and decision makers to discuss and learn the practices of small hydropower financing model in China.
- **In the second stage**, ICSHP firstly develop one screening results report for Nigeria to find out 3 potential sites. Then ICSHP experts visited these 3 potential sites in Nigeria and other three in Ethiopia to provide technical guidance to local technicians, assisting in site selection, investigation and measures. Of them, the conditions of the Nigerian sites are better with relatively good data availability. Finally, one potential site in Nigeria was selected to further develop the feasibility study report.
- **The last stage** is to assist to conduct and produce a SHP Feasibility Study Report (FSR) on Nigeria, which shall include the following: topographical survey and mapping, geology and geo-techniques, hydrologic and sedimentation studies, FSR design and layout, financial and economic evaluation, social-economic study, risk evaluation/assessment and mitigation, environmental impact services, etc. This project finally found out the importance to scale up SHP development as a business model in the selected countries by taking an integrated and inter-disciplinary approach in order to maximize the impact.

Beneficiaries:

The primary beneficiaries will be the SMEs in and around rural areas in selected countries where SHP pilot projects sites will be identified, or demonstration projects will be set up. In the process, these communities, i.e. women, men and children, will have improved access to energy. The secondary beneficiaries will be national institutions and agencies participating in the capacity building activities in the field of SHP. Through them, the benefits will accrue to individuals and enterprises that will be provided with reliable renewable energy services renewable energy as a stimulus to rural development and income generation activities.

Ⅲ. Completed Activities

Activity-1

Time: September 2018

Location: Hangzhou, Chengdu and Yichang, China

Implementation: In September 2018, ICSHP organized a training seminar (the schedule shown in Appendix I) on small hydropower sustainable development and investment in China for developing countries including three targeted countries of this project (the name list of participants shown in Appendix-II). ICSHP invited engineers and experts on small hydropower development in China to share technologies, experience and financing mechanism of small hydropower development. The trainees mainly included project owners, developers, investors, administrators and technicians. During the training, ICSHP also organized several study tours to different sites, institute and university, providing a platform for the trainees to communicate with Chinese equipment manufacturers, decision makers and researchers to discuss and learn the practices of small hydropower financing model in China.

Activity-2
Time: November 2018
Location: Ethiopia




Implementation: In November 2018, the expert team of ICSHP went to Ethiopia to provide technical guidance for local technicians on site selection, investigation and data analysis. Three potential sites were investigated but their data availability is poor which is not suitable for the further development.

Activity-3
Time: March 2019
Location: Nigeria






Implementation: Based on the data and information provided by the focal point of Nigeria, ICSHP developed a screening results report (shown in Appendix-III) and selected three potential sites in Nigeria for further investigation. In March 2019, ICSHP experts went to Nigeria to provide technical guidance for local technicians on site selection and investigation. ICSHP experts visited these 3 potential sites and finally one site was selected to develop the feasibility study report with business models (the executive summary of the final feasibility study report shown in Appendix-IV).

Ⅳ. Activities Costs

Activities costs of this project were strictly based on the financial budget. ICSHP referred specialized accountants to manage the economic evaluation and review for this project. Project leaders were also responsible for monitoring of cost for each activity regarding to the project and required for submission of periodical report to the Director General of ICSHP for processing and stage of the project. The cost mainly included the international flights for international experts, consultancy fees, venue and equipment rental for the workshop and domestic trips, details shown below:

No.	Items	PGTF Fund	ICSHP Fund	Total
1	International travel	12,000 USD	40,000 USD	52,000 USD
2	International consultants	3,000 USD	0 USD	3,000 USD
3	National experts	3,000,000 USD	4,000 USD	7,000 USD
4	Workshop organization	8,000 USD	25,000 USD	33,000 USD
5	Domestic travels	0 USD	5,000 USD	5,000 USD
	Total	**26,000USD**	**74,000 USD**	**100,000USD**

Ⅴ. Project Management Arrangements

The project is implemented by the International Center on Small Hydropower (ICSHP). ICSHP has appointed a project coordinator. All project staff is appointed by ICSHP. ICSHP is responsible for producing and submitting a report to the UNDP China Office following allocation of 90% of the budget resources. The ICSHP 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, ICSHP 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. Appendixes

Appendix-I Schedule of the training seminar (2018.9.2-2018.9.19)

Date	Time	Activities	Lecturer	Venue
9.2	All day	Enrollment		Hangzhou Danube Relax Hotel
9.3	11:00-12:00	Opening ceremony	Huang Yan, Deputy Director of ICSHP	ICSHP International Conference Hall
	14:00-17:00	Lecture 1： General Situation of China	Huang Yan, Deputy Director of ICSHP	
9.4	09:00-12:00	Lecture 2： Overview of development of small hydropower and rural electrification in China	Cheng Xialei/Director General of ICSHP	ICSHP International Conference Hall
	14:00-17:00	Lecture 3： SHP plants efficiency improvement and capacity expansion/Three Gorges project	Fu Zilong, Deputy Director of ICSHP	
9.5	09:00-12:00	Lecture 4： River hydropower development planning and site selection	Li Zhiwu/Engineer	ICSHP International Conference Hall
	14:00-17:00	Lecture 5： Hydraulic structures	Li Zhiwu/Engineer	
9.6	09:00-12:00	Lecture 6： Green small hydropower	Ou Chuanqi/Division Chief of ICSHP	ICSHP International Conference Hall
	14:00-17:00	Lecture 7： Design of SHP	Ye Suigao/Engineer	
9.7	09:00-12:00	Lecture 8： Financing mechanism in China	Ma Zhijie/Engineer	ICSHP International Conference Hall
	14:00-17:00	Lecture 9： project management, risk management and economic appraisal	Wang Xin/Engineer	

Date	Time	Activities	Lecturer	Venue
9.8	09:00-12:00	Workshop 1： Green hydropower and Belt and Road workshop	Ye Zhou/Professor	Zhejiang University of Water Resources and Electric Power
	14:00-17:00	Study tour 1：Electrical laboratory of Zhejiang University of Water Resources and Electric Power	Zhou Ming/Professor	
9.9	09:00-12:00	Lecture 10：Hydraulic machinery	Chen Xing/ Engineer	ICSHP International Conference Hall
	14:00-17:00	Study tour 2： Hangzhou Fuchun River Hydropower Equipment Company		Hangzhou Fuchun River Hydropower Equipment Company
9.10	All day	Go to Chengdu		
9.11	07:00-12:00	Study tour 3：Biogas Institute of Ministry of Agriculture	Luo Ximin/Engineer	Biogas Institute of Ministry of Agriculture
	14:00-17:00	Lecture 11：Case studies of small hydropower design	Liu Hong/Engineer	
9.12	All day	Go to Yichang		
9.13	All day	Study tour 4：visit Houzibao hydropowr plant and Baisha River plant	Fu Zilong/Deputy Director of ICSHP	Hubei Xingfa Chemicals Group Co., Ltd
9.14	09:00-12:00	Go to Three Gorges Hydroelectric Power Station	Fu Zilong/Deputy Director of ICSHP	Three Gorges
	14:00-17:00	Study tour 5：visit Three Gorges Hydroelectric Power Station		
9.15	All day	Back to Hangzhou		
9.16	All day	Preparation of national reports		ICSHP International Conference Hall
9.17	09:00-12:00	Lecture 12：Small hydropower standards in China	Zhao Jianda/Engineer	ICSHP International Conference Hall

Date	Time	Activities	Lecturer	Venue
	14:00-17:00	Lecture 13： Case studies of small hydropower cooperation and investment in African countries	Dong Guofeng/Division Chief of ICSHP	
9.18	09:00-12:00	Workshop 2 national reports	Dong Guofeng/Division Chief of ICSHP	ICSHP International Conference Hall
	15:00-16:00	Closing ceremony	Cheng Xialei/Director General of ICSHP	
	17:30-19:30	Farewell dinner		

Appendix-II List of participants of the training seminar

No.	Name	Nations	Gender	Organization	Position
1.	Mebrahtom Yohannes	Ethiopia	Male	Tigray Water Resources Administration	Construction Director
2.	Yonas Tesfay Woldegebriel	Ethiopia	Male	Tigray Water Resources, Mines and Energy Bureau	Energy Expert
3.	Guesh Weldemicael	Ethiopia	Male	Tigray Water Resources Administration	Engineer
4.	Mustefa Jemal Oumare	Ethiopia	Male	Oromia Land Development Administration	Planning Officer
5.	Amensisa Tsegaye Bedane	Ethiopia	Male	Oromia Water, Mines and Energy Administration	Director
6.	Abera Godorie	Ethiopia	Male	Ethiopia SNNPR Mines and Energy Bureau	Energy Expert
7.	Workulijalem Fenta	Ethiopia	Male	AIYRS Water, Irrigation and Energy Administration	Officer
8.	Bishaw Endalew Anagaw	Ethiopia	Male	Amhala Water, Irrigation and Energy Administration	Hydropower Engineer
9.	Adugna Erena Dorsis	Ethiopia	Male	Oromia Rural Land Development Administration	Director
10.	Samwel Orenge	Kenya	Male	Kenya Government Public University	Lecturer
11.	Josiah Maroko	Kenya	Male	Energy Engineering Projects, Ltd	Assist Engineer
12.	Falana Folaranmi	Nigeria	Male	Federal Ministry of Science &Technology	Engineer
13.	Mohammed Sulaiman Nma	Nigeria	Male	Federal Ministry of Water Resources	Chief Civil Engineer
14.	Thurston Semple	Guyana	Male	Lethem Energy Company	CEO
15.	Angelo Semagulu	Uganda	Male	Uganda Electricity Transmission Co., Ltd	Civil Engineer
16.	Enos Kalyesubula	Uganda	Male	Uganda Electricity Transmission Co., Ltd	Civil Engineer
17.	Karam Saad Said Saadawy	Egypt	Male	New Energy and Renewable Energy Administration	Chief Engineer
18.	Mamasheane Cynthia Rampai	Lesotho	Female	Ministry of Energy and Meteorology	Assist Economic Planner
19.	Refiloe Prince Qhojeng	Lesotho	Male	Ministry of Energy and Meteorology	Junior Engineer
20.	Lekhafola Motlomelo	Lesotho	Male	Ministry of Energy and Meteorology	Senior Economic Planner

21.	Raoël Brian Bunsee	Surinan	Male	Import/Trade Office	CEO
22.	Miguel Angel Cristinvaldez	Mexico	Male	National Electricity and Clean Energy Institute	Researcher
23.	Jose Israel Chavezestrada	Mexico	Male	National Electricity and Clean Energy Institute	Researcher
24.	Ismael Eduardo Arzola Nuño	Mexico	Male	National Electricity and Clean Energy Institute	Researcher
25.	Juan Carlos Arellanocervantes	Mexico	Male	National Electricity and Clean Energy Institute	Researcher
26.	Agustin Moises Alcaraz	Mexico	Male	National Electricity and Clean Energy Institute	Researcher

Appendix-III Screening results report for the development of feasibility study report

International Center on Small Hydro Power

Screening Results Report for the Development of Feasibility Study Report of Nigeria

September 2018

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Annex I: Country report

Annex II: Long list

Annex III: Final site template

1. SHP status report

In order to have a deep knowledge on the SHP status in Nigeria, as well as to collect more background information for the final site selection, ICSHP prepared an SHP Development Status Report on Nigeria based on the 2016 World Small Hydropower Development Report, the information provided by the FP and Internet-based data collection. The report includes analysis of the country's energy sector, SHP installed and potential capacity, the history of SHP development in the country, planned SHP projects with related regulatory framework, and barriers to SHP development. For the final version of the full report see Annex I. For a brief summary see the Country overview below. Nigeria was selected to participate in the project based on the following four criteria:

1) high level of national ownership,
2) availability of SHP resources,
3) willingness of SHP experts to undertake capacity building, and
4) interest in foreign investment in SHP development.

Nigeria has an electrification rate of 48 per cent, with a population of approximately 173 million. However, approximately 50 per cent of the population lives in rural areas where the electrification rate is only 20 per cent.

Energy in Nigeria is generated primarily through the burning of traditional biomass and fossil fuels. The total installed electricity generating capacity of Nigeria was 25,255 MW in 2015. Fossil fuel-based power stations account for approximately 81 per cent of the total installed generating capacity. The three major large hydropower stations (1900 MW in total) account for 7.5 per cent of the national total installed capacity. Of the country's total installed capacity, less than 5,000 MW is actually available due to the aged equipment. This is attributable to the current state of the grid network, which is characterized by frequent overloading, system collapses and transmission and distribution losses of up to 30 per cent. On average, consumers do not have electricity supply from the grid network for 10 hours every day. This has compelled many consumers (both industrial and residential) to buy diesel/petrol generators to meet their energy needs.

Small hydropower, according to the definition in the National Renewable Energy and Energy Efficiency Policy, is defined as 1 to 30 MW. The combined installed capacity of current small hydropower stations is approximately 45 MW with a total estimated potential capacity of 3,500 MW indicating that only 1.3 per cent has been developed. ICSHP has focused on creating awareness among relevant stakeholders in Nigeria on the huge SHP potential available in the country. ICSHP's activities have led to over 200 potential SHP sites identified, 17 feasibility studies with detailed project reports carried out, and the development of three sites that are under construction.

The Government has reformed the electricity industry and enacted several laws and regulations that are expected to help develop the nation's abundant renewable energy (RE) deposits. The Renewable Energy Master Plan of Nigeria has a 10-year target (2007-2017) for increasing the contribution of renewable energy technologies to the energy mix of the country. The initial targets for peak supply from small hydropower were: 40 MW by 2007, 100 MW by 2008 and 400 MW by 2016. The targets were based on the assumption that over 200 identified potential SHP sites would be developed.

However, achieving these targets has been a difficult task and only one of the sites has been developed.

There are a number of incentives for small hydropower construction. The 2005 Electric Power Sector Reform Act (EPSRA) allows constructing, owning or operating an off-grid power plant not exceeding 1 MW in aggregate without a license. This exemption favors SHP development since some of the identified SHP sites fall within the required range. It is also expected to encourage private sector participation to invest in small/mini/micro-scale hydropower, especially in rural areas for off-grid generation.

The main constraints to the rapid development and diffusion of technologies for the utilization of renewable energy in the country are the absence of markets, and the lack of appropriate policy, regulation, and institutional frameworks to stimulate demand and attract investors. Though several policies and regulatory frameworks are in place to promote RE-based electricity, there is no definite and well-framed pathway to make these policies successful. The comparatively low quality of the systems developed, and the high initial upfront costs also constitute barriers to the development of markets. So far, private sector participation in renewable energy implementation in the country focuses on importing and marketing components. Full participation by the private sector, especially in the form of investment towards local fabrication of turbines, will enhance the development of SHP potential. In addition to the above barriers, other barriers to SHP development include a lack of public awareness, a lack of participation through experience sharing, and insufficient skills and experience.

2. Site information

The desk review process will be carried out through the following process:

1) FP submitted a selection of 5 to 10 recommended sites, with required details to the ICSHP.

2) ICSHP reviewed the list and compares it with site information available from other sources

3) A short list of 5 sites for final site screening is determined.

As discussed before, a list of 73 SHP potential sites with prefeasibility studies (“Long List”) from the FP in Nigeria was received by ICSHP (see Annex II). The Long List contained only the project name and estimated capacity. Then, FP re-sent the site template with 5 recommended projects. This submission was more detailed but lacked important data. Hence, as required by ICSHP, FP sent a revised site template (Annex III).

2.1 Project location

The distribution of the 73 initially submitted sites on the Long list is shown in Figure 1.

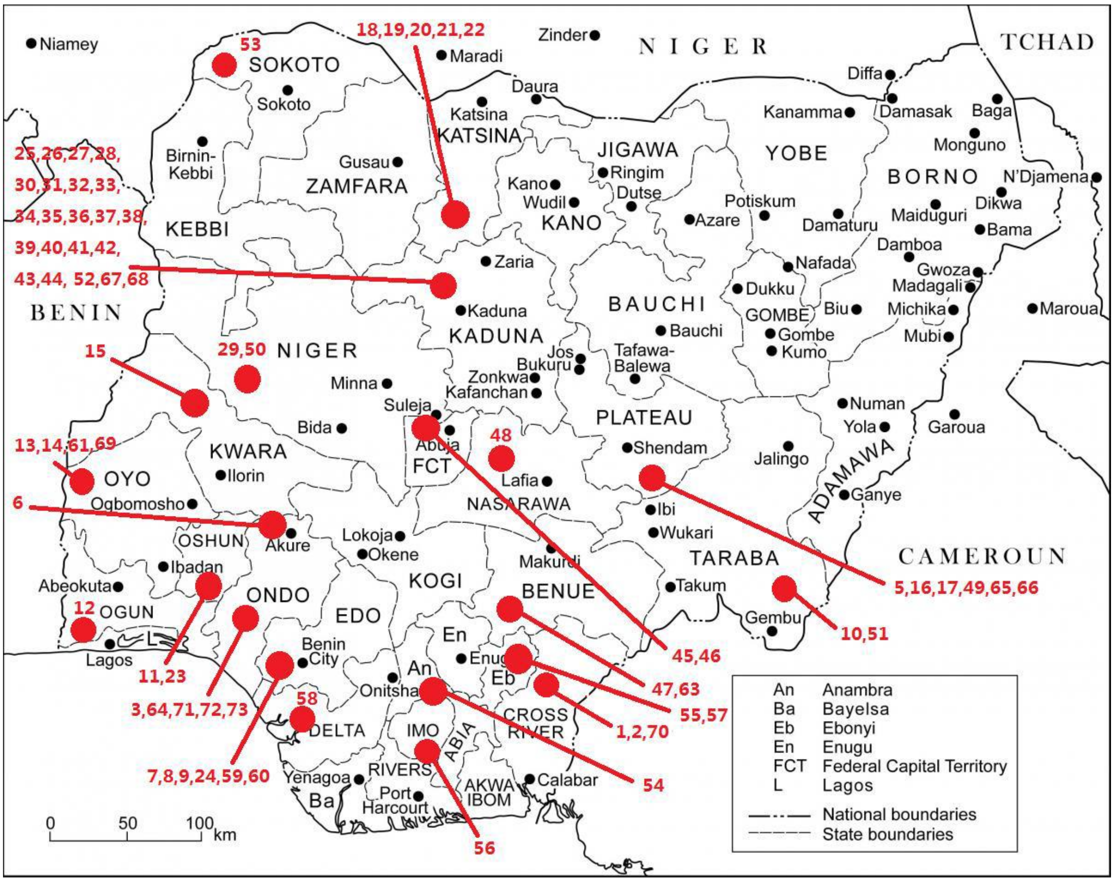

Figure 1: The distribution of the 73 potential sites

The SHP sites selected by FP the second time are shown in Table 1.

Table 1: Location of selected SHP sites

No.	Project	Coordinates	Distance from nearest local community/town
1.	Otukpo Hydropower Plant	N6°49'12", E8°40'12"	located in Cross River State, about 115km away from Port Harcourt, capital of the Cross River State
2.	Monaya Ogoja	N8°49'48", E6°35'24"	located in Niger State, 93km away from Abuja, capital of Nigeria and 91km away from Minna, capital of Niger State
3.	Nnewi (Green Field)	N6°1'11", E6°54'53"	located in Edo State, 76km away from Benin City, capital of Edo State
4.	Ingawa Dallaje	N13°13'48”, 7°44'39”	located in Katsina State, 30km away from Benin City, capital of Katsina State
5.	Ile-Ife	N7°0'25”, E4°0’37”	located in Osun State, 21km away from Ijebu Ode, capital of Osun State

2.1 Preliminary assessment of previous studies

The information provided by the FP about the selected sites is presented in Table 2 (see Annex III).

Table 2: Selected SHP Sites

No.	Basin/River Name/Region	Installed Capacity (MW)	Annual Generation (GWh/yr)
1.	Otukpo Hydropower Plant	3	18
2.	Monaya Ogoja	1	6
3.	Nnewi (Green Field)	1	6
4.	Ingawa Dallaje	1	6
5.	Ile-Ife	2	12

3. Site screening

The Site screening process will include (1) the development of a screening standard by ICSHP, (2) identification of a final list of 3 sites by ICSHP, and (3) approval of the final list by FP of Nigeria.

3.1 Site screening standard

For site selection optimization, a comprehensive evaluation of engineering technology, economic benefits, social impact and environmental impact should be conducted. The following principles should be abided by in the process of the SHP site screening.

(1) On the basis of the topography, geology, hydrology, engineering construction, and engineering technical conditions, the selected SHP site should be economically beneficial. The evaluation of engineering technical conditions should include the rationality and feasibility of the site of hydropower development.

(2) The proposed SHP sites should be located near a load center. Providing electricity access for nearby residents and industrial users should be prioritized.

(3) The proposed SHP sites should be connected to roads in order to reduce costs and demonstrate a better pilot function.

(4) The principles of sustainable development and the "prevention first, ecological priority" strategy should be followed. The SHP sites should be away from natural reservation areas, sources of drinking water, scenic spots, cultural relics. Finding a balance between the requirements of environmental protection and effective use of the resources is of primary importance.

(5) The adverse impact on the ecology and environment should be avoided if possible and mitigated if not. Required measures should be taken to avoid impact to human settlements along the river banks and farmlands. Hydropower development should promote economic and social sustainable development in the river basin. The comprehensive consideration of the economic, environmental and social benefits will maximize the benefits of the hydropower development project.

(6) The social impact assessment should include promotion and cover the influence of

hydropower development on regional economic development and urban construction, and the adaptability and acceptability of the local social environment to the development of the hydropower project.

3.2 Comparison of sites

(1) Analyze specific site conditions

Based on the basic information provided by the FP and the data collected from other sources by ICSHP experts, the site development conditions should be analyzed according to the screening principles mentioned above. ICSHP experts have analyzed the site's topographical conditions and other factors. The initial general layouts of the recommended sites have been carried out, and the location and dimensions of dams (or weirs), water conveyance systems, and power houses have also been initially selected.

1) Otukpo Hydropower Plant

Otukpo Hydropower is located in Cross River State, South Nigeria, and about 115km away from Port Harcourt, capital of the Cross River State, in the northeast. The project's coordinates are Latitude N6°49'12", Longitude E8°40'12".

Otukpo Hydropower Plant is located on the Okpokwu River, which has a length of more than 200km. The river basin is mainly tropical humid climate. It belongs to the dry season from November to March and turns to flood season from April to October.

At the dam site, the maximum and minimum annual average discharge is 17.5 m^3/s and 10.3m^3/s. In this district, annual average precipitation is 1366 mm, the maximum and minimum annual average rainfall 1407mm and 1060mm respectively. The annual average maximum and minimum temperature is 38℃ and 22℃respectively.

The total length of the river section upstream the dam site is 55km, and controlled drainage area of about 1317km^2. The river slopes gently. The land form in the project area is sedimentary (Asata-Nkporo Group), with the river bank's elevation 350m and below. The plant will be developed by dam type. 68% of engineering of the dam has been completed and the dam is a multipurpose project. Total spillway discharge is 1264 m^3/s. The discharge for power generation is 18m^3/s, the water head is 21.2m. The total installed capacity is 3MW, divided by 3 units, each with the capacity of 1MW, and the power generated will be supplied for the local people. Around 65000 people will benefited by the project. The powerhouse is 7 km away from Otukpo Town. A 24 km access road to the plant will be constructed, and a 4 km transmission line will be built for power distribution at the voltages of 33kV & 11kV.

The location of the hydropower plant is shown in Figure 2.

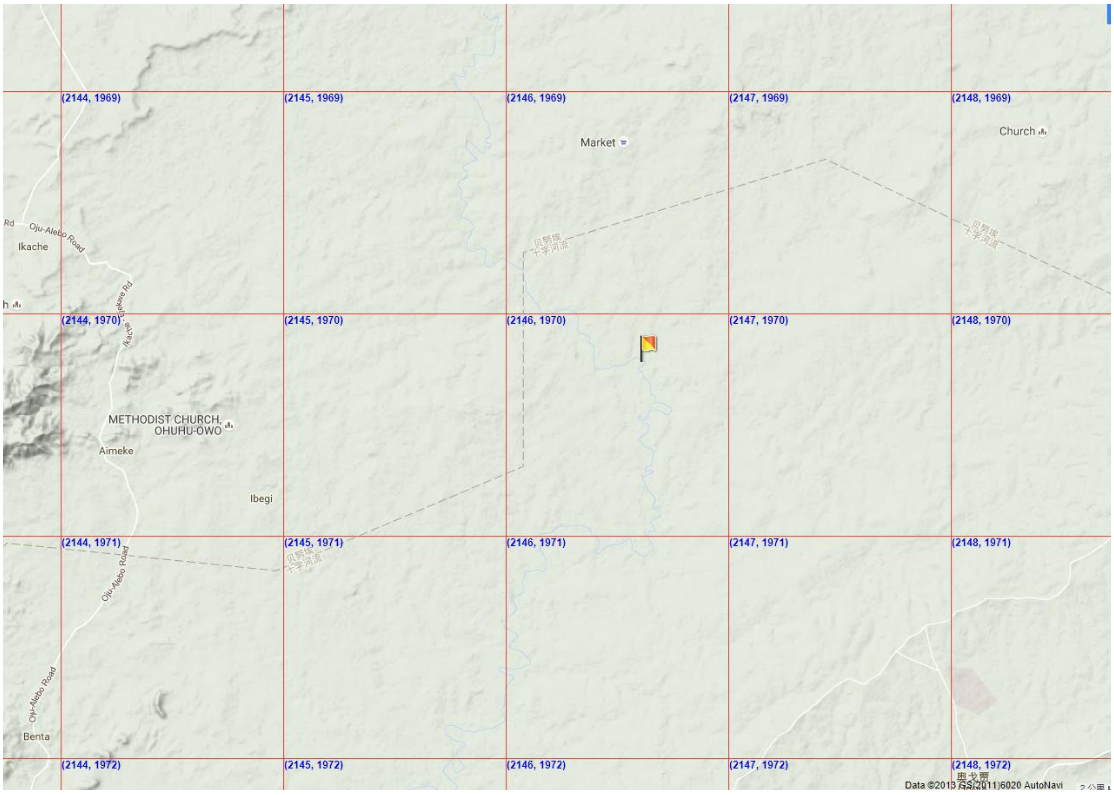

Figure 2: Otukpo Hydropower Plant Location

2) Monaya Ogoja Hydropower Plant

Monaya Ogoja Hydropower Plant is located in Niger State, Central Nigeria, and about 93km away from Abuja, capital of Nigeria, in the southwest, and about 91km away from Minna, capital of Niger State, in the south. The project's coordinates are Latitude N8°49'48", Longitude E6°35'24".

Monaya Ogoja Hydropower Plant is located on Monaya River, a tributary of Niger River, along the left bank. Niger River is located in Western Africa and is one of the longest river in Africa, only behind Nile River and Congo River. At an elevation of 900m, Niger River originates from mountains in Fouta Diallon highland, near the border with Sierra Leone, in Guinea.

The main stream flows through Guinea, Mali, Niger and Nigeria, and finally runs into Gulf of Guinea. The tributary stretches to Ivory Coast, Burkina Faso, Chad and Cameroun. The total length of Niger River is 4160km, the basin area is 1.5 million km^2, the annual average discharge is $6300m^3/s$, the annual runoff amount is 200 billion m^3. The length of tributary on which the project will be located is about 65km. The project is located between an elevation of 220m and 50m resulting in a total hydraulic head of about 170m. The maximum and minimum average rainfall is 3000mm and 2000mm respectively. The annual average maximum and minimum temperature is 28.7℃ and 25.3℃respectively. The maximum volume of runoff of the basin is $31L/sec/km^2$.

The river basin is mainly Guinea Tropical climate. It belongs to the dry season from November to March and turns to flood season from April to October. According to the topographical condition, the dam site is initially planned on upstream channel, about 35km away from the river mouth, with controlling drainage area of 450km2. The river slopes gently. The elevation of river bed and banks is about 80m and 100m~140m respectively. The hydropower plant will be a run-of-the-river type. A concrete sluice dam will be built with a length of 50m and a height of 15m. The discharge capacity is 11m3/s with a water head of 12m for power generation. The total installed capacity will be 1MWwith an annual electricity production of6 GWh. The power generated will be supplied to the Ogojia people. Around 171000 people are estimated to benefit from the project. The powerhouse is 20 km away from the city. An access road to the plant has been constructed. The transmission line for power generation, with a voltage of 33kV, already exists there.

The location of the hydropower plant is shown in Figure 3.

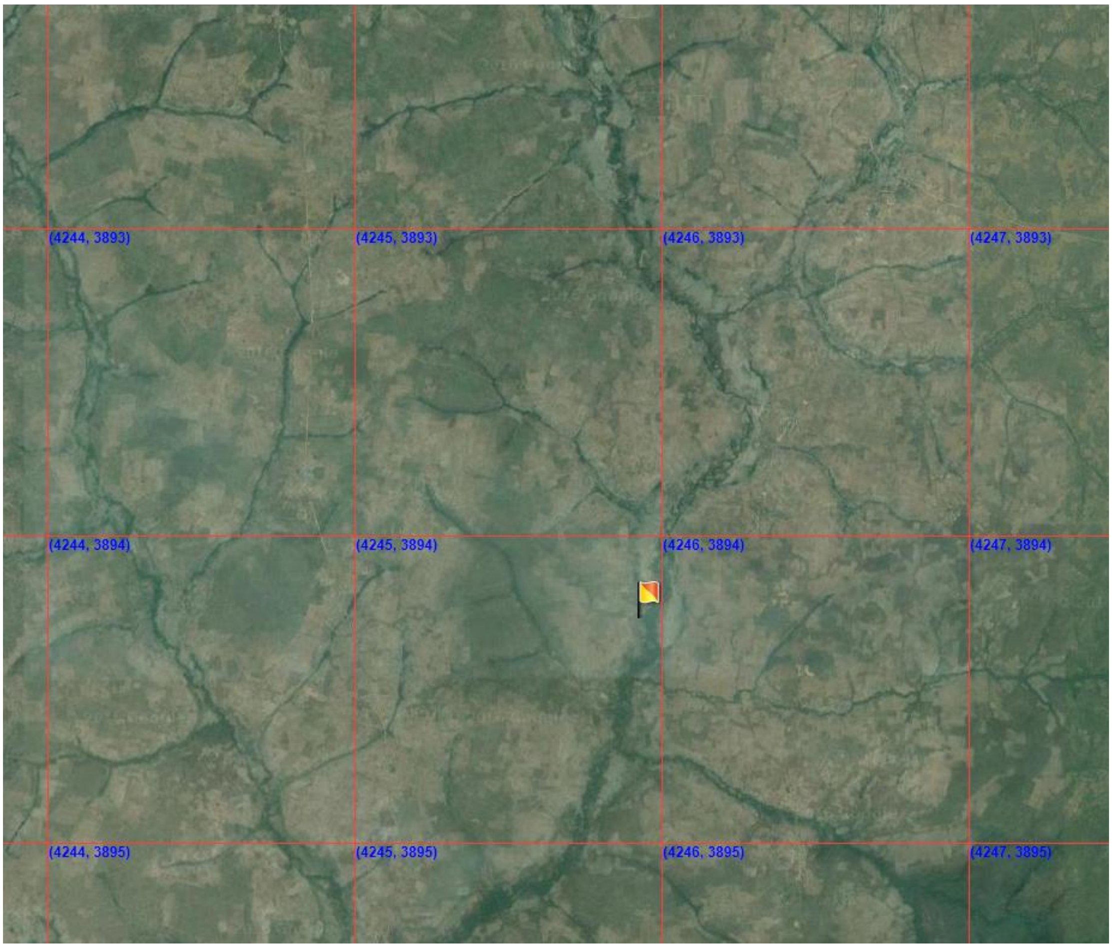

Figure 3: Monaya Ogoja Hydropower Plant Layout

3) Nnewi (Green Field) Hydropower Plant

Nnewi (Green Field) Hydropower Plant is located in Edo State, South Nigeria, about 76km away from Benin City, capital of Edo State, in the northeast. The project's coordinates are Latitude N6°1'11", Longitude E6°54'53".

Nnewi (Green Field) Hydropower Plant is located on the Anambra River, the tributary to the Niger River, on the right bank when looking downstream. The length of tributary on which dam is located is about 105km, with an elevation of 220m~50m and total water head about 170m. In this district, the maximum and minimum average rainfall is 2000mm and 1500mm respectively. The annual average temperature is 26.7℃. The maximum volume of runoff of the basin is 23.6L/sec/km^2.

The river basin is mainly Guinea Tropical climate. It belongs to the dry season from November to March and turns to flood season from April to October. According to topographical condition, the dam site is initially planned on an upstream channel, about 70km away from the river mouth, with controlled drainage area of 1200km^2. The river slopes gently, elevation of river bed and banks is about 80m and 100m~120m respectively. The hydropower plant will be a run-of-the-river type. A concrete sluice dam will be built with a length of 50m and height of 10m. The discharge is 25m^3/s, with a water head of 6m for power generation. The total installed capacity is 1MW, and annual electricity production is 6GWh. An access road to the plant has been constructed. The transmission line for power generation with a voltage of 33kV already exists there.

The location of the hydropower plant is shown in Figure 4.

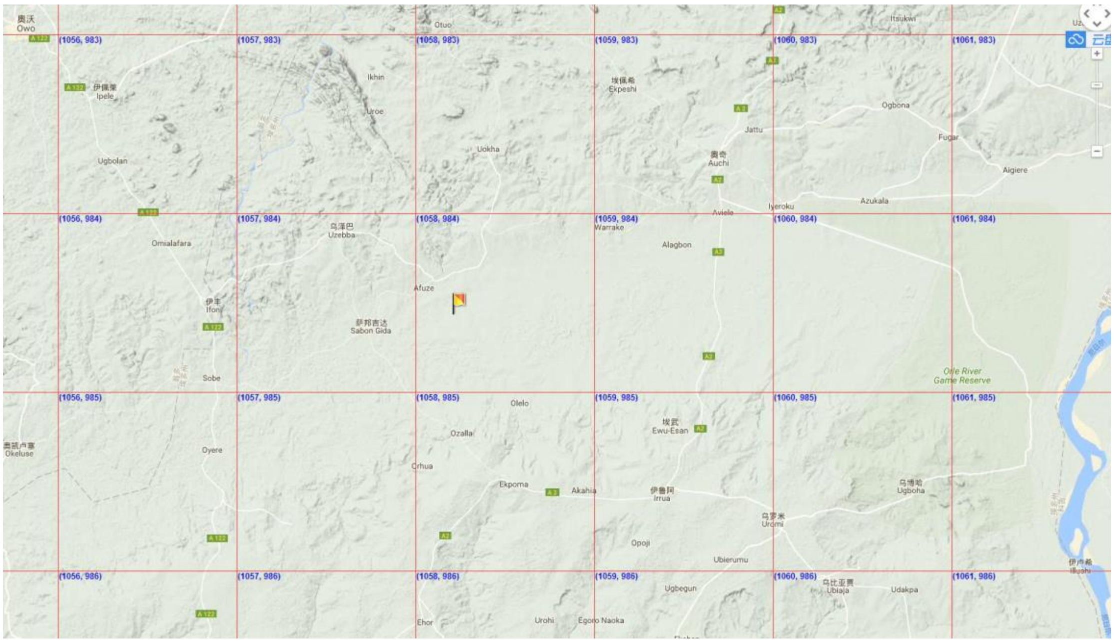

Figure 4: Nnewi (Green Field) Hydropower Plant Layout

4) Ingawa Dallaje Hydropower Plant

Ingawa Dallaje Hydropower Plant is located in Katsina State, north Nigeria, and about 30km away from Benin City, capital of Katsina State, in the northeast. The project's coordinates are Latitude N13°13'48”, Longitude E7°44'39”.

Ingawa Dallaje Hydropower Plant is located on the Dakau River, which is a tributary of the Niger River, on the right bank when looking downstream. The elevation of the dam is about 500m. The maximum and minimum average rainfall is 1000mm and 600mm respectively. The annual average rainfall is 826mm. The annual average temperature is 26.7℃. The average volume of runoff of the basin is 23.6L/sec/km^2. The river basin is mainly Sahel Tropical climate. It belongs to the dry season from November to May and turns to flood season from June to October. The controlled drainage area of the plant is 2900km^2, the river slopes gently. The elevation of river bed and banks is about 490m and 500m respectively.

The plant will include a dam. 40% of the total engineering quantity of the dam has been completed and the dam is part of a multipurpose project. The discharge is 25m^3/s, with the water head of 6m for power generation. The total installed capacity is 1 MW, annual power generation is 6GWh. The power generated will be supplied for the local people. Around 75000 people will benefit from this project. The powerhouse is 10 km away from the city. Access road to the plant, about 10 km, has been constructed. The transmission line for power generation with the voltage of 33kV exists there. The location of hydropower plant is shown in Figure 5.

Figure 5: Ingawa Dallaje Hydropower Plant Layout

5) Ile-Ife Hydropower Plant

Ile-Ife Hydropower Plant is located in Osun State, South Nigeria, about 21km away from Ijebu Ode, capital of Osun State, in the northeast. It is about 3km away from Ijebu-Igo City in the north. The project’s coordinates are Latitude N7°0'25”, Longitude E4°0’37”.

Ile-Ife Hydropower Plant is located on the Kajola River. The elevation of the dam site is about 100m. The maximum and minimum average rainfall is 1965mm and 1565mm respectively. The annual average temperature is 23.5℃. The river basin is mainly Tropical wet and dry climate. It belongs to the dry season from November to May and turns to flood season from June to October. The controlled drainage area of the proposed plant is 167km^2, the river slopes gently, elevation of river bed is about 100m. The plant will be developed by dam type. 75%of the total engineering quantity of the dam has been completed, and the dam is of a multipurpose project. The water head for power generation is 42 m. The total installed capacity is 2 MW, two units installed each with the capacity of 1MW. Annual power generation is 12GWh. The power generated will be supplied to the local people. Around 168000 people will benefited by the project. The powerhouse is 2.9 km away from the city. An access road to the plant and the transmission line, about 1.9 km length, will be constructed. The transmission line for power generation operates at a voltage of 33kV.

The location of hydropower plant is shown in Figure 6.

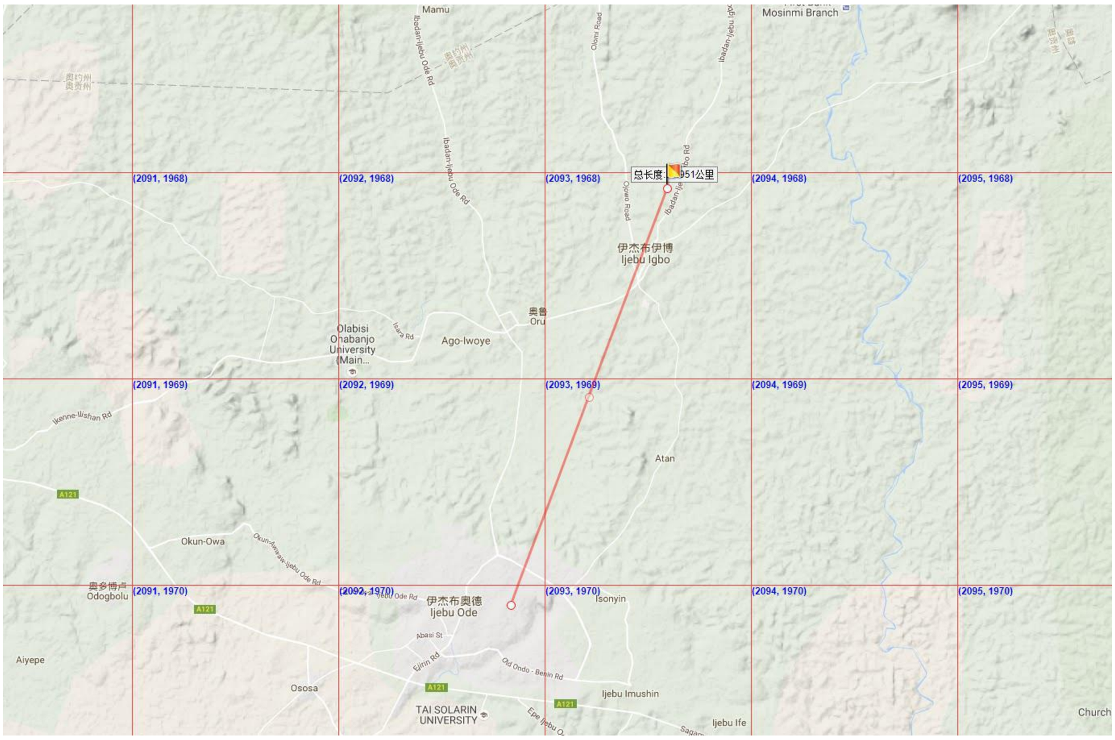

Figure 6 Ile-Ife Hydropower Plant Location

The main features of the potential sites are list in Table 3.

Table 3 Main features of the potential sites

Site name / Technical parameters	Otukpo SHPP	Monaya Ogoja SHPP	Nnewi (Green Field) SHPP	Ingawa Dallaje SHPP	Ile-Ife SHPP
1. Project Information					
Development type	dam type	run-of-the-river type	run-of-river/ diversion type	dam type	dam type
New project or refurbishment	new project/68%of the total engineering quantity of the dam has been completed	new project	new project	new project/ 40%of the total engineering quantity of the dam has been completed	new project/ 75%of the total engineering quantity of the dam has been completed
Dam site elevation(m)	350	80	80	490	100
Dam type	unclear	concrete sluice dam	concrete sluice dam	unclear	unclear
Dam dimension (length*height) (m)	unclear	50*15	50*10	unclear	unclear
Water conveyance system type	penstock	penstock	penstock	penstock	penstock
Total length of Water conveyance system (m)	unclear	unclear	unclear	unclear	unclear
Powerhouse site elevation(m)	unclear	unclear	75	485	18
Proposed capacity (MW)	1.0	1.0	1.0	1.0	2.0
Discharge(m^3/s)	18	11	25	25	8.8
Water head(m)	21.2	12	6	6	42
Target power generation (GWh)	7	4.5	4.5	4.5	10
2. River in the Project Area					
Name	Okpokwu	Monaya, the tributary of Niger River	Anambra, the tributary of Niger River	Dakau, tributary of Niger River	Kajola
Length of river (length of river upstream dam site) (km)	200 (55)	65(30)	105(45)	unclear	unclear
Catchment area of river (catchment area of river upstream dam site) (km^2)	unclear (1317)	unclear (450)	unclear (1200)	2900(unclear)	Unclear (167)
3. Meteorology Data					
Precipitation(mm)	annual average=1366 mm, maximum=	maximum=3000mm, and minimum=	maximum=2000mm, and minimum=	annual average=826 mm, maximum=	maximum=1965mm, and minimum=

	1407mm and minimum =1060mm	2000mm	1500mm	1000mm and minimum =600mm	1565mm
4. Hydrological Data					
Discharge(m^3/s)	At the dam site, maximum and minimum annual average discharge is 17.5 m^3/s and 10.3m^3/s	maximum volume of runoff of the basin 31L/sec/km^2	maximum volume of runoff of the basin 23.6L/sec/km^2	average volume of runoff of the basin 23.6L/sec/km^2	unclear
Flood season	April to October	April to October	April to October	June to October	June to October
5. Transportation and Grid Access					
Distance from town or city(km)	7 km away from Otukpo Town, about 115km away from Port Harcourt, capital of the Cross River State	7 km away from the city, 91km away from Minna, capital of Niger State and 93km away from Abuja, capital of Nigeria	76km away from Benin City, capital of Edo State	10 km away from the city, 30km away from Benin City, capital of Katsina State	2.9 km away from the city, 21km away from Ijebu Ode, capital of Osun State
Access road to the project(km)	24 km access road to the plant shall be constructed	Access road to the plant has been constructed.	Access road to the plant has been constructed	Access road to the plant, about 10 km, has been constructed	.1.9km access road to the plant shall be constructed
Grid Access (km)	4 km length of transmission line to be built with the voltages of 33kV & 11kV combined	transmission line for power generation with the voltage of 33kV exists there	transmission line for power generation with the voltage of 33kV exists there	The transmission line for power generation with the voltage of 33kV exists there	1.9 km length of transmission line to be built with the voltage of 33kV
Power supply area and people		Ogojia, around 171000 people		75000 people	168000 people

(2) Comparison of sites

The sites should be analyzed and compared as per the following aspects: river-bed longitudinal slope, water head for power generation, flow, flow distribution within a year, geological conditions, topographical conditions, regulation capacity, project layout conditions, transportation conditions, natural building materials, electricity load, construction cost index, environmental impacts, and social impacts using qualitative or quantitative methods.

The assessment of the potential sites is shown in table 4.

Table 4 Assessment of the potential sites

	Advantages	Disadvantages
Otukpo SHPP	1. The SHPP is of a dam type type. The power plant has a better regulatory capacity due to the water impoundment in the reservoir. There is a higher power supply guarantee rate, to ensure the normal use of electricity to local residents. 2. The Otukpo dam is one of the multipurpose projects, furthermore, 68% of the total engineering quantity of the dam has been completed. It is economical to add a SHPP to the project. 3. It is easy to reach the project site due to only 7 km away from Otukpo Town, about 115km away from Port Harcourt, capital of the Cross River State. 4. Around 65000 people will be benefited by the project.	1. 4 km length of transmission line shall be built with the voltages of 33kV & 11kV combined. 2. The 24 km access road to the plant shall be constructed.
Monaya Ogoja SHPP	1. The SHPP is of a run-of-river type, which has little negative impact on the environment. 2. The project area is rich in hydro resources. The maximum and minimum average rainfall is 3000mm and 2000mm respectively. The maximum volume of runoff of the basin is 31L/sec/km^2. 3. The project is of relatively simply civil works such as the concrete sluice dam with a length of 50m and height of 15m. 4. The discharge is 11m3/s with the water head of 12m for power generation. 5. Access road to the plant has been constructed. 6. The transmission line for power generation with the voltage of 33kV exists there. 7. Around 171000 people will be benefited by the project.	1. The powerhouse is 20 km away from the city. 2. The SHHP is of a run-of-river power station, with poor water storage regulation performance and poor power supply quality.
Nnewi (Green Field) SHPP	1. The SHPP is of a run-of-river type, which has little negative impact on the environment. 2. The project area is rich in hydro resources. The maximum and minimum average rainfall is 2000mm and 1500mm respectively. The maximum volume of runoff of the basin is 23.6L/sec/km^2.	1. The discharge is 25m^3/s with the water head of 6m for power generation. Generally speaking, the lower water head for power generation, the higher investment. 2. The project is 76km away from Benin City, capital of Edo State.

	3. The project is of relatively simply civil works such as the concrete sluice dam with a length of 50m and height of 10m. 4. Access road to the plant has been constructed. 5. The transmission line for power generation with the voltage of 33kV exists there.	
Ingawa Dallaje SHPP	1. The SHPP is of a dam type type. The power plant has a better regulatory capacity due to the water impoundment in the reservoir. There is a higher power supply guarantee rate, to ensure the normal use of electricity to local residents. 2. The Ingawa Dallaje dam is one of the multipurpose projects, furthermore, 40% of the total engineering quantity of the dam has been completed. It is economical to add a SHPP to the project. 3. Access road to the plant, about 10 km, has been constructed. 4. The transmission line for power generation with the voltage of 33kV exists there. 5. It is easy to reach the project site due to only 10 km the city. 6. Around 75000 people will be benefited by the project.	1. The project is located in a relatively dry area. The maximum and minimum average rainfall is 1000mm and 600mm respectively. The annual average rainfall is 826mm.
Ile-Ife SHPP	1. The SHPP is of a dam type type. The power plant has a better regulatory capacity due to the water impoundment in the reservoir. There is a higher power supply guarantee rate, to ensure the normal use of electricity to local residents. 2. The project area is rich in hydro resources. The maximum and minimum average rainfall is 1965mm and 1565mm respectively. 3. The Ile-Ife dam is one of the multipurpose projects, furthermore, 75% of the total engineering quantity of the dam has been completed. It is economical to add a SHPP to the project. 4. The water head for power generation is 42 m which is in the medium range of water head for SHPP. The total installed capacity is 2 MW, two units installed each with the capacity of 1MW. 5. Around 168000 people will be benefited by the project. 6. The powerhouse is 2.9 km away from the city, about 21km	1. Access road to the plant and the transmission line, about 1.9 km length respectively, will be constructed.

	away from Ijebu Ode, capital of Osun State, in the northeast. It’s about 3km away from Ijebu-Igo City in the north.	

3.3 Recommended sites

Based on the analysis of site development conditions, 3 recommended sites are tentatively selected as shown in Table 5. ICSHP will hold communication with the FP, and the final list of 3 recommended sites will be proposed with the approval of the FP.

Table 5: Tentatively selected sites

No.	Project	Remarks
1.	Otukpo SHPP	
2.	Monaya Ogoja SHPP	
3.	Ile-Ife SHPP	

4. Potential problems and measures

Potential problems that can be encountered by ICSHP during the realization of the projects, and the mitigations to these problems, are covered in the table below.

Potential problems

No.	Problems	Responsibility	Mitigation
1.	Difficulties with finding and accessing the project site(s)	ICSHP, FP	For the site visit, the FP should provide transfer and send technical personnel who are familiar with the location and the proposed layout of the project, working together with ICSHP experts.
2.	Various difficulties and obstacles might be encountered by ICSHP team during the reconnaissance stage	ICSHP, FP	To ensure the smooth implementation of the reconnaissance, the FP should send local experts to assist the ICSHP team, including coordination with the local community and authorities.
3.	Delayed implementation due to limited access to accurate data on the selected sites.	ICSHP, FP	Increased communication with respective stakeholders and the ministries will be sought and followed up tightly. Incorporate the risk of delays into the schedule of works in each stage of the project as required.
4.	Difficulties in attracting investors as a result of site selection not fully matching investors' requirements.	ICSHP, FP and other related institutions	Maintaining effective communication with the FP, including setting clear tasks and providing detailed information on the requirements and priorities. Organizing a site visit to collect additional information.

Annex I: Country Report

Nigeria Small Hydropower Development Status Report

Key facts

Population	173,000,000 [1]
Area	924,000 km^2
Climate	The climate of Nigeria is monsoonal in character and, like other monsoonal climates, it features contrasting dry and wet seasons. These seasons are highly dependent on the two prevailing air masses blowing over the country at different times of the year: the dry north-easterly air mass of Saharan origin and the humid maritime air mass blowing from the Atlantic. The rainy season is generally between May and October however it tends to begin earlier in the south in February or March. Average monthly temperatures vary from 30 °C in April to 24 °C in January.[2]
Topography	Nigeria has great topographical variety. Although much of the country is dominated by plains generally below 609.5 metres, the eastern border with Cameroon is marked by an almost continuous extent of mountains, the eastern highlands, which rise to about 2,419 metres in the Chappal Waddi, the highest point in Nigeria. In the north, the Jos Plateau rises abruptly from a general height of approximately 609.5 metres in the Hausa Plains to an average level of 1,219 metres, reaching 1,781.6 metres in the Shere Hills.[2] It should also be noted that 63 per cent of Nigeria land space is occupied by water. [18]
Rain pattern	Annual rainfall in Nigeria is highest in coastal areas and decreases inland towards the north. The lowest levels are found in the northern borders of the country. The wettest areas are the riverine areas and the mid-western and rivers regions, close to the borders with Cameroon. Mean annual rainfall in these areas varies between 2,540 mm and 4,064 mm. The wet characteristic of coastal and near coastal areas can be attributed to their nearness to the Atlantic Ocean; the moderately high rainfall in the plateau area can directly be related to relief or orographic effect. Rainfall in the dry season varies from less than 508 mm in the Niger-Delta to 0 mm in the Niger-Benue and the north.[2]
General dissipation of rivers and other water sources	The majority of rivers flow towards the south discharging into the Atlantic Ocean and are largely dominated by the Niger and the Benue rivers which join up before forming the Niger Delta, one of the world's largest arcuate fan-shaped river deltas. Nigerian rivers generally show a marked seasonal variation in river stages and discharges. The distribution of average monthly water levels at some gauging stations show that a large proportion of the annual run-off occurs in the rainy season when the monsoon winds bring rains to swell the rivers, occasionally causing floods. During the dry season some of the smaller streams, especially in the northern parts of the country, virtually dry up. The bigger rivers are reduced to carrying only a small proportion of their rainy season discharges.[2]

Electricity sector overview

In 2013 electricity production was 27.03 TWh with 63.3 per cent from gas, 20.9 per cent from large hydropower and 15.8 per cent from oil (see Figure 1).[4,5] Total installed capacity in 2015 was approximately 25,255.2 MW; however only 4,978 MW of the installed capacity was available due to the need for rehabilitation of many power plants.[18] Most of the power stations in the country are fossil fuel-based contributing approximately 81 per cent of the total installed generating capacity. The three major large hydropower stations (Kainji of 760 MW; Jebba of 540 MW; and Shiroro of 600 MW) account for approximately 7.5 per cent of the installed capacity. The total annual electricity generation in 2014 was 29,697.36 GWh.[19]

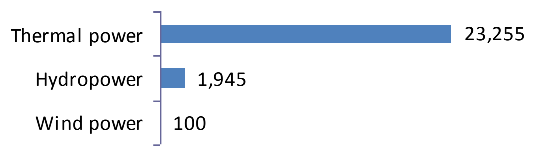

Figure 1 **Installed electricity capacity in Nigeria by source (MW)**
Source: American Journal of Electrical and Electronic Engineering [18]

Nigeria has an electrification rate of 48 per cent, with a population of approximately 173 million and an annual growth rate of 2.8 per cent. Approximately 50 per cent of the population lives in rural areas with approximately 20 per cent with access to electricity.[5]

The electricity supply is presently unreliable in the country with frequent shutdowns, load shedding and grid failures. On average consumers do not have electricity supply from the grid network for 10 hours every day. This has compelled many consumers (both industrial and residential) to buy diesel/petrol generating sets to meet their energy needs. The estimated electricity demand in the country is approximately 15,000 MW while only approximately 5,000 MW is effectively operating. This is attributable to the current state of the grid network that is characterized by frequent overloading, system collapses and transmission and distribution losses of up to 30 per cent. Diesel and petrol generators are presently meeting the current gap in the demand and supply.

Primary energy generation in Nigeria is mainly through the burning of traditional biomass and fossil fuels. In 2011, the total primary energy consumption mix was dominated by traditional biomass and waste (83 per cent), oil (11 per cent) gas (5 per cent) and hydropower (1 per cent) (Figure 2).[16]

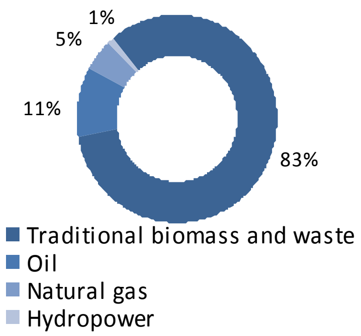

Figure 2 **Primary energy generation in Nigeria by source (%)**
Source: IEA[16]

The installed generating capacity of the country was increased from approximately 6,000 MW in 2005 to 10,396 MW through the *National Integrated Power Project* (NIPP) initiative. Nonetheless, in 2013, the available capacity was 6,056 MW while the energy demand was estimated to be 3,300 GWh.[6] The NIPP, conceived in 2004, was a fast-track government-funded initiative to stabilize the country's electricity supply, while the private-sector led structure of the *2005 Electric Power Sector Reform Act* (EPSRA) took effect. The NIPP was designed around gas-fired power stations in the gas-producing states with a cumulative power capacity of 5,222 MW. Notwithstanding the increase, the peak capacity generation is still approximately 4,978 MW as of 2015.[7,18]

The Government has reformed the electricity industry and enacted several laws and regulations to develop the country's abundant renewable energy (RE) deposits. The reform commenced with the preparation of a *National Electric Power Policy* (NEPP) in 2001 followed by the preparation and passage of EPSRA into law in March 2005.[10] The NEPP planned a three-stage legal and regulatory reform for the electricity sector comprising:

- A transition stage characterized by private power generation via Independent Power Producers (IPPs) and Emergency Power Producers (EPPs), corporate restructuring, unbundling and privatization of the National Electricity Power Authority (NEPA).
- A medium-term stage characterized by energy trading between generation and distribution companies on the basis of bilateral contracts.
- A long-term competition structure characterized by the optimal operation of various power generation, transmission and distribution companies.

The EPSRA provides for the vertical and horizontal unbundling of NEPA into separate and competitive entities, the development of competitive electricity markets, the setting up of a legal and regulatory framework for the sector, a framework for rural electrification, framework for the enforcement of consumer rights and obligations and establishment of performance standards. With the passage of EPSRA, NEPA was deregistered and the Power Holding Company of Nigeria (PHCN) was incorporated to manage the unbundling of NEPA into 18 companies: 6 Generating Companies (GENCOs), 1 Transmission Company (TRANCOs) and 11 Distributing Companies (DISCOs). Together these companies constitute the Nigerian Electricity Supply Industry (NESI) which is regulated by the Nigerian Electricity Regulatory Commission (NERC).

The restructuring broke the monopolistic framework of the power sector allowing private operators to apply for and obtain a licence through NERC to build and operate a power plant with aggregate capacity above 1 MW. It also established the Rural Electrification Agency (REA) together with an independent Rural Electrification Fund (REF) whose main objective is to fully incorporate renewable energy into the energy options.

In 2008, NERC introduced a Multi-Year Tariff Order (MYTO) in its effort to provide a viable and robust tariff policy for the NESI, as well as the framework for determining the industry pricing structure. The MYTO provides a 15 year tariff path for the electricity industry with minor reviews biannually and major reviews every five years. New tariff classes under the 2012 Tariff Order were published by NERC as part of a summary of the MYTO-2 Retail Tariffs.[11] A review of this has also been released for 2015. There are three separate Tariff Orders, one for each of the sectors in the NESI namely: GENCOs, TRANCOs and DISCOs/retail. Table 1 and 2 provide details of residential R2 category tariffs that came into effect on 1 July 2015 for four of the six DISCOS including expected increases for 2016, 2017 and 2018. The charges are in two parts, a fixed monthly charge and an energy charge for electricity consumption. Energy charges increased significantly from 2014 to 2015 to reflect the repayments of loans granted to all the DISCOS by the Central Bank of Nigeria.[12]

Table 1
Fixed monthly charges by DISCO 2015 - 2018

DISCO	*Fixed monthly charge (Nigerian Naira (US$))*			
	2015	*2016*	*2017*	*2018*
Benin	750 (4.50)	900 (5.4)	1 080 (6.48)	1 296 (7.78)
Ibadan	625 (3.75)	750 (4.5)	900 (5.40)	1 080 (6.48)
Ikeja	750 (4.50)	900 (5.4)	1 080 (6.48)	1 296 (7.78)
Eko	750 (4.50)	900 (5.4)	1 080 (6.48)	1 296 (7.78)

Source: NERC [12]

Table 2
Energy charges by DISCO 2014 - 2018

DISCO	*Energy charge (Nigerian Nairi (US$) per kWh)*			
	2015	*2016*	*2017*	*2018*
Benin	18.46 (0.111)	17.02 (0.102)	18.23 (0.109)	15.23 (0.091)
Ibadan	18.00 (0.108)	17.36 (0.104)	19.60 (0.118)	17.93 (0.108)
Ikeja	14.96 (0.090)	14.50 (0.087)	13.88 (0.083)	12.85 (0.077)
Eko	18.75 (0.113)	18.01 (0.108)	19.39 (0.116)	16.42 (0.099)

Source: NERC [12]

Small hydropower sector overview and potential

Small hydropower, according to the definition in the National Renewable Energy and Energy Efficiency Policy (NREEEP), is defined as 1 to 30 MW in Nigeria (see Table 3).[13] Installed capacity for small hydropower is approximately 45 MW with a total estimated potential capacity of 3,500 MW indicating that only 1.3 per cent has been developed.[9] To ascertain the technical and economically feasible potential, data was compiled on planned and studied sites, which provided a total of 735 MW.[17] Compared to data from the 2013 *World Small Hydropower Development Report* installed capacity has remained the same however estimated potential has increased considerably (see Figure 3).[3] It should be noted that since the previous report, at least one SHP plant (Tunga 0.4 MW) has been installed; however, the total installed capacity did not change as it is only an estimated total value.

Many studies, though concrete numbers vary, have stated that hydropower potential, and specifically small hydropower is very vast in Nigeria, with 63 per cent of the country's land space being occupied by water. [18] The United Nations Industrial Development Organization (UNIDO) has focused on creating awareness among relevant stakeholders on the huge small hydropower potentials available in the country. In November 2002, the Energy Commission of Nigeria (ECN) collaborated with UNIDO and other relevant Government parastatals to organize a national stakeholders' forum on renewable energy technologies specifically based on small hydropower for rural industrialization with the aim of formulating strategies to provide access to clean and reliable energy services for Inclusive and Sustainable Industrial Development (ISID). A memorandum of understanding was signed between ECN and UNIDO and the International Center on Small Hydro Power (ICSHP) for further cooperation in harnessing the identified small hydropower potential.

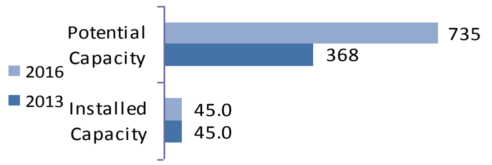

Figure 3 **Small hydropower capacities (up to 30 MW) 2013-2016 in Nigeria (MW)**
Sources: ICEED,[8] *WSHPDR 2013,*[3] A. I. Agbonaye,[17] *IEA.*[9]
Note: the comparison is between data from the *2013 WSHPDR* and the 2016 report

ECOWAS Centre for Renewable Energy and Energy Efficiency (ECREEE) in collaboration with UNIDO has also jointly developed the ECOWAS Small-Scale Hydropower Programme (2013 – 2018) for the West Africa Region. Prior to UNIDO's intervention small hydropower development in the country had been minimal. Approximately 45 MW of SHP has been developed so far, 70 per cent of which by the independent power producer, the Nigerian Electricity Supply Corporation.

Table 3
Categories of hydropower by installed capacity

Category	*Installed capacity (MW)*
Pico	< 0.1
Micro	0.1 - 0.5
Mini	0.5 - 1
Small	1 - 30
Medium	30 - 100
Large	> 100

Source: NREEP [13]

UNIDO's intervention includes establishment of the following pilot plants: Ezioha Mgbowo plant (30 kW), Enugu State; Waya dam plant (150 kW), Bauchi State; and Tunga dam plant (400 kW), Taraba State. The Tunga plant was operational as of 2016. Small hydropower capacity has been developed by various institutions in a range of river basins in the country. This has led to over 200 potential small hydropower sites identified, 17 feasibility studies with detailed project reports carried out and the development of three sites that are under construction which includes a 1,200 kW small hydropower project in Benue State with donor support. Although 17 sites have bankable documents, private investors are hesitant to develop them as the investment costs are high and obtaining finance is difficult. In the 5th Global Environmental Facility project cycle (GEF-5), 3.1 MW cumulative capacity has been planned for implementation directly and to be replicated by private investors to an estimated capacity of over 30 MW.[15]

UNIDO has facilitated the transfer of technology in manufacturing micro-hydropower turbines up to a capacity of 125 kW to the National Agency for Science and Engineering Infrastructure (NASENI), and the Project Development Agency (PRODA). Under the same GEF-5 cycle, upscaling of local turbine and control system manufacturing to 300 kW capacity has been planned.

The Renewable Energy Master Plan launched in 2005 has a 10-year target (2007-2017) for increasing the contribution of renewable energy sources to the energy mix of the country. The initial targets based on peak supply from small hydropower were: 40 MW by 2007, 100 MW by 2008 and 400 MW by 2016. The targets were based on the assumption that over 200 identified potential SHP sites would be developed. However, achieving these targets has been a difficult task and only one of the targets has been met.[14]

There are a number of incentives for small hydropower construction. The EPSRA allows a person to construct, own or operate an off-grid power plant not exceeding 1 MW in aggregate at a site without a licence. This exemption to holding a licence favors energy generation through small hydropower since some of the identified small hydropower sites fall within the required range. It is also expected to encourage private sector participation to invest in small/mini/micro-hydropower especially for rural development and off-grid generation.

Renewable energy policy

The Federal Ministry of Power has a renewed focus on rural electrification using renewable energy sources, as a result of the successful privatization of the power sector. This project aims to create a conducive environment for independent power producers to invest in small hydropower plants which is in line with Nigerian Energy Policy, the Nigerian Renewable Electricity Policy, as well as the Renewable Energy Master Plan and Vision 2020, which aims to generate 6,000 MW of electricity by focusing on renewable and sustainable energy sources.[14] To develop the potential of its renewable energy resources and achieve the Millennium Development Goals (MDGs) and National Economic Empowerment Development Strategy (NEEDS) targets, the Government has formulated many RE-related policies including:

- National Energy Policy, which includes renewable energy, initiated by the Energy Commission of Nigeria and approved by the Federal Government in 2003.
- Draft Renewable Energy Electricity Policy initiated by the Federal Ministry of Power in 2006.
- Nigerian Biofuels Policy Incentives initiated by the Nigeria National Petroleum Company (NNPC) and approved by the Federal Executive Council (FEC) in 2007.
- The Vision 2020 document initiated by the National Planning Commission and approved by FEC in 2012.
- National Climate Change Policy initiated by the Federal Ministry of Environment and approved by FEC in 2011.
- National Environmental Regulation (2009, 2011) initiated by the National Environmental Standards and Regulations Enforcement Agency (NESREA).
- Electric Power Sector Reform (EPSR) Act of 2005, which liberalized the electricity sector, unbundled the PHCN in preparation to its privitization, and established the Nigerian Electricity Regulatory Commission (NERC) as the sector regulator.
- Regulation on Independent Electricity Distribution Networks (IEDN) and Embedded Generation initiated by NERC.

The Renewable Energy Master Plan (REMP) is structured into the following programmes with short (2013 – 2015), medium (2016 – 2020), and long term (2021 – 2030) goals. Programme under the Master Plan include: National Biomass Energy Programme, National Solar Energy Programme, National Hydropower Programme, National Wind Energy Programme, Emerging Energy Programme and Framework Programme for Renewable Energy Promotion. The framework programme articulates issues that are common to all other subsectoral programmes and ensures that activities within the subsectors are mutually supportive.

Financing is crucial for realizing the federal Government policy on renewable energy and funding requirements will be substantial. New investments are needed for research and development activities. The required type of financing is long-term and involves both foreign and domestic financing sources however foreign investment capital will provide a greater proportion of needed funds.

Table 4
Renewable energy feed-in tariffs 2012 - 2016 by source

Type of power plant	*Wholesale contract price (Nigerian Nairi (US$) per MWh)*				
	2012	*2013*	*2014*	*2015*	*2016*
Large hydropower	4,898 (29.39)	5,290 (31.74)	5,715 (34.29)	6,174 (37.04)	6,671 (40.03)
Small hydropower	23,561 (141.37)	25,433 (152.60)	27,456 (164.74)	29,643 (177.86)	32,006 (192.04)
On-shore wind power	24,543 (147.26)	26,512 (159.07)	28,641 (171.85)	30,943 (185.66)	33,433 (200.60)
Solar power	67,917 (407.50)	73,300 (439.80)	79,116 (474.70)	85,401 (512.41)	92,192 (553.15)
Biomass power	27,426 (164.56)	29,623 (177.74)	32,000 (192.00)	34,572 (207.43)	37,357 (224.14)

Source: NERC [11]

The Government will provide guarantees and financial frameworks aimed at stimulating the expansion of the renewable electricity market. Considering the risk element involved in financing renewable energy projects, Government investments should enhance rates of return and shorten pay back periods in order to attract investors. Additionally, the federal Government shall continuously improve the conditions for enhanced funding of renewable electricity through equity, debt financing, grants and microfinance.[13]

To ensure a stable and attractive pricing policy for renewable energy sources, NERC plans to develop optimal feed-in tariffs (FIT) for small hydropower schemes not exceeding 30 MW as well as all biomass co-generation, solar and wind-based power plants, irrespective of their size. It is expected that specific tariff regimes formulated by NERC shall be long-term, guarantee buyers under a standard contract and provide reasonable rates of return. NERC will also develop other tariff-related incentives and regulations to support renewable energy development.[13]

Barriers to small hydropower development

The main constraints in the rapid development and diffusion of technologies for the exploitation and utilisation of renewable energy resources in the country are the absence of a market and the lack of appropriate policy, regulatory and institutional frameworks to stimulate demand and attract investors. Though several policies and regulatory frameworks are in place to promote renewable energy-based electricity, there is no definite and well-framed pathway to make these policies successful. The comparatively low quality of the systems developed and the high initial upfront costs also constitute barriers to the development of markets. So far, private sector participation in renewable energy implementation in the country is concentrated in the area of importation and marketing of components. Full participation by the private sector in small hydropower development, especially in the form of investment towards local fabrication of turbines, will enhance the development of small hydropower potential. Additionally, the recent unbundling of the Power Holding Company of Nigeria (PHCN) into different companies under the privatization programme have made accessing reliable data rather difficult.

In addition to the above barriers, other barriers to small hydropower development include a lack of public awareness and participation through experience sharing, and limited skills and experience for developing small hydropower projects.

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Annex II: Long list

SUMMARY OF SMALL HYDRO POTENTIAL SITES IN NIGERIA WITH PREFEASIBILITY STUDIES

S/N	Site	State	Estimated Potential (KW)	Investigation Stage
1	Afundu	Cross River / Obudu	30 / 1000	Prefeasibility
2	Agbokim Fall	Cross River / Ikom / Etung	2,000 / 1,500	Prefeasibility
3	Owena	Ondo / Bolorunduro	1,300	Prefeasibility
4	Dindima	Gongola /	16,000	Feasibility
5	Miango Dam	Plateau / Bassa	N.A	Prefeasibility
6	Ero Dam	Ekiti / Moba	870	Prefeasibility
7	Okhuanwan River	Edo / Uhunwode	600	Prefeasibility
8	Iguoriakhi Village	Edo / Ovia N.E.	100 / 78	Prefeasibility
9	Ikpoba River	Edo / Ikoba-okha	3,120	Prefeasibility
10	Monkin	Taraba	900	Prefesibility
11	Eti-Oni	Osun / Oriade	278 / 300	Prefeasibility
12	Oke-Odan	Ogun / Yewa	250	Prefeasibility
13	Sepeteri Dam	Oyo / Sepeteri	194	Prefeasibility
14	Omi River	Oyo	625	Prefeasibility
15	NCAM (Ilorin)	Kwara	111	Prefeasibility
16	Richa II	Plataeu	25,000	Prefeasibility
17	Ta hoss Community	Plateau	100	Prefeasibility
18	Jibia	Katsina	31,300 / 3,000	Prefeasibility
19	Fajina	Katsina	30,000	Prefeasibility
20	M/Fashi	Katsina	23,004	Prefeasibility
21	Mairuwa	Katsina	16,800	Prefeasibility
22	Sabke	Katsina	18,750	Prefeasibility
23	Iddo	Osun	242.9	Prefeasibility
24	Ugonoba	Edo	485.4	Prefeasibility
25	Kangimi Dam	Kaduna	1,470	Prefeasibility
26	Birnin Gwari	Kaduna	84	Prefeasibility
27	A.B.U. Dam	Kaduna	68.25	Prefeasibility
28	Fatika Dam	Kaduna	29.40	Prefeasibility
29	River Dogon Ruwa (F.U.T), Minna	Niger	734	Prefeasibility
30	Yola Buruku	Kaduna	6,475.00	Prefeasibility
31	Matari Dam	Kaduna	34.65	Prefeasibility
32	Zaria Dam	Kaduna	73.50	Prefeasibility
33	Pambegua Dam	Kaduna	115.50	Prefeasibility
34	Gimbawa Dam	Kaduna	402.50	Prefeasibility
35	New Galma Dam	Kaduna	2,730.00	Prefeasibility
36	Karami Dam	Kaduna	3,780.00	Prefeasibility
37	Lukarbu Dam	Kaduna	84.00	Prefeasibility
38	Gurara Dam	Kaduna	1,575.00 / 10,000	Prefeasibility

39	Fadan Kagoma	Kaduna	246.00	Prefeasibility
40	Sabon Sarke	Kaduna	14.70	Prefeasibility
41	Magama Dam	Kaduna	7,350.00	Prefeasibility
42	Madakiya Dam	Kaduna	3,780.00	Prefeasibility
43	Manchok Fall	Kaduna	115.00	Prefeasibility
44	Kogi Dam	Kaduna	14,490.00	Prefeasibility
45	Idu / Igu	FCT	2,000.00	Prefeasibility
46	Gwagwalada	FCT / Kaida	500.00	Prefeasibility
47	Oturkpo	Benue / Okpaflo	50.00	Prefeasibility
48	Tede	Nasarawa / Tede	8,000.00	Prefeasibility
49	N'gell	Plateau / Ganawuri Bassa	150.00	Prefeasibility
50	Tappa I	Niger / Gami	700	Prefeasibility
51	Monkin	Taraba / Zing	900	Prefeasibility
52	Agai / Lapai	Kaduna / Agai Lapai	200	Prefeasibility
53	Rima	Sokoto / Goronyo	3,000	Feasibility
54	Nnewi	Anambra / Nnewi	200	Prefeasibility
55	Echiku	Ebonyi / Ngbo W.	970	Prefeasibility
56	Urashi	Imo / Orlu	200	Prefeasibility
57	Ezilo Water works	Ebonyi / Ngbo W	135	Prefeasibility
58	Ethiope	Delta/Abraka	1,000	Prefeasibility
59	Ogha	Edo/Ovia S.W	780	Prefeasibility
60	Ogba	Edo	100	Prefeasibility
61	Omi	Oyo/Ono-ara	568	Prefeasibility
62	*Gwaran		30,000	Feasibility
63	*Kasimbila	Benue / Katsina Ala	30,000	Prefeasibility
64	*Ifon	Ondo / Osse	30,000	Prefeasibility
65	*Kurra I	Plateau	15,000	Prefeasibility
66	*Kurra II	Plateau	25,000	Prefeasibility
67	*Zurubu	Kaduna	20,000	Prefeasibility
68	*Kafanchan	Kaduna	10,000	Prefeasibility
69	UI	Ibadan/Oyo	7.5	Prefeasibility
70	Kwa Falls Dam	Aningeje, Akamkpa Cross River	10,000	Prefeasibility
71	Owena River	Ondo State	192.44	Prefeasibility
72	Aponmu River	Ondo State	19.91	Prefeasibility
73	Odowo (Irore River)	Ondo State	105.5	Prefeasibility

Annex III: Final Site list

Information needed for 5 selecting potential site in Nigeria

Notice:

- Please provide the following information of **5 potential sites**
- **Sites will be considered with priorities for the following:**
  1) Preliminary work has been done: investigation, look for potential sites, etc.
  2) Financing sources are pre-identified.
  3) Installed capacity is **no more than 1000kW.**
- 4) Replicability is preferred.
- If any **photo or video** of site condition is available, please attach.

1. Site Location			
Site name	**Otukpo Multipurpose Dam (Dam 68% Completed) Brown Field**	No. in proposed sites	No. 1
Location	Otukpo, Otukpo L.G.A	Latitude /Longitude (xx°xx'xx")	**Lat**: 6°49'12''N **Long**: 8°40'12''E
2. Project Information			
Discharge(m^3/s)	1,264m^3/s (Total Spillway Discharge for multi-purpose uses)	Water head(m)	21.2m
Proposed capacity(kW)	1MW X 3Units (Ministry will provide 2Units)	Target power generation (kWh)	
3. River in the Project Area			
Name	Okpokwu	Length upstream the dam site (km)	55km
Width at the dam site (m)		Average water level at the dam site (m)	
Average water level at the powerhouse site (m)		Basin area upstream the dam site (km^2)	1,317km^2
4. Meteorology Data			
Climate type	Humid Climate		
Precipitation(mm)	Annual average:1,366mm/yr	Max:1,407mm	Min: 1,060mm
Evaporation(mm)	Annual average:	Max:	Min:
Temperature(°C)	Annual average:	Max: 38°C	Min: 22°C
5. Hydrological Data			
Discharge(m^3/s)	Max:545.24MCM/yr Min:321.08MCM/yr	water level(m)	Max: Min:
Flood season	April- October	Dry season	Nov-March
6. Topographical and Geological Data			
Land form	Sedimentary(Asata-Nkporo Group)	Elevation	350m& below
Additional available data	**1. Topographical map with the scale of 1:50000 or larger(with the marked dam site and powerhouse site)**		

	2. The geological data already are available at the dam site and powerhouse site (if any). 3. The prefeasibility study report (if any). 4. The hydrologic station located in the proposed basin or in its neighboring basin.		
7. Transportation and Grid Access			
Distance from town or city(km)	7km from Otukpo Town	Access road to the site to be constructed(km)	24km
Transmission line length to be constructed(km)	4km	Transmission line voltage(kV)	33KV & 11KV Combined
8. Economic and Social Development Status			
Population (power supply area）	65,000	GDP	
Feed-in tariff($/kWh)		Electricity access rate(%)	
9. Other Related Information			
Licensing requirements			
Policy and regulations requirements (e.g., investment policy, tariff, tax issue)			
Potential investments and resource mobilization plan for the project			
10. Project Contact Information			
Government co-coordinating agency		Federal Ministry of Water Resources	

1. Site Location			
Site name	**MonayaOgoja**(Green Field)	No. in proposed sites	No.2
Location	MonayaOgoja	Latitude /Longitude (xx°xx'xx")	Lat. $8^0$47’ Long. 6^0 39’
2. Project Information			
Discharge(m^3/s)		Water head(m)	
Proposed capacity(kW)	1000kw	Target power generation (kWh)	
3. River in the Project Area			
Name	Monaya	Length upstream the dam site (km)	
Width at the dam site (m)		Average water level at the dam site (m)	
Average water level at the powerhouse site (m)		Basin area upstream the dam site (km^2)	
4. Meteorology Data			
Climate type	Guinea/Tropical		
Precipitation(mm)	Annual average:	Max: 3,000mm	Min:2,000mm
Evaporation(mm)	Annual average:	Max:	Min:
Temperature(°C)	Annual average:	Max: 28.7^{0}c	Min:25.3^{0}c
5. Hydrological Data			
Discharge(m^3/s)	Max:31.0lt/sec/km^2 Min:	water level(m)	Max: Min:
Flood season	April- October	Dry season	Nov-March
6. Topographical and Geological Data			
Land form	Lowland	Elevation	0m –300metres
Additional available data	5. **Topographical map with the scale of 1:50000 or larger(with the marked dam site and powerhouse site)** 6. The geological data already are available at the dam site and powerhouse site (if any). 7. The prefeasibility study report (if any). 8. The hydrologic station located in the proposed basin or in its neighboring basin.		
7. Transportation and Grid Access			
Distance from town or city(km)	20km	Access road to the site to be constructed(km)	Access road already completed
Transmission line length to be constructed(km)	There is existing Transmission Line	Transmission line voltage(kV)	33KV
8. Economic and Social Development Status			
Population (power supply area）	171,901(Ogoja)	GDP	
Feed-in tariff($/kWh)		Electricity access rate (%)	
9. Other Related Information			

Licensing requirements	
Policy and regulations requirements (e.g., investment policy, tariff, tax issue)	
Potential investments and resource mobilization plan for the project	PPP
10. Project Contact Information	
Government co-coordinating agency	Federal Ministry of Water Resources

1. Site Location			
Site name	**Nnewi (Green Field)**	N	No. 3
Location	Nnewi	Latitude /Longitude (xx°xx'xx")	Lat.$6^0$1'11''N Long.$6^0$54'53''E
2. Project Information			
Discharge(m^3/s)		Water head(m)	
Proposed capacity(kW)	1000kw	Target power generation (kWh)	
3. River in the Project Area			
Name		Anambra	
Width at the dam site (m)		Average water level at the dam site (m)	
Average water level at the powerhouse site (m)		Basin area upstream the dam site (km^2)	
4. Meteorology Data			
Climate type	Guinea (Tropical)		
Precipitation(mm)	Annual average:	Max:2,000mm/yrMin:1,500mm/yr	
Evaporation(mm)	Annual average:	Max:	Min:
Temperature(°C)	Annual average: 26.7^{0}c	Max:	Min:
5. Hydrological Data			
Discharge(m^3/s)	23.6lt/s/km^2 (catchment Av. Discharge)	water level(m)	Max: Min:
Flood season	April-October	Dry season	Nov.-March
6. Topographical and Geological Data			
Land form	Lowland with dotted hills	Elevation	300m–600m
Additional available data	9. **Topographical map with the scale of 1:50000 or larger(with the marked dam site and powerhouse site)** 10. The geological data already are available at the dam site and powerhouse site (if any). 11. The prefeasibility study report (if any). 12. The hydrologic station located in the proposed basin or in its neighboring basin.		
7. Transportation and Grid Access			
Distance from town or city(km)		Access road to the site to be constructed(km)	Access Road already completed.
Transmission line length to be constructed(km)	There is existing Transmission line	Transmission line voltage(kV)	330KV
8. Economic and Social Development Status			
Population （power supply area）	121,065(as at 1991)	GDP	
Feed-in		Electricity access rate	

tariff($/kWh)		(%)	
9. Other Related Information			
Licensing requirements			
Policy and regulations requirements (e.g., investment policy, tariff, tax issue)			
Potential investments and resource mobilization plan for the project		PPP	
10. Project Contact Information			
Government co-coordinating agency		Federal Ministry of Water Resources	

1. Site Location			
Site name	**IngawaDallaje Dam Project(Dam 40% Completed) Brown Field**	No. in proposed sites	No.4
Location	IngawaDallajeBindawa L.G.A	Latitude /Longitude (xx°xx'xx")	Lat: 13^0.06'N Long: $8^0$00'E
2. Project Information			
Discharge(m^3/s)		Water head(m)	
Proposed capacity(kW)	1,000kw	Target power generation (kWh)	
3. River in the Project Area			
Name	Dakau	Length upstream the dam site (km)	
Width at the dam site (m)		Average water level at the dam site (m)	
Average water level at the powerhouse site (m)		Basin area upstream the dam site (km^2)	
4. Meteorology Data			
Climate type	Sahel(Tropical)		
Precipitation(mm)	Annual average: 826mm/year(catchment Av) Max: 1,000mm/year Min:600mm/year		
Evaporation(mm)	Annual average: 27.2^{0}c Max: Min:		
Temperature(°C)	Annual average: Max: Min:		
5. Hydrological Data			
Discharge(m^3/s)	Max: Min:	water level(m)	Max: Min:
Flood season	June-October	Dry season	November-May
6. Topographical and Geological Data			
Land form	Lowland/upland (Undulating)	Elevation	300m – 600m
Additional available data	**13. Topographical map with the scale of 1:50000 or larger(with the marked dam site and powerhouse site)** 14. The geological data already are available at the dam site and powerhouse site (if any). 15. The prefeasibility study report (if any). 16. The hydrologic station located in the proposed basin or in its neighboring basin.		
7. Transportation and Grid Access			
Distance from town or city(km)	About 10km	Access road to the site to be constructed(km)	There is existing access road (About 10km)
Transmission line length to be constructed(km)	Completed	Transmission line voltage(kV)	33KV
8. Economic and Social Development Status			
Population（power supply area）	75,440(as at year 2011)	GDP	

Feed-in tariff($/kWh)		Electricity access rate (%)	
9. Other Related Information			
Licensing requirements			
Policy and regulations requirements (e.g., investment policy, tariff, tax issue)			
Potential investments and resource mobilization plan for the project		National Budget and PPP	
10. Project Contact Information			
Government co-coordinating agency		Federal Ministry of Water Resources	

1. Site Location			
Site name	**Ile-Ife Dam (Dam 75% Completed) Brown Field**	No. in proposed sites	No. 5
Location	Osun State	Latitude /Longitude (xx°xx'xx")	Lat: 4^{0}0’37’’N Long:7^{0}0’25’’E
2. Project Information			
Discharge(m^3/s)	8.8M^3/sec(spillway discharge)	Water head(m)	600m
Proposed capacity(kW)	1 MW x 2Units (Ministry will provide 1Unit)	Target power generation (kWh)	
3. River in the Project Area			
Name	Kajola	Length upstream the dam site (km)	33.5km
Width at the dam site (m)	60m	Average water level at the dam site (m)	18.7m
Average water level at the powerhouse site (m)	18m	Basin area upstream the dam site (km^2)	167km^2
4. Meteorology Data			
Climate type	Tropical wet and dry climate		
Precipitation(mm)	Annual average:1,565mm/year		Max: 1,965mm/year
Evaporation(mm)	Annual average:	Max:	Min:
Temperature(°C)	Annual average:23.5	Max:29.6	Min:21.2
5. Hydrological Data			
Discharge(m^3/s)	Max: Min:	water level(m)	Max: Min:
Flood season	June- September	Dry season	November-April
6. Topographical and Geological Data			
Land form	Lowland with hills (un-dulating)	Elevation	239m-350m
Additional available data	**17. Topographical map with the scale of 1:50000 or larger(with the marked dam site and powerhouse site)** 18. The geological data already are available at the dam site and powerhouse site (if any). 19. The prefeasibility study report (if any). 20. The hydrologic station located in the proposed basin or in its neighboring basin.		
7. Transportation and Grid Access			
Distance from town or city(km)	2.9km	Access road to the site to be constructed(km)	1.9km
Transmission line length to be constructed(km)	1.9km	Transmission line voltage(kV)	33KV
8. Economic and Social Development Status			
Population （ power supply	168,000	GDP	

area）			
Feed-in tariff($/kWh)		Electricity access rate (%)	
9. Other Related Information			
Licensing requirements			
Policy and regulations requirements (e.g., investment policy, tariff, tax issue)			
Potential investments and resource mobilization plan for the project		National Budget	
10. Project Contact Information			
Government co-coordinating agency		Federal Ministry of Water Resources	

Appendix-IV Executive Summary of Nigerian Feasibility Study Report

The Feasibility Study Report

Otukpo Small Hydropower Project

March 2020

International Center on Small Hydro Power (ICSHP)

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Executive Summary

1. Introduction

The proposed Otukpo Multi-Purposed Dam project is located within Four (4) Local Governments Areas of Otukpo, Ohimini, Ado and Okpoku all in Benue State, North Central Nigeria. The proposed facility which has an approximate height of 31m with 8.5m crest width and a length of about 2.3km with expected reservoir water holding capacity 132.4 million cubic meters is designed to be a multipurpose as it will serve as source of public water supply majorly to Otukpo and its neigbouring communities, irrigation (to ensure year-round agricultural activities) and hydro-power generation (as a means of ensuring reliable electricity supply to the area). The project is however planned to be executed in two (2) phases with the Dam construction and Irrigation components and water supply and electricity generation as the second phase. The station is located at 7^{o} 6' 50" N, 8^{o} 4' 41" E.

The Otukpo project composes of dam, spillway, intake and powerhouse. The project was started to construction since 2013, and so far, 68% of first phase has been completed.

The dam of Otukpo power station is an earth dam, and the dam axis is about 2,460m of length, the dam crest is 8.0m of width and 112.0m of height, the dam base is 90.0m of height and the maximum height is 22m. The dam upstream slope is 1:3, and the downstream slope is 1:2.5.

The project has an open spillway, arranged at the right bank of the dam. The weir is an arch with 60m of width and the weir crest is 106.0m of height, and the maximum discharging flow is 2,000 m^3/s.

The diversion system of the project is transformed by diversion culvert. The diameter of the water supply pipeline is DN1,000 mm and the diameter of pre-embedded penstock is DN3,000mm. The power station of proposed power station is arranged on the right side of the downstream of diversion culvert, which is the ground-type plant behind the dam, with a total installed capacity of 1,000kW.

Outgoing transmission line of the project is 33kV, and 12km long to the nearby city Otukpo, serving 650,000 population. The remaining power can be connected to the national grid. At present, the transmission line has been connected to the dam area.

Location of Otukpo power station by satellite picture

The Otukpo Multipurpose Dam was initially designed by S.C.C. (NIGERIA) LTD and completed in March 2014.

2. Hydrology

2.1 Overview of the Basin

The proposed project is located on River Okpoku near Okpokwu community about 14km far away from Otukpo Town covering parts of Otukpo, Ohimini, Ado and Okpoku Local Government Areas of Benue state. Access to the selected location is through the main highway from Otukpo leading to Enugu in Enugu State which is at the moment in good conditions. The dam of Otukpo power station is located at 8°05′E, 07°07′N. The area of the Otukpo dam catchment was determined as 1,100 km^2.

2.2 Climate and precipitation

This region has two seasons: rainy (April to October) and dry (November to March). Rainfall is mainly in rainy season and the average annual rainfall is about 1,345 mm. The precipitation during dry season only accounts for 3.36% of the annual total, but the rainfall in rainy season accounts for 96.64% of the total. July, August and September have the most rain, accounting for 17.93%, 19.68% and 16.3% of the annual total respectively. Serious flood also happens in these three months. The maximum temperatures (27-38℃) are recorded in the months of March to May, while the minimum temperatures (23-32℃) are recorded in the rainy season months of July to September.

The annual maximum values of 80 to 95% occur around August to September while the minimum (21 to 44%) are recorded between November and March. The wind of the area varies between light, gentle and moderate breeze and speed varies from 3.1m/s upward to 9.8m/s for both dry and wet season.

2.3 Hydrological data

There is no hydrological station or precipitation station in this basin. There is a Railway Bridge hydrological station downstream of the project, 1.2km far way. The Railway Bridge hydrological station has daily runoff data from 1972 to 1978 and 1987 to 1994, and daily precipitation data from 1973 to 1979 and 2001 to 2010.

2.4 Annual runoff

The runoff of Otukpo station can be directly calculated by the runoff series from the Railway Bridge hydrological station. The data series is not enough to calculate the runoff frequency. Therefore, according to the precipitation and runoff data, the runoff coefficient of this basin is 0.21. The average annual flow data of 20 years can be obtained by the extended runoff series with precipitation and runoff correlation interpolation, and the runoff frequency can be analyzed and calculated.

According to the frequency analysis, the average annual flow of Otukpo power station is 13.9m^3/s, the annual runoff Cv is 0.46, and Cs/Cv is 2.0. The flow in rainy year (P=10%) is 22.5m^3/s, the flow in normal year (P=50%) is 12.9m^3/s, and the flow in dry year (P=90%) is 6.60m^3/s.

The annual distribution of design annual runoff adopts the annual water quantity control and the same ratio scaling method. 1974-1975, 1972-1973, and 1973-1974 were selected as typical years of rainy, normal, and dry years.

2.5 Flood

As no information with regard to Design Flood Standards for Nigeria was available, the internationally accepted Design Flood Standards as applied in South Africa (SANCOLD, 1991), otherwise referred to as the "SANCOLD Guidelines", were applied. These guidelines specify design floods for existing or new dams based on the height of the dam and the dam's hazard rating (potential impact on life and property in the event of a failure). Based on the available information, Otukpo Dam can be classified as equivalent to a SANCOLD Category III dam, which implies a Recommended Design Flood (RDF) of 1:200 years and a Safety Evaluation Flood (SEF) equal to the Probable Maximum Flood (PMF).

There is no measured flood data series at or near the upstream and downstream of the Otukpo power station, so the flow series cannot be used to calculate the design flood. It can use the design storm to calculate the design flood. The catchment area of this project is large enough to use the 24h (1 day) for design storm. The results of the design storm are shown in table 2-11, and the results of the design flood are shown in table 3-17 and table 3-18.

2.6 Sediment

The Otukpo project basin has relatively good vegetation cover, which belongs to mild soil erosion area. The soil erosion modulus is not large, and the suspended sediment and bed sediment content in the basin are small.

2.7 Stage/flow relation

The stage-discharge relation at the section of the tail water of the Otukpo station is determined by the river section data and hydraulic calculation formula according to the river section characteristics.

3. Geology

3.1 Regional Geology

The land is generally lowly (averaging 100m – 250m) within the Benue valley. The basement rocks are dominated by porphyritic granites, migmatites, diorites, pegmatites and gneisses. These rocks are rich in solid minerals, such as limestone, baryte, coal, gypsum, salt, shales, silica, sand and kaolin which are currently being mined.

The dam site is located in an area underlain by sedimentary strata of the Asata-Nkporo Group which mainly comprises shales and mudstones. Intrusive dolerite dykes are recognized in the general area.

3.2 Seismic Hazard

In terms of the seismic hazard, the entire country of Nigeria is characterized by a low seismic hazard. An internet source (http://earthquake.usgs.gov/regional/world/africa/gshap.php) indicated a peak ground acceleration with a 10% probability of being exceeded in a 50 year period (equivalent to a recurrence interval of 1:475 years) for neighbouring Cameroon to be in the order of about 0.02g to 0.04g. A peak ground acceleration of 0.05g was adopted as the Maximum Credible Earthquake (MCE) for the site due to its proximity to Cameroon.

3.3 Engineering Geological Conditions

The geological profile in the engineering area may be summarized as follows:

Poorly developed topsoil cover (average thickness 0.2 m);

Lateritic clay which comprises soft to stiff clay containing laterite nodules (thickness generally between 0.9 m and 1.7 m;

Residual clay, derived from the weathering of the underlying shale, with average thicknesses varying between 1.5 m and 3.7 m.

Site geological parameters: red soil bulk density is 1912 kg/m^3, c = 6 kPa, ϕ = 32 °; Residual slope sediment bulk density is 1526 kg/m^3, c = 0 kPa, ϕ = 28 °.

3.4 Quarry

The relatively high percentage of secondary minerals (19% to 22%) identified within the limited number of rock samples is an indication that the process of decomposition of the rocks in question is well advanced.

The durability tests on the hard rock dolerite indicated that the rock can generally be considered acceptable for use as coarse aggregate / rip-rap.

Since the spillway concrete project of this Otukpo Multi-Purpose Dam has been completed, the borrows for spillway concrete coarse aggregate and sand, and can be used as the concrete pouring in powerhouse facility. The concrete quantity of powerhouse is not large, and the storage and quality of concrete aggregate can meet the requirements.

4. Project scale

4.1 Brief introduction

The proposed Otukpo Multi-purposed Dam project is located within Four (4) Local Governments Areas of Otukpo, Ohimini, Ado and Okpoku all in Benue State, North Central Nigeria. The proposed facility which has an approximate height of 31m with 8.5m crest width and a length of about 2.3km with expected reservoir water holding capacity 132.4 million cubic meters is designed to be a multipurpose as it will serve as source of public water supply majorly to Otukpo and its neigbouring communities, irrigation (to ensure year round agricultural activities) and hydro-power generation (as a means of ensuring reliable electricity supply to the area). The project is however planned to be executed in water (2) phases with the Dam construction and Irrigation components and water supply and electricity generation as the second phase.

4.2 Storage Capacity Curve

The relation between water level and capacity of Otukpo reservoir is based on the reservoir capacity curve in the dam design data.

4.3 Runoff regulation analysis

Otukpo hydropower station is an annual regulation station and only water supply and irrigation are satisfied, the station can generate the electricity. The hydrological year of this basin is from each April to next March. At the beginning of April, the reservoir begins to store water from the lowest level of power generation. When the flow is larger than the regulating flow during the flood season, the river flow is not only used to generate the electricity but also stored in the reservoir. When the reservoir water level is high, the power generation flow will be increased to full load, and the reservoir will be full to normal level and then discard. When the flow is smaller than the regulating flow during dry season, the regulating flow during dry season is used to generate the electricity. The reservoir supplies the water. By next March, when the reservoir is reduced from normal level to the lowest level, an annual regulation is completed.

4.4 Flood regulation analysis

According to the Otukpo dam design data, the spillway is 60m of length and 106m of height. The normal water level of the reservoir is 106m. According to the flood regulation calculation, the once encountered flood peak flow of the reservoir in 200 years is 885 m^3/s, the discharge peak flow of the reservoir is 215 m^3/s, and the designed flood level of the reservoir is 107.38m. The flood peak flow of possible maximum flood (PMF) is 4370 m^3/s, the discharge peak flow of PMF is 1760m^3/s, and the verified flood level is 111.55m.

4.5 Characteristic stage selection

According to the Otukpo dam design data, the spillway is 60m of length and 106m of height. The normal water level of the reservoir is 106m. According to the flood regulation calculation, the designed flood level of the reservoir is 107.38m and the check flood level is 111.55m. According to the river bed elevation at tail water and the stage-discharge relation curve, the designed tail water level of the power station is 86.5m.

4.6 Project scale

Three installed capacity plans are proposed for technical and economic comparison: 3×700kW, 3×1100kW and 3×1500kW. The dam of this project has been under construction, and the water delivery system of the power station has been almost completed. According to the diameter of penstock and water flow of the power station, the installed capacity of the power station is determined to be 3 x 1100kW.

According to the reservoir inflow of three hydrological years of rainy year, normal year and dry year and the operation mode of the power station, the station should operate at high water level as far as possible. It is calculated that the average power generation of the station is 10.66 million kWh, and the annual utilization hours is 3230h.

5. Project layout and hydraulic structures

5.1 Design basis

The Otukpo hydropower station is constructed on the basis of the existed Otukpo reservoir with 3.3 MW of the total installed capacity. The design flood standard of the dam is once every 200 years, and the verification standard takes the PMF. The structures have been completed.

According to the installed capacity of Otukpo power station, the flood control standard of powerhouse should be once every 20 years.

The peak acceleration of earthquake in the dam site of this project is 0.05g, and the seismic intensity is less than VI.

5.2 Project site selection

The powerhouse of this project is constructed based on the existed Otukpo reservoir, located at the Otukpo dam toe.

5.3 General project layout

1）Dam

The constructed dam is earth-rockfill dam with 2460m length of dam axis. The dam axis is plane transition. The left dam section is 1430m of length and the right dam section is 1030m of length. The base level of the dam is 90.0m, the crest level is 112.0m, and the maximum dam height is 22m. The dam crest is 8.0m of width, the upstream slope is 1:3 and the downstream slope is 1:2.5, and the maximum dam foundation width is 93.0m.

2）Spillway

The constructed open spillway is located at the right dam section, and the central line of spillway is located at dam pile no. 1+600m. The crest of the spillway is 106m of height and the surface is 60m of width. It adopts a stepped combined underflow energy dissipation method. The spillway is located downstream of the powerhouse.

3）Diversion system

The diversion system is composed of intake, diversion penstock and branch pipe. The intake is arranged in the left dam section of the dam. It is located at dam pile no.1+280m and is converted from the intake of the diversion culvert. It is a tower-type. The irrigation water supply and the power generation diversion are used together. The diversion culvert is almost completed.

The constructed intake of diversion culvert has two holes with 3.5m×6.2m for each. The bottom elevation is 85.8m of height, the dividing pier is 1.2m of thick, the side pier is 4.3m of thick, the top plate is 1.0m of thick, and the top elevation is 93.0m of height and 16.8m of width. The diversion culvert is square arched, with a bottom elevation of 85.8m~85.3m and a section size of 6.2m×6.2m.

The penstock and irrigation and water supply pipes are all exposed pipes and arranged side by side on the top platform of the diversion culvert, and the intake is arranged on the right side (the side of powerhouse). The horizontal projection length of the penstock from the center line of the gate to the branching point is 110m, and the central elevation of branding pipe is 87.3m of height.

4）Powerhouse

The powerhouse is arranged next to the right bank downstream of the diversion culvert. The current ground elevation is 92.0m~96.0m, and the downstream riverbed bottom elevation is 84.0m.

5.4 Diversion system

The diversion system is composed of intake, penstock and branch pipe.

1）Intake

The intake is of the tower well type and is arranged above the inlet of the diversion culvert. The plane is arranged in a hexagonal shape with a side length of 6.45m. The tower well is 13.4m of width, the length to the flow direction is 12.1m, the tower top elevation is 112.0m, the working platform elevation in the tower well is 99.5m, the tower well wall thickness is 1.7m, and the tower top is provided with reinforced concrete beam plate cover. An 80cm wide reinforced concrete staircase is arranged in the well for transportation. The tower well adopts the C20 reinforced concrete structure.

The elevation of the intake is 96.0m, and Q235B penstock is adopted. The diameter of the pipe is DN3800mm～DN3000mm, the length is 3.4m, the wall thickness is 12mm, followed by the 0.8m vent hole and the accident butterfly valve. The inlet is outsourced with C20 reinforced concrete, and the elevation of working platform of the butterfly valve is 99.5m.

Two sliding trash racks are installed 1.5m upstream of the intake. The trash rack is 6.0m of height, 2.4m of width and the dividing pier is 50cm of width. The working platform of upstream trash rack has 112.0m of elevation, the length to the flow direction is 5.5m, and the total width is14.0m. The trash racks use C20 concrete.

The irrigation intake is arranged at left side of the generation intake and multi-level intake structure is used. The diameter of Q235B penstock is DN1000mm and its wall thickness is 8mm. The central elevation of the lower water intake pipe is 95.0m, and the central elevation of the upper water intake pipe is 101.0m. The inlet adopts the divergent steel pipe and the diameter is 1.3m~1.0m and the length is 3.4m. It is followed by the accident butterfly valve and the 0.8m of vent hole.

One sliding trash rack is installed 2.2m upstream of the irrigation intake. The trash rack is 3.0m of height and 2.4m of width. The trash rack uses C20 concrete.

The tower well is connected with dam crest by the access bridge with 4.5m of width and 36m of length. The access bridge has three spans with 12m of length for each. The bridge plate adopts a T-shaped beam structure with a beam height of 1.35m and a plate thickness of 0.35m; the T-shaped frame column has a section of 1.0m×1.0m and a maximum height of 10.5m. The bridge reinforced concrete structure adopts C25 concrete.

2）Diversion penstock

The intake pipe and penstock are connected by 2 elbows with 80° of angle, and R=4.5m which is 1.5 times of pipe diameter.

The penstock is arranged along the diversion culvert. The horizontal pipe is 93.2m of length and the central elevation is 88.3m~87.9m. It is laid with an exposed pipe. The exposed pipe adopts Q235B steel pipe with 3000mm of diameter, 12mm of wall thickness and 9m of spacing. A sliding support ring is adopted with 25cm of height and 12mm of wall thickness. At the end of the pipeline, a horizontal 90° elbow is placed in front of the powerhouse, and the radius of the elbow is R=4.5m, and it is provided with C25 reinforced concrete pier. The elbow is connected to the DN1000mm drainage pipe and led to the downstream of the diversion culvert. The length of the pipeline is 27.6m, and the control gate valve is installed at end of the pipeline.

The irrigation penstock is arranged on the left side of the generation penstock. The distance between the pipe centers is 2.8m, the horizontal pipe of the irrigation penstock is 125.0m of length, and the central elevation is 87.3m~86.8m. It is an exposed pipe. The exposed pipe adopts Q235B steel pipe with 1000mm of diameter, 8mm of wall thickness and 9m of spacing. A sliding support ring is adopted with 10cm of height and 8mm of wall thickness. The control gate valve is installed at end of the pipeline.

3）Branch pipe

The penstock is arranged along the upstream of the plant after turning, the diameter of main pipe is 3.0m, and the central elevation of the pipe is 87.9m. The installation elevation of the unit is 84.0m. The diameter of branch pipe is 2.0m. The main branch pipe is connected by a side pipe with 60° of split angle, and is connected with a diversion branch pipe to the generator-turbine unit.

5.5 Powerhouse and booster station

5.5.1 Layout of hydropower station

The project is composed of main powerhouse, auxiliary powerhouse, booster station, tailrace and transportation road to the station. The project is a ground diversion hydropower station.

According to the project layout and topographic condition, the main and auxiliary powerhouses are arranged side by side from left to right. The powerhouses all face to south by east. The longitudinal axis of the powerhouse is orthogonal to the axis of the penstock.

The tailrace is located on the downstream of the main powerhouse. It adopts a rectangular section with 21.00m of width.

The booster station is located on the right side of the auxiliary powerhouse, and the elevation of the floor in the booster station is 90.35m.

The transportation road to the station is located at the back of the powerhouse and is connected to the management road under the dam. The transportation is convenient.

5.5.2 Powerhouse layout

1）Main powerhouse

The main powerhouse has 38.25m of length, 17.00m of width and 651.0m^2 of building area. Three 1100kW shaft extension tubular turbines are arranged in the powerhouse. The installed elevation is 84.0m. There is an electric single-beam bridge crane with 13.2m of span and 16t/3t of lifting weight inner the powerhouse. The space between the frame bent of the main powerhouse is 6.0m and 8.5m, totally 5 spans. The assembly area is located at the left of the main powerhouse, and the floor elevation is 90.50m. It is mainly used as the unit installation and maintenance, and the entrance gate is located on the upstream of the assembly area.

At the elevation of 86.25m, it is the auxiliary equipment layer, mainly equipped with auxiliary equipment such as electric panel cabinets.

The ground elevation of the turbine-generator layer is 83.19m. Three GD007-WZ-130a turbines, three SFW1100-12/1430 generators and pump room are arranged on this layer. The space between each two units is 8.5m and a water-collecting well is arranged between each two units with 80.2m of bottom plate elevation.

The butterfly valve pit is located on the upstream of the main powerhouse. The bottom elevation is 82.6m. Three heavy-duty butterfly valves with a diameter of 2000mm are arranged here. On the downstream of the butterfly valve pit, there are stairs connecting the butterfly valve pit and the turbine-generator layer.

There are stairs on the left and right sides of the main powerhouse to connect the upper and lower layers, and it is very convenient.

2）Auxiliary powerhouse

The auxiliary powerhouse is located on the left of the main powerhouse with 19.89m of length, 17.00m of width, 339.00m^2 of building area and 90.50m of floor elevation. The central control room, 6kV switch room, 33kV switch room, bathroom and stairs are arranged in the auxiliary powerhouse.

3）Booster station

The outdoor booster station is located on the left of the auxiliary powerhouse with 10.74m of length, 19.83m of width, 213.00m^2 of building area and 90.35m of floor elevation. Three main transformers and transmission line frames are arranged here, and a wall and a wire mesh gate are arranged around the booster station.

5.5.3 Other structures

The main powerhouse is the mixed structure with masonry and reinforced concrete, and the auxiliary powerhouse adopts the frame structure. Above the terrace inner the powerhouse, except the gable walls of left and right sides are 37cm of thick load-bearing walls, others are 24cm of thick brick walls. Below the terrace, it is the slab floor and the reinforced concrete cast-in-place structure. The main powerhouse adopts bent structure with the steel roof truss roofing. The auxiliary powerhouse adopts frame structure and the roofing is a cast-in-place structure with rigid waterproof layer. The bent column is a second-order variable-section column with a single span of unequal height, and the prefabricated "T" beam is used for the crane beam.

A permanent expansion joint is provided between the assembly area and the unit, and between the main powerhouse and the auxiliary powerhouse. The joint width is 2 cm, and the joint is separated from the foundation bottom to the roof of the powerhouse. The expansion joint is located below the generator layer and is provided with copper to stop water in both the vertical direction and the horizontal direction.

5.6 Engineering monitoring

The observation items and measuring points for the project are selected according to the comprehensive consideration.

The main observation items of this project include: building deformation observation, water level observation, upstream and downstream erosion and siltation observation. Manual observation is used in this project.

6. Mechanical and electrical equipment & metal structures

6.1 Mechanical and electrical equipment

The head of the power station varies from 10 to 20 m. After comparison, three horizontal-shaft tubular turbine-generator units are adopted, and the installed capacity of each unit is 1100kW.

It is recommended that the model of the hydro-generator unit is GD007-WZ-110a, the rated speed is 500r/min, the corresponding rated point speed is 488 m·kW, and the rated output is 1100kW.

It is recommended that the model of the generator is SFW1100-12/1430, the rated capacity is 1170kVA, rated voltage is 6.3kV, rated speed is 500r/min, and rotational inertia is 11t • m^2.

The power station bridge crane is installed in the main powerhouse, and a QD16.0/3.2-13.2 bridge crane is adopted with a span of 13.2m. The crane track uses the QU-120.

6.2 Electrical engineering

The Otukpo hydropower station is near Otukpo City with 65,000 of population. The electricity generated by the power station is delivered to Otukpo City and connected to the national grid.

Power station main wiring scheme: the power station adopts one 33kV transmission line to Otukpo City with about 12km of distance, and the line adopts aluminum conductor steel reinforced wire with a diameter of 150 mm^2.

Generator-transformer unit adopts unit wiring mode with bus voltage of 6.3KV. The high voltage side adopts single bus connection with bus voltage of 33kV. Power supply of the station is considered by one transformer of 33 kV /0.4 160kVA, and one diesel generator of 150kW.

The main powerhouse is equipped with 3 turbine-generator units, and the excitation device screen, the unit temperature measuring screen and the unit LCU screen are arranged next to the units. The auxiliary powerhouse is equipped with a central control room, a 6.3kV switch room, a 33kV switch room, a station transformer room, a communication room, and a duty lounge.

The booster station is arranged with a main transformer and an outlet portal, and the area of the booster station is 19.83×10.74 m^2.

6.3 Metal structures

Quick-acting shut off gate should be installed at the outlet of the tailrace.

One quick-acting shut off gate with 3 holes should be installed at each tailrace downstream. Q235B submerged hole type planar fixed-wheel steel gate is adopted. The orifice size is 3.0x2.0-17.0m. The gate is closed with dynamic water and opened with static water.

The fixed winch hoist QPK-2×160kN-14.0m is selected.

The gate is normally suspended 1m above the orifice, in an emergency standby state.

7. Construction organization

7.1 Construction condition

The construction materials such as cement, steel and wood required for this project are purchased from the market.

The water for construction can be pumped from river or reservoir.

The power for construction is taken from nearby power grid. According to the survey, the transformer capacity of this hydropower station can meet the construction power requirements.

7.2 Natural construction materials

The sediment and concrete aggregates can be taken from the river or purchased from the market.

7.3 Construction diversion

According to the hydrological situation in this region, the duration of diversion and flood can be divided in to rainy season and dry season. The rainy season, from May to October, has many southwest monsoons, and the dry season, from November to the next April, has many northeast trade winds.

The diversion culvert is transformed into the power generation diversion tunnel. The original diversion intake has been constructed with a gate. The original gate can be directly used to block the water. Therefore, the construction can be carried out in a dry environment. There is no construction diversion problem. For this reason, the power generation diversion tunnel reconstruction plan is arranged in the dry season.

The tailrace is planned to be constructed in dry season, and the cofferdam mainly uses the soil to block water.

The regular drainage such as construction waste water and foundation pit seepage in the diversion tunnel is pumped by a water pump.

7.4 Construction of the main civil works

1) Construction of diversion system

Rock is excavated by hand air drill and blasted by the explosive. The materials are excavated by 1~2m^3 excavator and transported by 10~12t dump truck.

The concrete is mixed by a 0.4 m^3 of concrete mixing machine and transported by a manual iron bucket double rubber wheels truck. The concrete is pouring through the concrete pump.

The steel pipes are manufactured in the factory and transported by 15t truck to the construction site.

2) Construction of powerhouse

The earthwork excavation of the powerhouse and booster station shall be carried out by the order of bank slope first and then the powerhouse foundation. The earthwork is excavated by the 1m^3～2m^3 excavator, and the muck is transported 1000m by10t～12t dump truck.

Rock is excavated by hand air drill and blasted by the explosive, and are excavated by 1~2m^3 excavator and transported by the 10~12t dump truck.

The concrete is poured in two phases. The concrete is mixed by a 0.8 m^3 mixing machine, and transported by a 1t tilting cart 100m to the place. There is less concrete in the second phase, and it is mainly used in conjunction with the installation of electromechanical equipment for pouring.

3) Installation of electromechanical equipment

The installation of turbines and generators is carried out after powerhouse is capped, and turbines and generators are successively hoisted by the bridge crane into the pit for assembly.

The metal structure installation mainly includes the inspection gate at the intake of the diversion tunnel and the trash rack. After the inspection and measurement are passed, the opening and closing test is carried out in the entry slot of the gate by the hoist or the mast.

7.5 Transportation and construction

Highways pass near the reservoir, and construction machinery and equipment and materials can be transported to the construction site by road. The existing traffic roads of the reservoir should be fully utilized. During the construction of this project, about 1.0km of new slag transportation road is needed, which is designed as the four-level highway of mountain ridge and heavy hill. The pavement is mudstone pavement with a 4.5m of width and the roadbed is 6m of width.

7.6 General layout of construction

Considering that the power station is constructed within the existing reservoir, and the outsourcing conditions of the project are very well, the construction facilities are simplified. According to the layout characteristics of the reconstruction of the project, temporary construction facilities and living facilities are mainly arranged on the right bank of the dam. The construction areas of living facilities, auxiliary enterprises and warehouse are 1500m^2, 900m^2 and 600m^2 respectively.

The total amount of slag is about 30,000 m^3. The waste disposal area is planned to be arranged on the downstream of the dam with 0.013 km^2 of area.

Under the premise of meeting the construction layout, the construction area is based on the principle of less occupation of farmland and combined reservoir for future management. During the construction period, the construction area of living buildings, warehouses, industrial facilities, and waste slag is about 0.02 km^2.

7.7 General schedule for construction

Combined with the layout characteristics of the buildings and the owner's planning for the project, the total construction period is determined to be 12 months after comprehensive analysis.

The maximum number of the construction workers is 360 people per day, and average number of workers is about 300 people per day, with a total 200,000 working days.

The maximum earthwork and rock excavation is about 14,000 m^3 per month and the maximum pouring amount is about 300 m^3 per month.

7.8 The main material supply

This project requires 86t of rolled steel, 747t of steel, 8,066t of cement and 199t of diesel.

8. Fire protection system

The fire protection of the hydropower plant should implement the policy of "Putting prevention first and combining prevention and fire-fighting". Practical fire prevention measures should be taken for the parts and equipment that may cause fires, in order to prevent the fire spreading. Underground buildings should set up ventilation and fire prevention, smoke extraction measures and safety exits, evacuation passages and signs, etc., to provide conditions for personnel to evacuate in time the fire happens. Fire extinguishing measures shall be provided for major fire hazard sites and major equipment.

9. Engineering management

9.1 Management institution

The power station should have technology office and administration office. The administration office is responsible for labor and management, and the technology office is responsible for power station operation, equipment maintenance and building maintenance.

9.2 Operation management personnel

According to the scale of the project, the power station should at least have 15 operation administrative staff, in which 7 operating personnel, 2 inspection personnel and 6 administrative staff.

9.3 Range of engineering management and protection

The management scope should include engineering area and production and living area. Engineering area should include diversion structures, powerhouses, booster station, etc. According to the general layout and topographic condition, it is determined that the management scope of the engineering area is from the water intake, diversion structures and the 25m inner the outer contour line of the powerhouse. The scope of engineering protection is 50m in the boundary of the project management area. Land within the scope of project protection is not requisitioned.

9.4 Management facilities

According to the principle of proximity, the production and living area are close to the plant area. The production area mainly includes the main and auxiliary powerhouses and the booster station; the living area is arranged in the open area on the left side of the plant.

1) Administration rooms

The administrative office of the power station is 500m^2, the auxiliary production room is 200m^2, the equipment warehouse is 50m^2, and the other living and cultural welfare houses are 1000m^2, and the total house area is 1750m^2.

2) Transportation

There is one off-road vehicle and one tool van.

3) Observation facilities

There is one theodolite and one level.

10.Environmental protection design

According to the feasibility study and the analysis of the local environmental conditions, it is believed that the project will have an impact on the local environment in the following aspects.

10.1 Changes in hydrological situation and its impacts

The hydropower station is located behind the dam. The construction of the dam may cause changes of the river hydrology. After the reservoir impoundment, the downstream river flow is regulated by the tail water of the station. Since the hydropower station is completed, it can release water and produce clean renewable energy according to irrigation and living requirements.

According to preliminary investigation and analysis, there is no endemic fish or migratory fish in this river section. The impact of power station construction on fish in this area is very limited.

10.2 Analysis of the influence on human health

According to the survey, there is no special endemic or natural epidemic disease in the area where the power station is located. However, since the floating population is increasing once the construction starts, the workers are prone to intestinal infectious diseases and may even be infected with malaria. Health promotion and disease prevention should be carried out.

10.3 General environmental impact assessment

The adverse impact of the project on the environment is mainly concentrated on the construction aspect, but the impact is not significant and can be reduced by environmental protection measures. Therefore, there is no unfavorable factor restricting the construction of the project. Environmentally, the construction of the project is feasible.

10.4 Environmental protection measures

（1）During the construction, management should be strengthened and awareness of water and soil conservation should be enhanced, in order to ensure well implementation of the water and soil conservation plan.

（2）The environmental protection awareness of residents should be enhanced. Reasonable soil and water conservation farming measures should be adopted to reduce newly-added soil erosion.

（3）During the construction, temporary measures for water and soil conservation should be adopted, in order to minimize the water and soil loss during the construction.

（4）During the construction, disturbance and occupation of the land outside of the construction area should be forbidden.

（5）It should strictly manage the construction, and waste slag must be stored in the designated waste slag yard.

11.Load estimation

According to the hydrological analysis calculation results of the hydropower station and the comparison results of the installed capacity, the final installed capacity of the project is 3×1100 kW, and the annual average generation is 10.66 GWh. According to the geographical location, the main power supply load is the near-field power load, the power load of the plant dam area, and the excess power is connected into the grid.

12.Budget estimation

The total investment for the project is estimated on the basis of major work quantities and the method of project cost estimate defined in Chinese criteria, exchange rate of 100 USD =683.89RMB on Dec. 10, 2019.

Project materials

Main materials include sand, macadam, block stone, cement, reinforcement, diesel oil, explosive, etc. Prices of these materials and their transportation and collection fees are all defined in local criteria.

It is estimated that the total static investment of this project is USD8.3345 million.

13.Economic, financial and policy analysis

The Nigerian project is a hydropower station.

It is planned that the project capital fund accounts for 20% of the total investment funded by local owner (government or power company), and the remaining 80% can apply for low-interest loans to international banks (such as the World Bank, African Development Bank, etc.).

13.1 Economic analysis

According to the project investment estimate, the total static investment of the project is USD 8.33 million. The shadow investment is USD 8.08 million. According to the construction design of the project, the construction period is 1 year. The annual operating cost is USD80,000 and the circulating fund is USD20,000.

The average annual power generation is 10.66 GW·h.

The on-grid tariff of Nigeria currently is USD0.0889 /kW • h. One tariff is adopted during the operation period, and the average annual power generation benefit is calculated to be USD900,000.

The economic indicators are calculated according to the dynamic method, and the social discount rate is 7%. The economic analysis period of the project is 30 years, the construction period is 1 year, and the discounted calculation reference point is from the beginning of the construction period.

It is calculated that the EIRR of the project is 10.9%, which is greater than the social discount rate of 8%. The net present value of the economy is USD16.5 million, which is greater than zero; the economic benefit cost ratio is 1.28, which indicates that the project is economically reasonable.

13.2 Financial analysis

The total static investment of the project is USD 8.33 million, the construction period is 1 year, and the total investment is USD8.83 million. The investment constitutes a tentative capital of USD1.67 million, accounting for 20%; the loan is USD6.66 million, and the loan interest rate refers to the loan interest rate of the World Bank and the African Development Bank, which is calculated at 1.20% this time.

The circulating fund is USD20,000 and the interest of loan of project during construction period is USD40,000.

The total cost of the project consists of depreciation fee, annual operating cost and interest expense. The annual depreciation fee shall be 3.3% of the fixed assets value. The repair fee, project maintenance fee and other expenses shall be 0.5% of the fixed assets value at USD40,000 per year. The total cost of the project is USD11.18 million.

Over a 30-year operating period, the power station could have sales income of USD28.5 million. The project construction calculation period is 1 year, the normal operation period is 30 years, and the calculation period is 31 years.

The project financial profitability index should use the dynamic calculation considering the time factor. It is calculated that the payback period of all investment in the project is 11.18 years (before static investment income tax), and the internal rate of return of all investment (pre-tax) is 9.11%, (after-tax) is 8.69%, and the internal rate of return of capital is 13.87%. The financial net present value of all investments is USD1.72 million before tax, USD1.37 million after tax, and USD2.85 million for capital.

13.3 Construction for economic and financial analysis

According to the national economic evaluation index, the internal rate of return of the project is 10.08%, which is higher than the social discount rate of 7%. The net present value of the economy is USD2.47 million, which is greater than zero; The benefit cost ratio is 1.29, greater than 1. Therefore, the project is economically feasible.

13.4 Analysis on national renewable energy policies

The internal rate of return of all investment (pre-tax) is 9.11%, (after-tax) is 8.69%, which are higher than financial benchmark of 7% of the industry and also higher than long-term loan interest of 1.20% of the bank. The financial net present value of all investments is USD1.72 million before tax and USD1.37 million after tax. According to various indicators and parameters, the project is feasible. At the same time, the maximum repayment period of the project is 9.94 years, and the payback period of all investments is 11.18 years (before tax). The project has strong profitability and strong anti-risk ability.

14.Project parameters

All data of this project is shown in table 1.14-1.

Table 14-1: Project data

No. and Item	Unit	Qty.	Remark
A. Hydrology			
1.Catchment area	km^2	1100	
2.Typical flow			
Multi-year average flow	m^3/s	13.9	
3.Flood peak flow			
Probable Maximum Flood (PMF)peak inflow	m^3/s	4370	
Probable Maximum Flood (PMF)peak outflow	m^3/s	1760	
1:200year RI flood peak inflow	m^3/s	885	
1:200year RI flood peak outflow	m^3/s	215	
B. Reservoir			
1.Water level			
Check flood level	m	111.55	PMF，masl
Design flood level	m	107.38	P=0.5%，masl
Full supply level (FSL)	m	106.0	masl
Storage capacity at FSL	Mm^3	133	
Minimum Operating Level	m	101.0	
2.Regulating characteristics		Yearly regulating	
C. Discharging flow and tailwater level			
1. Maximum flow at check flood level	m^3/s	1760	PMF
2. Maximum flow at design flood level	m^3/s	215	P=0.5%
3.Design tailwater level	m	86.50	Q~~8.0m^3/ s
4.Normal tailwater level	m	87.6	Q~~22.5m^3/s
D. Project performance indicators			
Installed capacity	MW	3.3	3×1.1MW
Average annual output	10^4kwh	1066	
Annual utilization hours	h	3230	
E. Inundation loss and permanent occupied land			
1.Permanent occupied land			
Forest	m^2	0	
2.Migrant		0	
3.Inundation road	km	0	
F. Main buildings and equipment			
1.Embankmemnt			
Type of embankment		Zoned earthfill	
Characteristics		Residual slope strata in hilly areas	
Seismic basic intensity		Ⅵ	
Non-overspill crest elevation (excluding settlement allowance)	m	112.0	
Maximum height of embankment (above river bed level at d/s toe)	m	22	
Embankment crest length	m	2460	
Base width of embankment at maximum cross section	m	93	
Crest width of embankment	m	8.0	

Upstream slope	m/m	1V:3H	
Downstream slope	m/m	1V:2.5H	
River bed level at downstream toe	m	90.0	masl
2.Spillway			
Type		Ogee overflow weir	
Overflow weir crest length	m	60	
Overflow weir crest level	m	106.0	masl
Total freeboard	m	6.0	
Maximum discharge with zero freeboard	m^3/s	2000	
Energy dissipation		Stepped discharge chute and stilling basin	
3.Outlet Works			
3.1 Diversion culvert			
Bottom elevation	m	85.8	
Size of the orifice	m×m	2－3.5×6.2	2
3.2 Intake of diversion pipe			
Intake	Model	Tower well	
Pipe diameter / length		DN3800mm ～DN3000mm/3.4m	
Intake center elevation	m	96.0	
Vent diameter	m	0.8	
Accident butterfly valve platform elevation	m	99.5	
Movable trash rack		2	
Orifice size of the trash rack	m×m	6×2.4	height×width
3.3 Intake of irrigation			
Diameter	mm	DN3000	
Moveable trash rack		1	
Orifice size of the trash rack	m×m	3×2.4	height×width
3.4 Traffic bridge on the tower well platform			
Width	m	4.5	
length	m	36	
3.5 Penstock			
Type		Exposed	Along with the diversion culvert
Horizontal length	m	93.2	
Center elevation	m	88.3～87.9	
Turnoff center elevation	m	87.3	
3.6 Irrigation penstock			
Type		Exposed	Along with the diversion culvert
Horizontal length	m	125	
Center elevation	m	87.3～86.8	
4.Powerhouses			
Type		Diversion ground	
Main powerhouse	m×m	38.25×17.0	height×width
Auxiliary powerhouse	m×m	19.89×17.0	height×width
Floor elevation of tailrace	m	80.2	
Turbine center elevation	m	84.0	
Butterfly valve layer elevation	m	82.6	
Floor elevation of turbine layer	m	82.6	
Floor elevation of installation area	m	90.5	
Floor elevation of generator layer	m	90.5	

Top elevation of crane rail	m	96.5	
Floor elevation of powerhouse	m	100.9	
5.Booster station			
Type		Outdoor	
Size	m	10.74×19.83	
6. Main electromechanical equipment			
Turbine model		GD007-WZ-130a	Horizontal shaft tubular turbine
Number		3	
Rated output	Mw	1.1	
Rated speed	r/min	500	
Maximum head	m	19.2	
Rated head	m	17.2	
Minimum head	m	11.8	
Diversion flow	m^3	22.8	
Generator model		SFW1100－12/1430	
Rated capacity	kVA	1170	
Rated power	kw	1100	
Rated voltage	kV	6.3	
Power factor		0.85	
Rated frequency	Hz	50	
Number		3	
Diameter of intake valve	mm	2000	Heavy hammer hydraulic butterfly valve with operating oil pressure of 16MPa
Number		3	
Governor model		YWT-1000-16	High oil pressure digital microcomputer dual adjustment with operating oil pressure of 16MPa
Number		3	
Crane model		16/3t Electric single-beam bridge crane	
Number		1	L_k=13.2m（span）
Main transformer model		S13-1600/36.3	
Number		1	
Capacity	kVA	1600	
Ratio		36.3±2×2.5%/6.3kV	
Outlet line voltage	kV	33	
Circuit number		1	
Transmission destination		Otukpo City	
Population		65000	
Distance	km	12.0	
Transmission line diameter distance	mm^2	150	Steel-cored aluminium strand wire
7. Metal structure			
Quick emergency gate at tailrace		3	
Quick emergency gate at tailrace	model	Steel gate with horizontal fixed wheel of submersible hole type	
Orifice size	m×m	3.0×2.0	
Hoist model	model	QPK-2×160kN-	Fixed winch quick

		14.0m	hoist
Number		3	
8. Construction organization			
Construction period	month	12	
Maximum workers	per capita/d	360	
Normal workers	per capita/d	300	
Maximum workers	per capita/d	360	
Total man-days	10^4 man-days	20	
Rolled steel	t	86	
Steel	t	747	
Cement	t	8066	
Diesel	t	199	
9. Construction cost			
9.1Civil Works	USD	3521296	
9.2Electro-mechanical Equipment and Installation works	USD	2461882	
9.3Metal Structure Equipment and Installation works	USD	844967	
9.4Temporary Works	USD	112354	
9.5Independent Cost	USD	644509	
9.6 Basic reserve funds	USD	758501	（10% of 9.1~9.5）
Total static investment	USD	8343509	
10. Financial analysis			
10.1 National economic evaluation			
(1) EIRR	%	10.08	Social discount rate7%
(2) ENPV	10^4 USD	247	
(3) EBCR		1.29	
10.2 Financial evaluation			
(1) Static investment	10^4 USD	833	
Capital fund	10^4 USD	167	
Loan	10^4 USD	666	Loan rate 1.20%
(2) IIDC	10^4 USD	4	
(3) Circulating fund	10^4 USD	2	
(4) On-grid tariff	USD/kW·h	0.089	
(5) Total sales income	10^4 USD	2700	
(6) Total cost	10^4 USD	1118	
(7) Total profit	10^4 USD	1582	
(8) Income tax	10^4 USD	85	
(9) Profit after tax	10^4 USD	1497	
(10) Profitability index			
(10-1) FIRR			
Total investment before income tax	%	9.11	
Total investment after income tax	%	8.69	
Capital fund	%	13.87	
(10-2) FNPV			
Total investment before income tax	10^4 USD	172	
Total investment after income tax	10^4 USD	137	
(10-3) Payback period			
Static investment before income taxt	y	11.18	
Static investment after income taxt	y	11.57	
(10-4) Return on investment	%	6.46	
(10-5) ROE	%	29.95	