PRE-FEASIBILITY STUDY REPORT FOR IKPOBA HYDROPOWER PROJECT , BENIN STATE

PART – I: EXECUTIVE SUMMARY

The Nigerian economy suffers from lack of diversification since its first commercial oil production in the late 1950's and the collapse of the nascent manufacturing sector from the mid-1980's onwards. The erratic availability of electricity still forces manufacturers to opt for diesel generators for reliable electricity supply. As a result, the electricity cost becomes non-affordable and frequently leads to factory closings .

The power sector in Nigeria is seen by many analysts as the key constraint on economic development. Assessing the ease of getting electricity, the World Bank ranked Nigeria 187 of 189 countries in the 2015 edition of its Doing Business report. For a business in Lagos, to obtain permanent electricity connection takes 260 days [WB; 2014: b]. Once connected to the electricity provider, Nigerian businesses' biggest reported problem is the erratic power supply. About 83% of all managers surveyed considered electricity outages to be a serious problem – more than any other constraint. Firms of all sizes, in all states and sectors, report average power outages equivalent to eight hours per day. The average firm claims outage related losses equivalent to more than 4% of sales. No peer country experiences such severe business losses related to the power supply.

Given this background, the Edo state government is very keen to develop an industrial park in the Benin City, with a captive hydro power plant. UNIDO was requested to help them with a technical report on the possibilities.

Ikpoba Dam small hydro project will bring sufficient electricity to uplift the economic activities of the region.

Figure 1 : Meeting the officials in Benin City

		UNIT/DETAIL
Project Name	Ikpoba Small hydro Project	
Location (Village, district , region)	Benin city, Edo State, Nigeria	
Developer (Physical address and contact details including telephone contacts)		
Position/project layout including GPS coordinates in accordance to the datum and coordinate system : Dam Forebay Surge Tank Power house Switch Yard Interconnection arrangement /delivery point	6.378596N, 5.646169"E	
Purpose, objective and scope of the project	To build a small hydro scheme to generate 1000 kW to to supply power to the industrial complex being planned by the Edo state government.	

Hydrological Features at the Diversion Weir site		
Catchment Area	720 km^2	
Mean Annual Flow	25 m^3/s	
Normal Average Flow – Wet season	30 m^3/s	
Normal Average Flow – Dry season	24 m^3/s	
Design Flow	25 m^3/s	
Flow (1,000y flood event)		
Flow (100y flood event)		
Present Use of Water		
Water used for irrigation		
Water used for drinking purposes		
Water used for other settlement/industry purposes (please specify activities)	Pump house on the dam is not fully functional. So no clear data is available for the water requirement for the city.	m^3/s
Diversion Weir		
Weir Construction	In place	
Type	RCC	
Slope	1:2	m/m
Crest elevation	38	m
Crest length	610	m
Diversion facilities (please specify) Side intake		
Length	N.A	m
Diameter/cross-section		m
Diversion flow		m^3/s
Spill way		
Type	Needs to be modified	
Crest Elevation	35	m
Maximum flood level	36.8	m
Width	4	m
Discharge	10	m^3/s
Penstock		
Penstock construction	Mild steel	
Total length	10	m
Horizontal length		m
Diameter	3 (15mm wall thickness)	m
Power facilities		

Power House type	Dam-toe	
Type of turbine	Kaplan/ Propeller	
Gross head surge bay-power house Design discharge	6 25	m m^3/s
Length of tailrace channel	2	m

Installed capacity	2 x 500	kW
Distribution / Transmission facilities		
Transformer type	A hermetically sealed step up transformer	
Transformer rating	600 kVA	
Transmission line type	HV, three phase	
Line voltage	33	kV
Line length	1	km
Line capacity Proposed conductor size		MVA mm^2
Proposed conductor material	ACSR	
Technical Loss factor along the line		Percentage
Power Production		
Total Efficient Capacity	1000	kW
Average generation during wet season	1000	kW
Average generation during dry season	1000	kW
Mean Annual Power Production during Peak Periods	7.68	GWh
Mean Annual Power Production during Shoulder Periods		GWh
Mean Annual Power Production during off-peak Periods		GWh
Mean Annual Total Power Production	7.68	GWh
Capacity factor		%
Plant factor *(The ratio of the average power load of the plant to its rated capacity)*	88	%
Average Generation for own use	NA	MW
Annual Power Production for own use	NA	GWh
Economics and Financials		
Investment Costs based on detailed underlying assumptions	1,500,000	USD
Annual Operational costs based on detailed underlying assumptions	20,000	USD/year
Annual Revenue from Operation	800000	USD/year
Net Present Value (NPV)		USD
Internal Rate of Return (IRR)	20	%
Pay-Back Period (PBP)	3	Years

Environmental and Social Indicators		
Distance to nearest residential zone	1000	m
Distance to nearest protected area	N.A	km (or “inside”)
Access roads through protected areas		km total

PART II- MAIN REPORT

1 INTRODUCTION

1.1 Background

With a population of over 190 million[1], Nigeria is the most populous country in Africa and the eighth most populous country in the world. According to the United Nations, one in six Africans is Nigerian. It is a regional power, listed among the "Next Eleven" economies, and a member of the Commonwealth of Nations.[i] But sadly, on the economic front, the country seems to be stagnant at the best. The main factor that hinders the development as perceived by many is the power sector. Nigeria is ranked 172 out of 187 countries by world Bank on the " ease of getting electricity"[2].

The Energy Commission of Nigeria (ECN) together with the International Atomic Energy Agency (IAEA) projected a demand of 15,730 MW for 2010 and 119,200 MW for 2030 under the reference scenario (7% yearly economic growth)[3]. Many studies indicate that the current gap between supply and demand is already very high (1:3) and that, it will become worse if the same reliance on fossil fuels is continued.

In order to bring a solution to these problems, the Federal Government of Nigeria (FGN), in its Power Sector Reform Roadmap (2013), set ambitious targets to increase installed hydro to 5,690 MW, thermal to over 20,000 MW and renewable 1000 MW capacities by 2020[4] . The targets also aim at diversifying Nigeria's energy mix to reduce its natural gas dependence.

Federal Government of Nigeria through the Federal Ministry of Power and Federal Ministry of Water Resources (FMWR) are undertaking studies of irrigation dams in the country to identify their potential for SHP integration and development.

1.2 Project Objective

The proposed mini-grid project aims at providing reliable, clean and affordable electricity access to the proposed industrial campus by the state government.

It envisages to use the existing dam on Ikpoba to generate power. The dam construction was started in 1977 mainly with the purpose of supplying water to the Benin City population. The dam is called Okhoro Dam.

1.3 Pre-feasibility Study Objective

UNIDO sent a technical team to assess the potential and to provide broad guidelines to design and implement the hydro-power project in the Ikpoba river. The objective is also to ascertain the technical and economical viability of the proposed project. The PFS will provide topographical data, hydrological data, analysis of historical rainfall data using flow duration curve, as well as

[1] Based on the latest United Nations estimates. www.data.un.org/en/iso/ng.html

[2] www.doingbusiness.org/data/exploretopics/getting-electricity

[3] A. S. Sambo, 2008, Matching Electricity Supply with Demand in Nigeria, Fourth Quarter, International Association for Energy Economic, p. 33

[4] The Presidency of the Federal Republic of Nigeria, August 2013, Roadmap for Power Sector Reform, Revision1, p. 24-25

assess the environmental and social impact that might arise from developing these sites.

2 DESCRIPTION OF PROJECT AREA

2.1 Project location with coordinates and relevant site maps

Edo State lies approximately between longitude 06°04'E and 06°43'E and latitude 05°44' N and 07°34' N. Edo State has a tropical climate characterized by two distinct seasons: the wet and dry season. The wet season occurs between April and October with a break in August, and an average rainfall ranging from 1500 mm in the extreme north of the State to 2500 mm in the south. The dry season lasts from November to April with a cold harmattan spell between December and January. The temperature averages about 25 °C in the rainy season and about 28 °C in the dry season. The climate is humid tropical in the south and sub-humid in the north.

Figure 2 Location of Edo state

2.1.1 Physical & Salient features of the project site

Ikpoba River is situated within the rainforest belt of Edo State, southern Nigeria. The River rises from the Ishan Plateau in the northern part and passes through Benin City and joins the Ossiomo River.

Ikpoba River is highly disturbed while passing through Benin City due to the high population density and the dependence on the stream. In the upper reaches of the stream, it flows through a dense rainforest where surface run-off and organic matter from the surrounding vegetation contribute to organic input.

Ikpoba River varies in width from (5-11) m and a depth of (3-8) m. The river flows for a distance of 48km across its sub-drainage catchment basin estimated at 722 km^2, 320 km^2 of which falls within Benin City, i.e. about 50% of the entire Ikpoba drainage basin.

Catchment area is shown below:

Figure 3 Ikpoba project catchment area

The stretch that passes through the Benin city limits is almost flat with a slope of 0.002. Over the years, accumulation of silt has proliferated the growth of grass and water hyacinth which covers a huge area of the small reservoir upstream.

100m upstream of the dam, main drainage canal from the city empties into the river.

2.1.2 Load profile and electricity demand

The entire power will be dedicated to the industrial park that is bing planned in the Benin city.

3 TOPOGRAPHICAL SURVEYS

A team led by Engineer Rufai prepared the topographic maps for the site. The team surveyed one km upstream and one km downstream. The height difference between these two points is 4m indication the river is almost flat. The only possibility of generating power is by building a dam. Fortunately, there is a small dam, called Okhoro Dam which was commissioned in October 1987. To call it a dam is a misnomer: it is actually a weir which is meant to divert water to the pump house. It is not a reservoir to store water across seasons. The total volume of the water that is impounded behind the weir is $1.5 \times 10^6 m^3$.

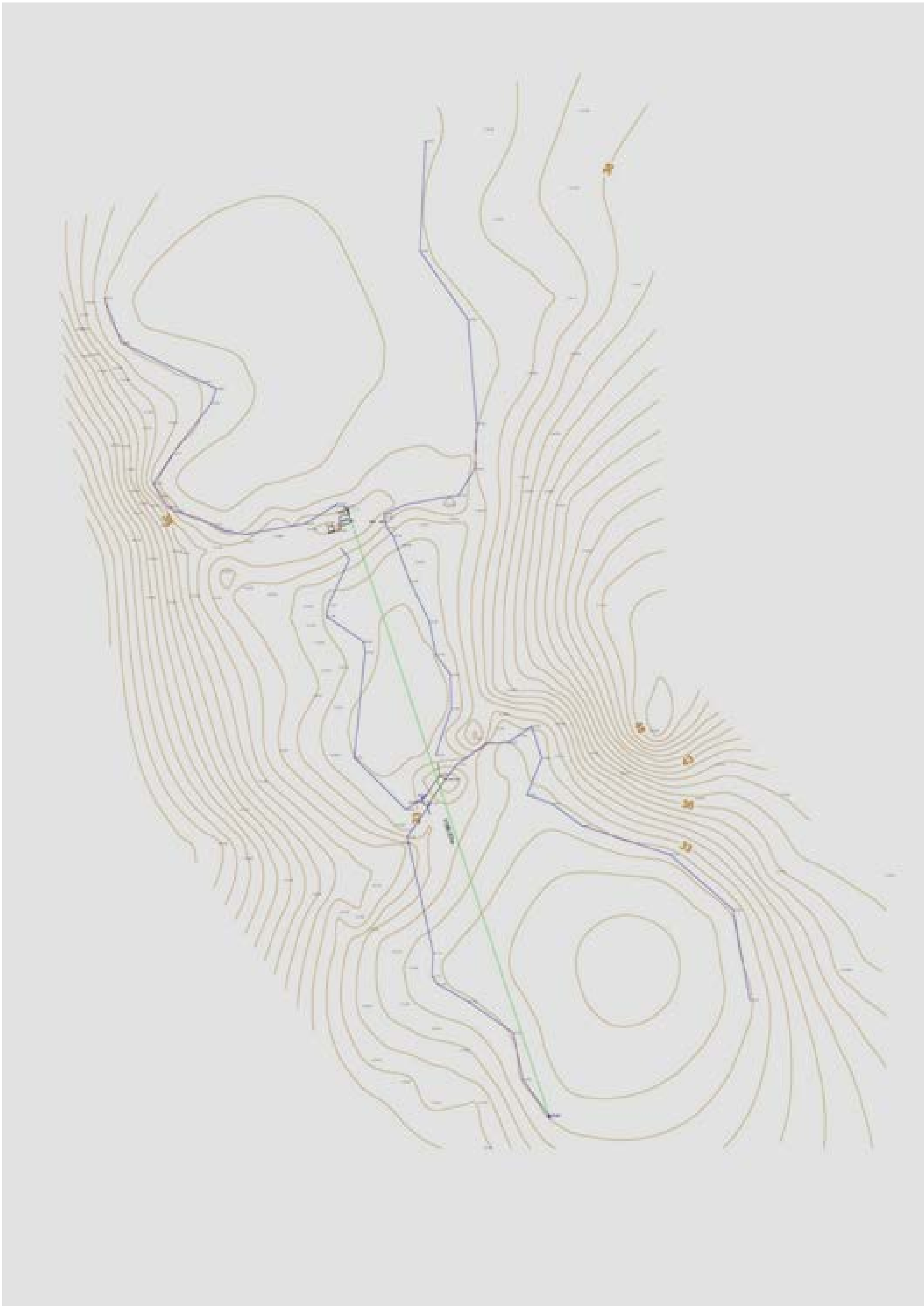


Figure 4 Topographic survey map the project area

The height of the existing spillway has to be raised by 1.0 m which will give a gross head of 6m for the power generation.

A detailed survey of the reservoir area which will be upto the level of the 36 m contour line has to be carried out.

The reservoir area, after the increased height, is calculated using the google earth application. The following picture shows the proposed reservoir area..

4 HYDROLOGICAL AND SEDIMENTATION STUDIES

Sedimentation studies need to be conducted for the increase of the height of the dam. This is not covered in this assignment.

It is observed that large quanitities of municipal waste are being dumped into the river from a drainage channel that runs along Okhoro Road , within a km upstream of the weir.

It is the main source of water supply for Benin City with water production per pump day of 34,080m^3. The water supply design capacity is 90,000m^3/day serving an estimated population of 1.0 million people at design. The dam was impounded first in 1975 and commissioned October, 1987. At present, problems associated with the reservoir are over-silting and growth of weeds over the years.[5]

4.1 Catchment characteristics

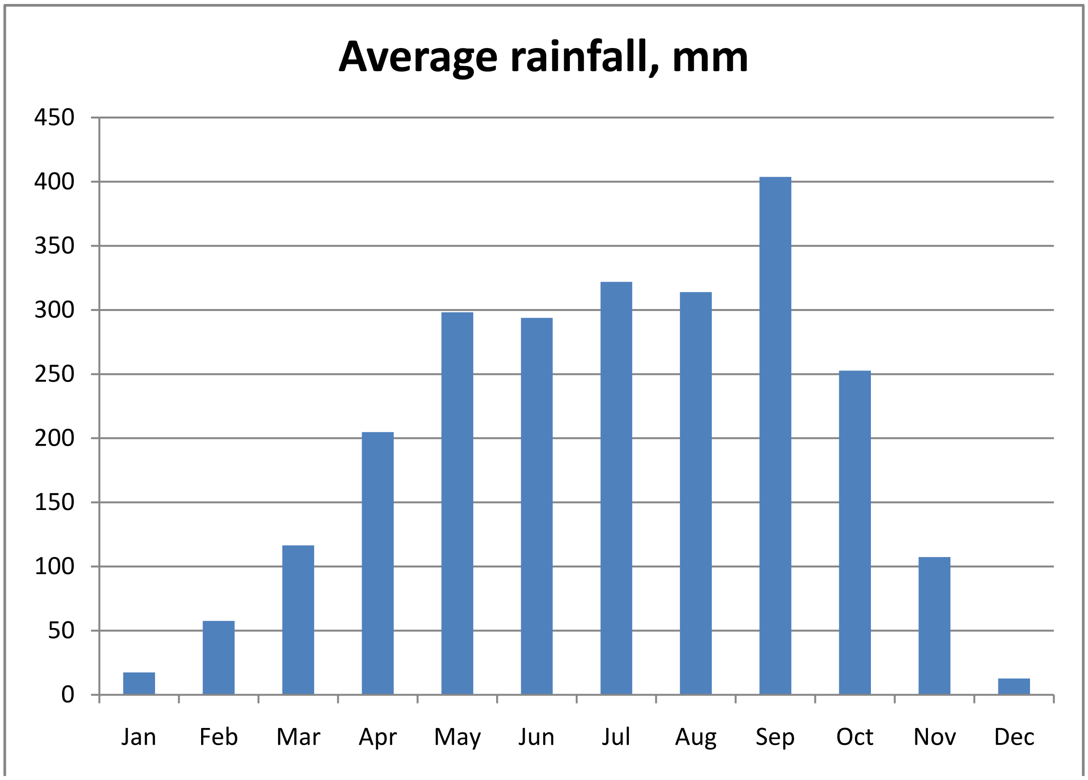
The river flows through a sedimentary terrain, geologically referred to as the Benin formation, one of the foremost prolific aquifers in Nigeria. The groundwater contribution to the total yearly run-off of the river is estimated at over 40%.

The Ikpoba River takes it source from an extension of the western highland in the north and northeast of the region. It flows from an east to west direction, then meanders at Utekon to flow southwards with Ekosodon, Ugbowo, Okhoro and New Benin to the eastern bank. It crosses Temboga and winds again to flow southeast after Ikpoba-Hill where it is bridged along Benin-Agbor road. It flows towards the Ikpoba Okha LGA in the region. It is a perennial stream flowing throughout the year. At the northern region the Ikpoba River is high above the water table and as such contributes an influent flow into the aquifer while in the southern reaches, the river receives groundwater from the water table aquifer and thus, become effluent flow.

4.2 Rainfall, climate and precipitation data analysis

Rainfall data recorded in Benin City station is used in this analysis. Data from 2001 to 2010 is obtained and the average monthly rainfall is presented below.

[5] Estimation Of The Life Of Ikpoba River Reservoir by C. N. Ezugwu , B. U. Anyata and E. O. Ekenta, 2013



As it can be seen, May to October is the wet season with peak rainfalls in July and September. The catchment area above the existing dam is shown in Figure 3. The total area is about 720 km^2. As the catchment area is in one of the foremost prolific aquifers and said to have a run-off coefficient of 40% .

The total run-off in a year = 2.4 x 720 x 10^6 x 0.4 = 691,200,000 m^3

The average flow rate = 21.9 m^3/s

4.3 Flow Duration Curve

With limited available data, a FDC was prepared. Q50 (25 m^3/s) is selected as design flow. This flow will be available for 6 months. This data doesn't include the other aquifer properties – only considers the surface run-off.

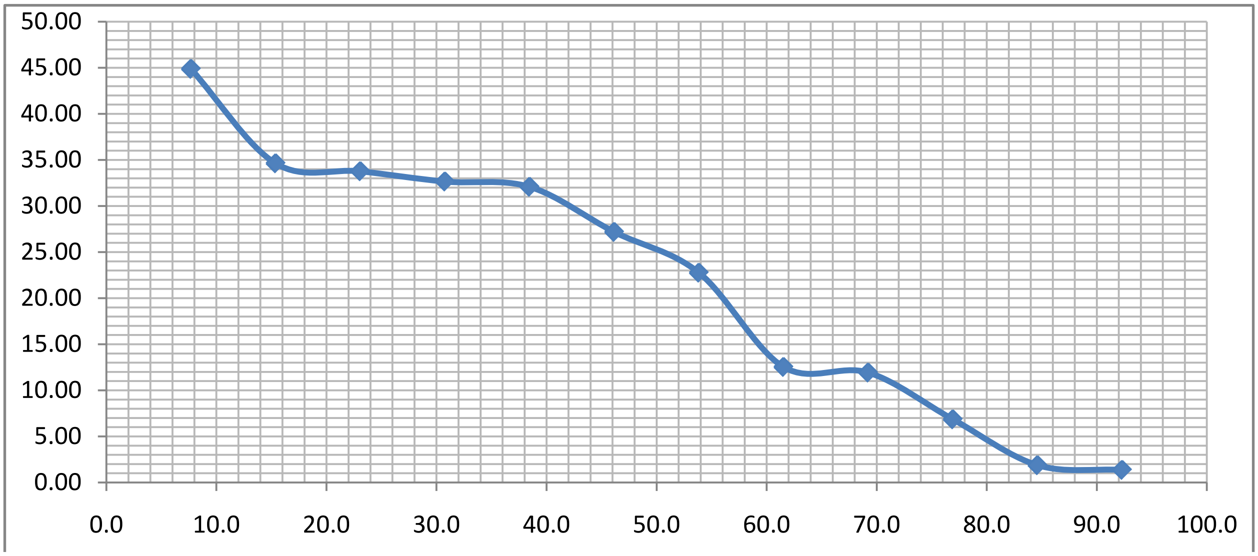


Figure 5 FDC for Ikpoba River

5 GEO-TECHNICAL STUDIES

Geologically, the Benin Region comprises of 1) the Benin formation; 2) alluvium; 3) drift/top soil and 4) Azagba-Ogwashi (Asuba-Ogwashi) formation.

95% of the region is covered by the Benin formation. The formation is characterized by top reddish to reddish brown lateritic massive fairly indurated clay and sand. This caps the underlying more friable pinkish-yellowish white often gravelly-pebble sands, clayey soils, sands and clay. The sedimentary sequences are poorly bedded with discontinuous clay horizons at various depths. It indicates that raft foundation should be avoided on this location and pile foundation should be used.

6 SUMMARY OF ENVIRONMENT AND SOCIAL IMPACT ASSESSMENT (ESIA)

6.1 Environmental Impacts

The ecological problems in the state are not necessarily peculiar to it. Some of these include leaching, erosion and general impoverishment of the soil..

Detailed flow reading are necessary to calculate the flood conditions – data not available.

6.2 Social Impacts

6.2.1 Local Dispute Resolution Procedure

6.3 Assessment of significance of environmental and social impacts

An in-depth study was not carried out at this stage. When the project moves onto the next stage of detailed technical design, this study could be taken up.

7 PROJECT OPTIMIZATION

7.1 Estimation of Power and Energy Production

7.1.1 Plant capacity

The proposed capacity of the power plant is 1000 kW. The available head is 6m. The design flow is 25 m^3/s.

7.1.2 Plant factor

The plant factor 0.9 for this project will be quite high as the stream is perennial and the design flow is Q57.

7.1.2.1 Annual energy

The generation profile is given in the table below:

	Power kW	**Energy kWh**
Jan	1000	744000
Feb	1000	672000
Mar	1000	744000
Apr	1000	720000
May	1000	744000
Jun	1000	720000
Jul	1000	744000
Aug	1000	744000
Sep	1000	360000
Oct	1000	372000
Nov	1000	360000
Dec	1000	744000
Total		7668000
Installed capacity		8,760,000

The plant factor is 0.88 because a downtime of one month in a year for maintenance is already considered.

7.2 Cost Estimates

Since the dam is already in place, only modifications are needed for the incorporation of the power plant. The electro-mechanical equipment cost is estimated to be 0.8 million USD (800 USD/kW), additional civil works at 0.6 million USD.

7.3 Economic Analysis

With the total project cost of 1.5 million USD, the benefits are enormous both in short term and long term..

The tariff charged in Nigeria is in different slabs: taking an average of 40 Naira/ kWh (10 cents), the IRR of the project is 20%

8 PROJECT DESCRIPTION AND BASIC DESIGN

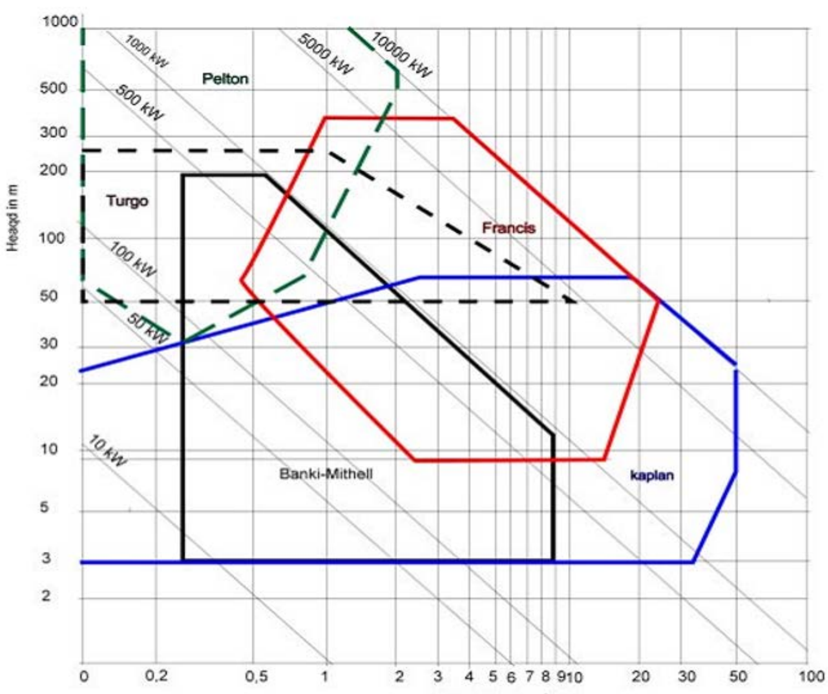
The project site has an existing embankment dam. The spillway height will be increased by 1m to provide total head of 6m.

The powerhouse location is at the foot of the dam. It will have two turbine units to handle the flow variations effectively. The turbines will be of kaplan type reaction turbines.

The tail race will be 5m long and leads the water back to the stream.

Penstock will be of mild steel and two pipes are suggested. Each pipe will be of 3m diameter and 15mm thick wall.

8.1 Turbine choice



The Kaplan water turbine is an axial flow reaction type of water turbine design in which the flow enters radially and makes a right angle turn before entering the runner in an axial direction. The control system is designed so that the variation in blade angle is coupled with the guide vane setting in order to obtain the best efficiency over a wide range of flows. The blades can rotate with the turbine during operation, through links connected to a vertical rod sliding inside the hollow turbine axis.

Since the blades are rotated in high-pressure hydraulic oil bearings, a critical element of Kaplan design is to maintain a positive seal to prevent emission of this oil into waterways. The turbine does not need to be at the lowest point of water flow as long as the draft tube remains filled with water..

8.2 Generator

A three phase AC synchronous generator with horizontal arrangement and air cooled as per the IEC regulations is considered for this project. Two sets of generators will be installed which can also be synched with each other through a power electronics panel.

Each unit has a synchronization microcomputer automation device to perform synchronism connecting to the grid. Switchyard is also equipped with a set of microcomputer automation synchronization device and a set of manual synchronization device, mainly used to finish synchronism connecting to net of main transformer and 33 kV line.

9 DISTRIBUTION / TRANSMISSION LINE AND CONNECTION TO THE GRID

This is not considered here as the location for the industrial park is not known/ shared.

10 OPERATION AND MAINTENANCE REQUIREMENTS

Most of the operation will be automatically controlled with SCADA. A team of 5 operators will manage the power plant to monitor the proper functioning of components. The plant will have two turbines to enable continuous power generation even during breakdowns / maintenance shut-downs.

The maintenance requirements are mainly desilting the dam once in a year, checking the seepage losses in the dam, fixing penstock leaks, transmission line issues, etc. For the T&D management, a team of five line-men will be needed.

11 CONCLUSIONS AND RECOMMENDATIONS

The following conclusions are made:

1. Ikpoba hydro project is technically and financially feasible.
2. Installed capacity and energy: The installed capacity of the plant is 1000 KW with a design discharge of 25 m^3/s and gross head of 6 m. The gross energy production is 7.68 GWh
3. A construction period of 18 months has been considered.

Based on the findings of this study, the project is financially attractive. It is recommended the detailed design for the dam & reservoir, penstock alignment, powerhouse and transmission& distribution design be initiated immediately.

[i] Energy Sector Study – GIZ NESP 2015-16 report