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Small Hydropower Projects for Rural Electrification in Nigeria: A Developer's Perspective

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Abstract-Power generation in developing nations is a vital index for the socio-economic development of these countries. Renewable and sustainable options for electric power generation have become attractive to many nations. This paper addresses power generation for rural applications by means of small hydropower plants. A flowchart is developed for use by Power utilities and Independent Power Producers that are interested in small hydropower generation. Recommendations and possible cost reductions for small hydropower projects for interested developers are also highlighted.

Keywords: small hydro, renewable energy, rural electrification, project financing, flowchart

I. INTRODUCTION

The development of any country is largely dependent on the optimal utilization of the available energy resources. Researches have linked national standard of living to energy consumption showing that developed countries consume more energy than under developed countries. As a result of such findings, Nigeria, with a vision to be among 20 most developed countries by 2020 cannot be realized without laying emphasis on meeting the existing energy needs. In Nigeria, the Rural Electrification Agency is tasked with the responsibility of providing electricity to rural areas. Such projects have been mainly limited to extension of the national grid and provision of solar panels. Even though, Nigeria, like the rest of the world can still benefit from the available hydro resources to generate power. Three Large hydro plants are already running in Nigeria and are contributing significantly to the country's generating capacity. While these large projects benefit from economies of scale due to their large size, they are unsuited for standalone rural communities as the demand of electricity in such communities are relatively low and the initial investment cost is high. Hence, Small Hydro power Plants, being a mature technology may be optimally employed for sustainable power generation in rural communities in Nigeria. Hydropower plants convert potential energy of water at a height to mechanical energy which is used to turn a turbine at a lower level for generation of electricity. Although there is no internationally accepted standard for classification of Small Hydro Power Plant (SHP), the upper limit, referred to in this work is 30MW as stated in the Renewable Energy Master Plan (REMP) of Nigeria [1]. Under this plan, Small hydro is further divided into two subunits: the mini hydro (<1MW) and the micro hydro (<100kW).

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To date, little has been done in terms of implementation of Small Hydro plants in Nigeria; this is evident in Table 1 which shows the available Small Hydro Power Projects in Nigeria.

Table 1: Existing Small Hydro Power Plants in Nigeria

Site	State	Installed Capacity (MW)	Installed By	Status
Kurra falls	Plateau	19	IPP	Operational
Kwali falls	Plateau	6	IPP	Operational
Bakalori	Sokoto	3	N/A	Dam construction completed. Electromechanical system yet to be installed
Tiga	Kano	6	N/A	Dam construction completed. Electromechanical system yet to be installed
Ezioma Mgbowo	Enugu	0.03	UNIDO	Completed
Waya Dam	Bauchi	0.15	UNIDO	Completed
Tunga Dam	Taraba	0.40	UNIDO	Under construction
Annoke Ugbokpo	Benue	1.20	UNIDO	Dam construction completed. Electromechanical system yet to be installed
Ikere Gorge, Iseyin	Oyo	6	N/A	Dam construction completed. Electromechanical system yet to be installed
Challawa Gorge Dam	Kano	7	N/A	Dam construction completed. Electromechanical system yet to be installed
Gurara Dam	Niger	0.03	IPP	Under construction
Oyan	Ogun State	9	N/A	Dam construction completed. Electromechanical system yet to be installed
Evoboro	Edo	0.003	Indigenous Technician	Operational
TOTAL		57.813		

UNIDO stands for United Nations Industrial Development Organization
NESCO stands for Nigeria Electricity Supply Corporation Limited
IPP stands for Independent Power Producer
N/A stands for Not Available
Source: [2,3]

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Nigeria has a hydro potential of 11,500MW out of which only 1972MW has been tapped including the 56.813MW utilized in small Hydro Power generation [3]. The Renewable Energy Master Plan of Nigeria on Small Hydro plants, had proposed a medium term target of 600MW by 2007 and a long term target of 2000MW by 2025[1]. It is obvious that if these goals are to be achieved, a proper framework should be proposed that will address the existing limitations as enumerated in the Renewable Energy Master Plan and also, both the Government and private sector should be involved in project implementation. The enumerated problems in the REMP are as stated below [1]:

1. Power can only be generated during the rainy season where there is sufficient flow, even when a reservoir is available it is unlikely that power would be available all through the year.
2. Location of SHPs is far from concentrated load centre.
3. High initial investment and long project development period
4. Water right of way problems.
5. Absence of technical standards leading to use of substandard equipment and consequent low efficiency.
6. Insufficient financial resources for Operations and Maintenance.
7. No real model for companies to finance and operate SHP on a developmental basis. Financial institutions may be reluctant to finance nontraditional power project
8. Land acquisition social and cultural controversies.

From the experience in other countries, small hydropower plants have failed because of poor planning, construction or operation [7]. This paper is aimed at proposing a framework for planning and financing SHP which will directly address the problems stated. Also, it will encourage private sector participation by elucidating the following aspects to be considered by developers:

1. Theoretical aspect
2. Technical aspect
3. Financial and Economic consideration
4. Environmental consideration
5. Legal consideration
6. Cultural consideration

The paper will also propose possible methods of cost reduction.

II. STRUCTURE OF THE SMALL HYDRO POWER PLANTS

The Small hydro plant consists mainly of a weir or low dam across a stream, an intake for the penstock, the penstock, power house and the tail race channel.

The SHP can either be a run-of-river project or a Storage project. The run-of-river project has no storage facility and is made to use the flow of the river all year round without provision for dry periods. A run-of-river project would not normally have a dam, other than an intake weir, which is a very low structure at the intake. The intake weir keeps the water in the stream high enough to fill the pipe at all times [6]. A storage project on the other hand, has a dam, which creates a water storage reservoir to maintain flow in the stream during low flow periods. The intake to the pipeline might be part of the dam or separate from it, depending on the location of the pipeline. The layout of a typical small hydro power scheme is shown in Fig. 1.

III. ASPECTS TO BE CONSIDERED BY POTENTIAL DEVELOPERS

Even though there is dire need for an increase in the generation capacity of Nigeria, it is also necessary for proper planning to be done before project implementation. This is to eliminate or at least, curb the project failure and ensure sustainable development. The various aspects that should be given consideration are explained below:

A. *Theoretical Considerations*

The basic theory upon which all hydro power plants operate is the power formula given below

$P = \eta\rho g HQ$

Where, P = the Total Available Power

g= acceleration due to gravity = $9.81ms^{-2}$

H= Head (m)

Q= flow (m^3/s)

ρ = density of water = $1000kgm^{-3}$

η= efficiency

Hence, a theoretically good SHP site should have a high head and a high flow rate. It implies that a hilly area with rivers that posses high flow should normally yield high power. The first step to carrying out an SHP project should be the evaluation of a number of sites in Nigeria based on the head and the flow.

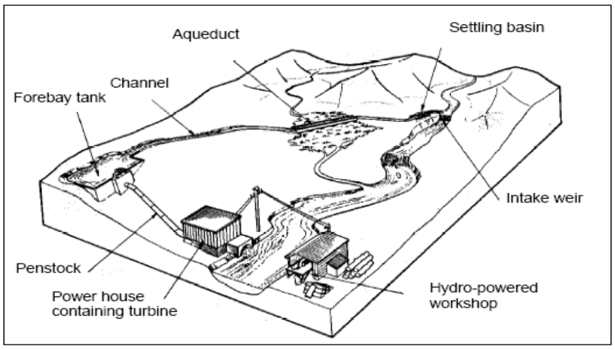

Fig. 1: Layout of a Typical Small Hydro Power Scheme Source [5]

The head can be determined by any of these methods which have been extensively discussed in [6]:

1. Spirit level and plank method
2. altimeter method
3. using sighting meters
4. using clear hose method

Other methods include the use of topographical maps and theodelites. The flow can be determined using either of the following methods:

1. Float method
2. Using measuring weir
3. Salt gulp method
4. Bucket method
5. Stage-discharge method

All of which are explained extensively in [7].

According to the World Meteorological Organization in 1979, the flow should be studied for 10 years. However since such data are usually not available for most sites in Nigeria and it is not realistic to delay project kick-off for 10 years, any of these methods may be employed to measure flow for at least one year in mini hydropower development[4].

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Any stoppage of power generation due to a reduced water flow volume significantly affects the generation of a micro-hydropower plant, thus it is essential to determine the least possible flow. With the flow data a flow duration curve should be drawn which shows the duration of each flow.

The next parameter worthy of consideration is the efficiency. The efficiency determines the amount of electrical power that can be obtained from the existing potential energy of water. The losses associated with SHP include:

1. losses due to civil work
2. losses due to penstock
3. tubing losses
4. generator losses
5. distribution losses
6. transformer losses(if the transformer is used)
7. losses due to the drive system

$P = \eta \rho g HQ$ (1)

Where,

$\eta = \eta_{civil\ work} \times \eta_{penstock} \times \eta_{turbine} \times \eta_{generator} \times \eta_{drive\ system} \times \eta_{line} \times \eta_{transformer}$

According to [4] the practical ranges of these efficiencies are as stated below:

$\eta_{civil\ work} = (1-(\text{channel length} \times 0.002 \sim 0.005)/H_{gross}$

$\eta_{penstock} = 0.90 \sim 0.95$ (it depends on the length)

$\eta_{turbine} = 0.60 \sim 0.85$ (it depends turbine type)

$\eta_{generator} = 0.80 \sim 0.95$ (it depends on the generator capacity)

$\eta_{drive\ system} = 0.97$

$\eta_{line} = 0.90 \sim 0.98$ (it depends on the length and cross sectional area)

$\eta_{transformer} \sim 0.98$

The losses due to civil work and penstock are calculated as head loss given as:

Head loss= $H_{penstock} + H_{valve} + H_{bend}$

Head loss ~ (between 0.05 to 0.15 the H_{gross})

The net power in KW,

$P_{net} = \eta_{turbine} \times \eta_{generator} \times \eta_{drive\ system} \times \eta_{line} \times \eta_{transformer} \times 9.81 \times (H_{gross} - H_{loss}) \times Q$ . . (2)

This yields the net theoretical electrical power that can be obtained from the site. This power can be determined for different values of flow. As at 2005, the head and flow for some potential sites in Nigeria were determined by the UNIDO SHP programme as shown in Table 3. It is worth noting that the list is not exhaustive as new sites could be discovered. Source [8]

Table 3: Potential of Small Hydropower (SHP) Sites For Development

River basin state govt.	Dam site	Town	Height (m)	Discharge (m^3/s)	Stage
Katsina	Jibia	Jibia	18.0	290-400	Pre-Feasibility
Katsina	Fajina	Ajiwa	12.5	400-500	Pre-Feasibility
Katsina	M/fashi	M/fashi	12.0	320-553	Pre-Feasibility
Katsina	Mairuwa	Funtua	8.0	350-550	Pre-Feasibility
Katsina	Gwadgwaye	Funtua	12.0	600-900	Pre-Feasibility
Katsina	Zobe	Dutsinma	19.8	600-900	Pre-Feasibility
Katsina	Sabke	Mapadua	12.5	250-350	Pre-Feasibility
Ogun-Oshun	Iddo	Iddo	15.0	2.699	Investor's forum
Ogun-Oshun	Sepeteri	Sepeteri	14.23	1.984	Investor's forum
Ogun-Oshun	Oke-adan		16.0	2.245	Investor's forum
Ogun-Oshun	Erin-Ijesha Waterfalls	Erin-ijesha	230.0	0.910	Investor's forum
Benin-Owena		Ugonoba	10.0	8.09	Investor's forum
Benin-owena	Owena	Owena	22.5	7.79	Investor's forum
Benin-Owena	Ele	Itapaji	22.5	11.87	Investor's forum
Upper Benue	Jada	Jada			Investor's forum
Upper Benue	Monkim	Zing	18	3.71	Investor's forum
Upper Benue	Kiri	Numan	22	6.0	Investor's forum

B. *Technical Consideration*

Having arrived at the theoretical power, technical considerations need to be made to arrive at an actual value of realizable power. The following technical considerations should be made:

1. Maintaining a steady flow at intake
2. Proper choice of turbine based on current technological trends
3. Proper choice of project layout
4. Choice of generator
5. Distance from the load centre.

Maintaining a Steady Flow at Intake

In Hydro projects, it is necessary to maintain a steady flow at the intake in order to ensure optimal power generation. This is achieved through the use of dams and weirs. For mini and micro hydro schemes no dam is usually constructed [9]. The reason being that apart from, adversely affecting the ecosystem, dams are usually not cost effective for these scales of project. However a weir is used to divert water into a forebay which allows for sediments to settle. The water falls through a penstock to the turbine and is discharged into the river [9]. Where proper engineering analysis have been done, considering cost, possible flooding of farm land, future silting and other uses of water, a decision could be made to construct a dam, in order to achieve the minimum head of the turbine and ensure power generation in dry season. The procedure for construction of dams and proper dam sizing are discussed in [4].

Project Layout

The project layout should be determined while planning. The actual layout is project-specific as it largely depends on the topography at the project site. Various project layouts are explained in [4]. A major trade off occurs between using a long penstock with a short channel and using a short penstock with a long channel. While the later may be more economical, it is not technically advisable due to the problems associated with using long channels like channel blockage, collapse or deterioration as a result of poor maintenance[4]. Also, as earlier stated in section 3.1 that:

$\eta_{civil\ work} = (1-(\text{channel length} \times 0.002 \sim 0.005)/H_{gross}$

From the above equation, it is obvious that a longer channel implies reduced efficiency due to civil work, this reduces the overall efficiency of the system.

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The shorter the channel, the better and where a dam is constructed over a stream, this efficiency is unity. As earlier stated, the length of the channel depends on the topography, existing channels and soil type [4].

Choice of Turbine

Equation 2 shows that the choice of turbine also affects the actual power, as it affects the overall system efficiency. It is important to choose turbines with high efficiency. The crossflow and pelton turbine types are the most widely adopted turbine technologies for local manufacture, as they are more suited for micro hydro schemes than reaction turbines [9]. The crossflow turbine has the advantage of maintaining high efficiencies when running below the design flow [10]. This is an important advantage as run-of- river hydro schemes do not maintain a steady flow all-year round. Also, it is easy to fabricate and is able to tolerate sand and other particles. Its peak efficiency is in the range of (0.70-0.80) and it be can operate at heads ranging from 4m to 50m [9].UNIDO facilitated the transfer of technology for manufacturing crossflow turbines up to a capacity of 125 kW to National Agency for Science and Engineering Infrastructure (NASENI) [2]. Hence in Nigeria, such indigenous technology may be employed. Current technological trends tilt towards producing ecologically friendly turbines examples are the current buoy, water vortex and the moveable underwater power plants.

Choice of Size and Number of Generating Units

The choice of generating unit should depend on the expected output from the turbine. For each turbine the prescribed speed of rotation is stated by the manufacturer. To achieve maximum efficiency, the turbine must be made to run at prescribed rotational speed. The speed of the turbine and the generator must be matched using power transmission facility such as a gear or belt which make both systems to maintain their rotational speed. Hence the chosen generator must run at a speed that can be coupled to the turbine and also run at a capacity that is above the estimated technical power. The rated capacity of the generator, Pg should be chosen such that, (Pnet/power factor) < Pg.

In the case of an isolated station(like those expected in the rural areas) in order to maintain reliability and continuity of power supply at all times, a second unit of equal capacity will be required.[11] The efficiency of generator should be between 0.80 to 0.95 [4]. Synchronous Generators are better suited for stand alone units like those expected in rural areas. This is because they are capable of independent operation and they can be operated at desired power factor in response to load factor.

Distance of the Load Centre from the Generation Site

Another technical consideration is the distance of the load centre from the generation site. The SHP site should be close to the consumers' location in order reduce cost of transmission and transmission losses. The transmission distance from the potential site to the target site should depend on various parameters, the power output, demand level, topography, accessibility conditions, transmission voltage and cost of transmission lines [4]. In Japan for instance, the transmission distance to the demand site is set to ensure a voltage drop rate which does not exceed 7% [4].The efficiency of a transmission line is given below [11].

Efficiency of transmission line = $(V_R I \cos\phi_R) / (V_R I \cos\phi_R + I^2 R)$

Where, V_R= the receiving end voltage

I= the line current

$\cos\phi_R$ = power factor

R = line resistance

Also, R= ρl/A

ρ= resistivity

l=length

A=cross sectional Area

The resistance, hence, the efficiency of the transmission line depends on the length and cross sectional area of the line. The range of efficiency should be between 0.90 to 0.98.To reduce losses the generated power may be stepped up through transformers at the SHP site and then stepped down close to the load centre. Where the load centre are significantly far from the SHP sites and the available power is not significant, transmitting over long distances may not be economical.

Switch Gear and Controls

Automation makes it possible to control turbine operation to match demand. Such controls should be in place. Also the cost of such controls should be included and a transformer if there is a need for transformer.

Estimated Average Annual Energy

The average annual energy should be estimate this will be used to calculate the estimated hydro energy cost(Naira/KWh). This cost is compared with the cost of alternative sources of power such as solar, wind and utility supply. The decision on continuing with the SHP project should then be made. The capacity factor depends on the design capacity in comparison with the actual flow and also the load demand characteristic.

According to British hydropower association, the capacity factor for most mini-hydro power schemes range from 50% to 70%.[12] Taking into consideration low flow periods, maintenance and contingencies involved in running stand alone systems,

The Capacity Factor = (units generated in a year) / (Rated Capacity of the power plant in kW x number of hours in a year)

Hence, if a capacity factor of 50% is assumed, the average annual energy, E_{annual} is:

$E_{annual} = 0.5 \times P_{net}(kW) \times 8760(h)$ in kWh

C. Economic Consideration

For feasibility studies, it is necessary to consider the cost implication of the SHP project and the possible methods of project financing. The project cost estimate should be calculated and the sum compared with the available funds. Where the estimate exceeds the available funds, the project components may be re-evaluated and necessary adjustments made, such as, considering local labour, using locally fabricated equipment or reducing capacity.

Also the per unit cost of energy generated (Naira/kWh) should be calculated and the value compared with alternative energy sources like, Power from PHCN, diesel generators and solar panel. Another aspect of economic consideration is energy use, that is, the potential consumers of electricity.

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Possible uses for rural communities in Nigeria include: lighting, refrigeration of farm produce, milling, barbing, pumping water, ironing and industrial use for extractive industries like saw mills, oil palm mills etc. this will enable potential investors determine the optimal use of generated energy. According to ESHA in [6], experience has proven that the use of generated power for industrial activities in the daytime and for lighting in the night has proven most economical. Apart from industries providing a reliable group of potential energy consumers, they could also be involved in implementing these SHP projects and selling power to the rural communities during their off peak periods. Whether the projects are to be implemented by the local industries, private investors, the government or international Non-governmental Organizations, it is important to study, the load pattern and energy requirement of potential consumers.

Project Cost Estimate

The project cost may be broadly divided into construction cost and running cost. The construction cost are incurred during construction these costs include: Cost of Clearing and Access road, Storage Dam and intake weir, intake, pipelines, electromechanical system, engineering and management cost and power house. The running costs include the cost of maintenance and repairs. Table 2 enumerates the expected costs and states the possible cost reduction based on experience in other countries.

Table 2: Cost components of a typical Small Hydro Plant and Possible Cost Reduction

Cost components	Possible cost reduction
Cost of Clearing and Access road	Community participation and use of locally available labour, as against using machineries which would be faster and more expensive
Storage Dam and intake weir	Using locally available materials for dam and weir construction.
Intake	-
Pipeline and valves	Using cost effective plastic pipelines and valves.
Turbine, Generator, Electrical Equipment and controls	Locally fabricated turbines are available in Nigeria. Fairly used generator, controls and switchgear may be refurbished and used at some sites
Powerhouse	-
Transmission Line	Wooden poles may be used for rural grid
Engineering and management cost	-
Cost of permits and licenses	-
Cost of training	The operators should local indigenes who may receive on-the-job training during construction
Running cost, maintenance and repair cost	Preventive methods should be taken to reduce silting which contributes significantly to the cost of operating the schemes. Also use of remote controls can reduce cost of transportation to the site for minor maintenance.

Power and Energy Costs

The Cost per kW is obtained by dividing the total cost by the generator capacity, while the cost per kwh is the cost of a unit of electrical energy generated. It is obtained by dividing the Total cost by the E_{annual}. This provides a basis for comparing the SHP project with alternative sources, in terms of per unit cost.

Project Financing

Project financing in Nigeria could involve, the World Bank, UNIDO, GEF Trust fund, Rural Electrification Agencies, banks and Independent Power Producers(IPPs) may be involved may be involved. However, it is important to carry out a thorough load characteristics study in the proposed region to ascertain that there is an unsaturated market for the generated electricity to ensure investment recovery. The major potential consumers of small hydro schemes in rural areas include extractive industries, farmers, tourist centre, commercial and residential consumers. Hence, the government may establish such industries to provide market for the SHP while the local community will benefit from the scheme for residential uses.

D. Environmental Consideration

The environmental impacts of small hydro plants differ from one site to the other depending on the ecosystem, the design and management of the plan from the beginning is very important to minimize the impact [14]. Hence, during the planning stage the impact of the SHP, upstream, within and downstream of the reservoir should be evaluated and necessary steps taken to mitigate all identified potential issues.

Upstream Impacts of Small Dams

Small dams cause silting upstream of the dams. It has been reported that a small dam in France created a reserve of 1900m^3 that was full of sand, the dam was opened to remove the silt, which resulted in the sand spreading over 5km and the disappearance of all species from the water [14]. Silting increases risk of flood; raises stream bed and limits the useful lifetime reservoirs. Also, Small Hydropower schemes endanger aquatic lives. it takes natural lakes, hundreds of years to evolve from oligotrophic (low in nutrients) to eutrophic (rich in nutrients) but small hydro plant reservoirs achieve this within a short period by obstructing flow, this leads to undesirable proliferation of algae and seaweed ,water quality degradation, changes to natural habitat of fishes and provides a suitable breeding ground for mosquitoes[14,16]. Other negative impacts of SHPPs include migration of aquatic fauna, fish mortality and alteration of natural hydrological regimes due to artificial hydro peakings, and difficulty in formation of new habitats [15].

Downstream Impacts of Small Dams

Downstream of the SHP, problems like temperature change of the water, drying out of stream side vegetation due to water storage in reservoirs and reduced flow downstream of reservoir can be expected. On the whole it is important to identify these issues during planning and take appropriate steps to mitigate them. Table 3 shows some identified problems on SHPs and the ways to reduce their impacts.

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Table 3: Identified Environmental Impacts and Methods of Mitigation

Identified Environmental Impacts	Ways of Mitigation
Silting and retention or nutrients in the reservoirs	By building Run-of –River schemes instead of building dams. Annual Maintenance: this involves the removal of sediments from the reservoir, accomplished by excavation, dredging, drainage, flushing and sluicing. Biological methods: planting of trees and grasses along the slopes within the catchment areas. Other methods include Contour bonding, gully plugging, wire crating, rock bolting and networking drainage wells.
Proliferation of algae, waterborne diseases (e.g. Bilharzias and river blindness) and seaweed due to rapid eutrophication.	Where the potential issues exceed the benefits, dams should be avoided
Alteration of water quality as evident in changes in temperature and dissolved oxygen concentrations in the water released from the dam.	Aerating reservoir forebay waters with air or oxygen, installing advanced aerating turbine runners, and constructing aeration weirs in the tailrace below the dam.
Interference with migration of aquatic fauna	Installation of fish ways such as fish ladders, fish elevators, and trap-and-haul operations to ensure safe passage of fish upstream. Using fish-friendly turbines. River abstraction.
Displacement of People and terrestrial life as in Sri lanka where villagers where displaced due to rock blasting at construction stage.	
Mortality of fisheries and people. In Sri Lanka a few deaths have been recorded when villagers were bathing in the forebay due to emergency spilling.	Using fish friendly turbines Providing caution signs for areas likely to be affected by spilling
Loss of river-based recreation, aesthetic sites and fisheries	Reservoir construction should be limited, where there are waterfalls and sites of aesthetic value downstream.
Drying up of river downstream of the dam where dams are constructed across the stream	Encourage river abstraction with legal limits to abstracted flow. Setting minimum discharge from the tailrace. Environmental flow releases from dams based on acceptable standards.

Source [15, 17]

Legal, Cultural and Social Consideration

Other factors worthy of consideration include the Legal Structure, culture and social life of the proposed host community. This is to ascertain land ownership, current use of the river and legal restrictions on water use. Special consideration should be given to the following sites [13]. Those that are characterized as national parks

- Archaeological sites
- Natural landscape
- Regions of cultural heritage
- Rare wetland

For SHPs to be installed in these sites the concerned stakeholders should be consulted and adequate permits obtained. Failure to consult villagers in a project in Sri Lanka led to protest by villagers who gave the following reasons for the protest [17]:

- The resource which belonged to the local people is exploited by strangers for the benefit of the city and the students in the village do not have a single bulb to study at night.
- The site is a sacred mountain for Buddhist
- Deforestation
- Change of natural topography.

In Nigeria, the bodies to be consulted should include, The Nigerian Electricity Regulatory Commission (NERC), National Basin Authority, Ministry of Land and Survey, Ministry of Works and Transportation, Traditional institutions and other stakeholders depending on the location. The proposed. Flowchart for Small Hydropower Project planning in Nigeria is shown below.

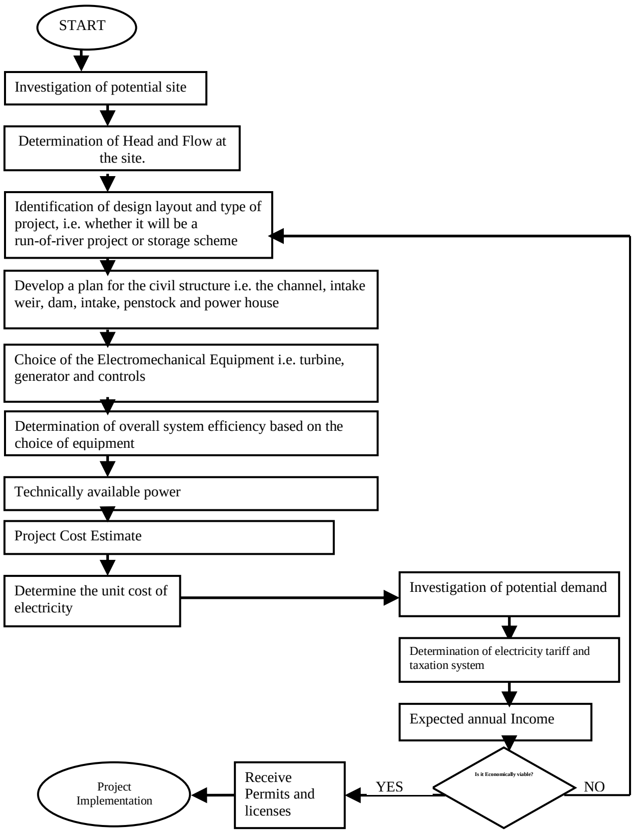

Fig 2: Proposed Flowchart for Small Hydropower Planning in Nigeria

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IV. CONCLUSION

Nigeria is still struggling with the persistent power problem and all available sources of power should be tapped optimally. SHPs present a very viable option for rural electrification given that they are durable, environmentally friendly and require little maintenance once they are commissioned. This paper has elucidated the various aspects of such projects which must be considered by both regulatory bodies and developers. This is to ensure that rural electrification is achieved optimally and negative environmental impacts as experienced in other countries are avoided. Our recommendations are as follows:

1. Pilot projects in Nigeria should consider high head and high flow sites instead of low head sites. Low head sites would usually involve dam construction with its associated problems.
2. To encourage private sector participation, the Government should provide incentives in the form of reduced taxation and attractive electricity tariff.
3. Rural Electrification projects in the various states of the federation should provide local grids for isolated rural areas that incorporate small hydro plants and other economical renewable energy sources. Such grids should operate as separate entities from the national grid, even though their operation should still be regulated by NERC.
4. The locally fabricated turbines should be improved to allow the passage of fish, harness low head sites, eliminating the need for dams and hence reduce the negative environmental impact.

The Nigerian Electricity Regulatory commission (NERC) and Energy Commission of Nigeria should provide a clear regulatory framework, taking into consideration, the technical, legal, economic, financial and environmental aspects of Small Hydro schemes. This will encourage potential investors and serve to regulated excessive exploitation and the associated problems as experienced on some SHP projects in other countries

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