Macro- and Micro-Hydropower: An Option for Socioeconomic Development. Case Study – Agbokim Waterfalls, Cross River State, Nigeria.

R. Uhunmwangho, Ph.D. and E.K. Okedu

Department of Electrical/Electronic Engineering, University of Port Harcourt, Nigeria.

E-mail: tripodeng@yahoo.com
kenokedu@yahoo.com

ABSTRACT

Over the last few decades, there has been a growing realization in developing countries that macro- and micro-hydro schemes have an important role to play in the economic development of remote rural areas, especially mountainous ones. The Agbokim Waterfalls located 23 km from Ikom Town is one of such macro-hydro schemes that can provide power for industrial, agricultural and domestic uses.

The Agbokim waterfall is located in a hilly terrain cuts < flow rate of $7m^3$/sec that is perpetual, flowing all year round unto a head of approximately 40m producing approximately 2.2 mega watt power to 8 communities of about 4,000 persons. Land acquisition problems, difficult and inaccessible sites, geological surveys, and funding are of some of the constraints in developing the Agbokim hydro schemes. The key areas of interest were stream flow data, water quality, interconnection cost consideration and financing. A cash flow evaluation was used to determine the economic viability of the hydro scheme by looking at the overall revenues which includes the energy sales and the expenses on a year by year basis.

(Keywords: hydropower, energy sales, electricity demand)

INTRODUCTION

Power is a critical infrastructure for economic development and for improving the quality of life. However, it is a matter of concern that the annual average per capita consumption of Nigeria is about 14.6kWh, which is among the lowest in the world. Further, people in a large number of urban and rural villages have no access to electricity. The end users of electricity like households, farmers, commercial establishments, and industries are confronted with frequent power cuts, both scheduled and unscheduled.

Power cuts, erratic voltage, and low or high supply frequency have added to the 'power woes' of the consumer. These problems emanate from:

- Inadequate power generation capacity;
- Lack of optimum utilization of the existing generation capacity;
- Inadequate inter – regional transmission links;
- Inadequate and ageing sub – transmission and distribution network leading to power cuts and local faults;
- Slow pace of rural electrification;
- Large scale theft and skewed tariff structure.

In order to improve on the social economic well-being of Nigerians, there is need to provide affordable power. With increasing price of fuels and cost of installation, the cost of power generation has significantly increased. While attending to the task of improving the country's generation capacity, high priority is to be given to reduce the cost of power to enable different segments of the population and the economy to effectively utilize power as an input. As a result, adoption of best practice and choosing least cost options in capacity addition will be encouraged. One of these options will be the small or macro–hydro power.

Hydro power became an important resource for electricity generations at the beginning of the electricity era. The first hydropower scheme was installed in Wisconsin in September 1882 only few years after Thomas Edison invented the light bulb (Energizing Sustainable Development, 2002). Soon after, it became a popular option for electricity generation around the world. At present nearly 20% of the total electricity consumed worldwide comes from hydroelectric plants (Micro Hydropower Systems, 2006). In some countries hydroelectricity accounts for more than 80% of the total electricity consumed.

For some years, interest in hydropower went down drastically due to a number of factors: fast growth in electricity demand globally; progress of other technologies, success of large generation schemes and large grids in bringing down cost; mass production of small diesel sets that are both portable and easily installed; and easy access to affordable diesel fuel.

In the more recent past, the energy crisis, climate change, energy poverty in developing countries, and commitments for achieving the Millennium Development Goals (MDGs) has led to a rethink. Planners and policy makers are being urged to review all available energy options, especially those decentralized sources that could play a role supplying poor and isolated communities with energy for development. These sources include hydro power schemes as well as solar photovoltaic systems, biomass energy and wind generators.

Hydroelectric power plants are an important and environmentally friendly tool for the achievement of the MDGs in the rural areas through the provision of sustainable electric power supply (Final synthesis report, for sustainable development of micro hydro power, 2000). It is economically and socially viable, when indigenous resources and appropriate technology are deployed in its implementations operations and management.

Hydroelectric power is an option which can generate energy 24hours a day continuously at its full capacity (if needed) the marginal cost are negligible, and it can in turns promote creation and the productive user of energy for income generation and social development of communities.

In spite of the existence of numerous reports and an apparent interest in the development of the micro hydro technology in the country, not many hydro plants have been constructed so far. In Nigeria, Preliminary Prospect of harnessing the hydro-electric potentials exist for Evboru II in Edo state with an estimated capacity of 20kW run off river, Ugonoba River along Benin/Asaba highway has a mathematical estimate of 600kW and other parts of the country.

Marco-hydroelectricity development has significant potential for contributing to Nigeria's long term energy mix. Nigeria has developed some hydroelectric schemes over the last century; however there are many opportunities for small- or macro-hydro developments in many part of Nigeria, especially Cross River State. The climate and geography of Cross River State is ideal for hydroelectric development as identified in Agbiokim Waterfalls, in Etung Local Government Area with estimated capacity of 2.2MW (Income Electricity Limited, 2008). Also, Baqui stream located about 300m from Agbokim Waterfalls, is another site capable of yielding up to 204kW of electricity. This brings the total energy yield of this area to about 2.4 mega watt. The estimated energy demand of this area is 1.0MW (Income Electric Limited, 2008).

THE AGBOKIM COMMUNITY

The Agbokim community is 23km from Ikom Town and a boarder community between Nigeria and Cameroon. Agbokim Waterfalls is in Etung Local Government area of Cross–River State. Agbokim community and the neighboring communities are connected to the national grid. The small hydro scheme can be a "Grid-tie" or "Off-grid". The main income of the people is from Agriculture. The crops are cassava, cocoa, and chewing sticks production is also a major source of income. The total population of the Agbokim community and other neighboring communities is about 4,000 (National Population Commission, 2007).

The proposed installed capacity of the major stream is 57 x 40 x 7.83 = 21932.4kW while the minor stream is 1x25x7.8 = 200kW. The annual energy generation on the major stream = 2122.4x8780 = 19,205,424kWh, while the minor stream is 200x8760 = 1,752,000kwh (Income Elecrtriy Limited, 2008).

The river drops on the Agbokim Falls is one cascade of about 40m. The upper part is the normal River course which will be used as the dam section, and the lower part of the valley is used for the generator house. The Agbokim Waterfalls is technically the most flexible for the construction of a medium head plant filled with a Kaplan turbine. The maximum power that can be derived from the major is 2192.4kw (Agbokim Waterfalls), while the minor is 200kw (Baqui steram). It should be taken into in consideration that the Agbokim Falls are extra ordinary natural beauty and the location has been declared a tourist area.

Actual stream flow measurements should also be undertaken and as much data as possible collected prior to a final commitment to go ahead; as this will give actual values with which the power derivable from that stream may be accurately determined.

The development and operation of a hydropower plant can be adversely affected by suspended sediment in the water like silt and fine sand, bed load (including the sand, gravel and rocks that move along the stream bed), flowing debris, dissolved chemicals, and ice these things must be determined before selecting the actual intake site and specifying equipment that would come into the contact with the water.

MACRO AND MICRO - HYDRO SCHEMES CASE OF CROSS RIVER STATE

The case for sustainable energy development in Cross River state is as follows:

- The Baqui stream development and
- Agbokim Waterfalls

Baqui Stream Micro–Hydropower

The key components of micro-hydro development are plan development, site selections, costs of financing, permitting process, grid interconnection energy sales, construction and operation, maintenance and surveillance (OMS).

Plan Development: A preliminary survey of the Baqui stream near Agbokim reveals that the basic requirement for the sitting of a micro-hydroelectric power station exist as shown in Figure 1, for example the stream flows all year round and is located in a hilly terrain. The available power P at this site can be determined from the relation:

$$P = Q \times H \times 7.83 \text{ kW} \qquad \textbf{(1)}$$

where Q = flow rate of the river in m^3/sec and H = height of the river head in meters.

Figure 1: Baqui Stream.
(Sources: Income Electrix, 2008)

Site Selection: The stream has a flow rate of $1m^3$/sec and it flows all year round. The head of this stream is approximately 26m (Income Electrix Limited, 2008). From Equation 1 above, the estimated power at this site is:

P = 1 x 26 x 7.83Kw = 203.58kW, approximately 204kW.

Cost of Financing: From the estimated average cost of building a micro- and macro-hydroelectric power station at $2,000.0 (240,000 naira) per kW, the cost of this hydro scheme will be as follows: $2,000.00 x 204 = $408,000.00 or ₦48,960,000.00, at the rate of ₦120.00 to $1.00. The environmental impact assessment (EIA) and all necessary permits in line with the EIA reports and recommendation result will be met as this is one of the necessary conditions in setting up a hydro scheme.

Grid Interconnection and Energy Sales: The 204kW to be generated from this unit will supply the community and surrounding settlements, this power could be sold to the consumers at ₦5/kwh. For a 204kW plant, this will yield 204 x 5x 24 = ₦24, 480.00 per day or ₦8, 935,200.00 per annum.

This revenue can be used to provide operations and maintenance service for the plant, as well as contribute to offset the cost of replacing the unit after the expiration of its useful life. The average useful life of a hydroelectric power plant is 20 years, given adequate maintenance. Hence, after the initial expenditure on the project, further investments in the project becomes unnecessary as the project would begin to generate enough revenue to take care of itself and even replace itself hen its useful life has expired.

Macro-Hydroelectric Power Plant at Agbokim Waterfalls

A preliminary survey of the Agbokim Waterfalls reveals that the basic requirement for the sitting of a hydroelectric power station exist, like the river flows which is all year round located in a hilly terrain. The available power P at this site can be determined from the relation in equation (1). The Agbokim River has a flow rate of $7m^3$/sec and is a perpetual river (flowing all year round). The head of this river is approximately 40m (income Electrix Limited, 2008), a shown in Figure 2.

Figure 2: Agbokim Waterfall.
(Source: Income Electrix Limited, 2008)

Also, from Equation (1), the available power at the Agbokim is:

P = 7 x 40 x 7.83kW = 2192.4kW which is approximately 2.2 megawatts.

Cost of Financing: It is estimated that the average cost of building a hydroelectric power station of about 125kW to 32MW is $2,000.00 per kW (240,000 naira), since the Agbokim plants falls within this range, the value can be use as a rough guide. This means that for a 2.2 megawatt plant, the total capital cost of construction could be estimated as:

$2,000.00 x 2,200 = $4,400,000 or ₦528, 000,000 at the rate of ₦120.00 to $1.00.

Grid Interconnection and Energy Sales: The 2.2 megawatt to be generated from this unit will supply the village and surrounding settlements. This power could be sold to the consumers at 5kWh. For a 2.2 megawatt plant this will yield: 2, 200 x 5 x 24 = ₦264, 000.00 per day or ₦96, 360,000.00 per annum.

This revenue can be used to provide operations as maintenance service for the plant as well as contribute to offset the cost of replacing the unit after the expiration of its useful life, as the average useful life of a hydroelectric power plant in 20 years, given adequate maintenance.

COST AND FINANCING

Developing a micro-hydro project can be an expensive undertaking. Total project costs should be estimated early in the project to provide a good understanding of the total investment required. Planning of project expenditures allows for the development of a financial plan, identifying how much money is needed at each stage of the project. This information is required when approaching potential project fenders. Cost for developing a micro project development; construction cost incurred in the day-to-day running of the project.

Annual cost includes operation, maintenance and surveillance expanses as well as applicable taxes and rental payments. The initial cost of a micro hydroelectric power plant include the cost of the preliminary survey, the cost of a detailed project survey or feasibility studies, and the cost of the project development. The preliminary survey costs includes the cost of initially visiting the site to determine whether the basic requirements for sitting a small or micro hydroelectric power plants exists (such as availability of a suitable head, sufficient flow rate, whether the stream is seasonal or constant, etc.).

The detailed survey or feasibility studies include the cost of hydrologic assessment EIA, preliminary designs, and drawing and detailed cost estimates. The cost for the studies is calculated based on an estimate of the time required by experts to complete the necessary work. For the project at Agbokim, about ₦5,000,000 (five million naira) is required for detail project report.

Engineering costs vary depending on whether one is designing the micro hydro project on ones own or hiring engineers and contractors to carry out the work. Engineering cost is calculated based on an estimate of the time required by experts to complete the necessary work. A micro hydro project requires various pieces of electrochemical equipment including turbine-generators, controls, electrical protection (including electrical equipment for the power house and possibly a remote monitoring system), pumps and gates. The cost of this equipment varies depending on the size and gross head of the project.

Typically, the generating equipment for projects with higher head and lower flow are less expensive than that for lower head, higher flow projects. In addition to equipment supply cost, there is also need to counter cost for transporting and installing the equipment. These costs are dependent on the size of equipment, as larger equipment will need to be transported in sections and assembled on site.

BALANCE OF PLANT

The balance of a plant for a micro hydro like the Agbokim type typically includes items such as access roads, transmission lines, substations, and costs for civil works such as down or weir construction, decorating, spill nary and intake construction and pipelines. The cost associated with each are specific to each project and vary according to the materials used and complexity of construction.

If the hydro project is located on leased land, an annual lease payment is required. These costs are site specific and will depend on the value of land that is leased. Applicable property taxes (provincial or municipal) have to be estimated on a site–by-site basis and will depend on the are and value of land and fixed structures (except equipment) used and/or the revenue generated by the hydro development.

OPERATION, MAINTENANCE AND SURVEILLANCE

The maintenance of transmission line associated with a micro hydro project involves periodic clearing of tress and replacement of parts of that becomes damaged as a result of lighting, impact or other events.

Annual general administrative costs include the costs of bookkeeping, preparation of annual statements, bank charges and communication. If legal services are required they generally fall under this category. There will be a cost for maintaining cooking capital, which is needed to absorb the sometimes-uneven flow of project reviews.

CONCLUSION

Macro- and micro-hydro systems are designed to operate for a maximum of twenty years, if they are properly looked after. By making a small charge for use, communities can accumulate energy money to pay for the replacement of the unit at the end of its useful life. Once schemes are set up, they should continue to function indefinitely without any more external funding. The calculation done above are enough proof that the Agbokim Waterfall project is the cost effective means of providing sustainable electric power supply in Cross Rives State.

The saying ‘prevention is better than cure’ holds true for motivation of environmental and human impacts of hydroelectric projects. It would be with while to abandon project when the environmental and social cost to be paid are high. The main criteria for choice of a project should be its sustainability. It is possible that the alternatives of hydroelectric projects might be worse. Therefore all options should be considered together to arrive at a choice. Big and small project have advantages and disadvantages. But a small project like the Agbokim would often be preferable owing to lower risk factors.

No conventional alternatives would take time to arrive on the scene in a big way. There is resistance to adopting some of these technologies owing to vested interest of those working in the field. It is up to the planner, policy makers and the Government to see that the decisions are proper when public money is involved.

To determined if the Agbokim project is economically viable a cash flow evaluation of the project is necessary. Cash-flow analysis looks at overall project revenues and expenses on a year by year basis over the life of the project.

The cash flow analysis demonstrates the viability of the project. It also highlights variation in year-to-year profit or loss. However, it should be remembered that this analysis is based only on average revenue and expenses. Actual project revenue varies from projected revenue due to variations in annual stream flow. Expenses can also vary due to unforeseen circumstances.

REFERENCES

1. Ofosu – Ahemkorah, A.K. and Seven Dern-edde. 2002. *Mini Hydro Power in Ghana: Prospect and Challenges*. Energy Foundation: Accra, Ghana.

2. Energizing Sustainable Development. 2003. “Concepts and Projects”. *Partner for the Future Worldwide*.

3. Final Synthesis Report. 2000. “Best Practices for Sustainable Development of Micro hydro power in Developing Countries”.

4. Income Electrix Limited. 2007, 2008. “Report on Preliminary Survey for the Construction of Small Hydroelectric Power Plant in Agbokim”. IEL: Lagos, Nigeria.

5. London Economics and Delucia Associates. 2002. For the Department of International Development UK. Cambridge, MA.

6. Quest Enterprise. 2006. *Micro-Hydroelectric System Design Manual* Quest Enterprise: Russellville.

7. Micro-Hydropower System. 2006. “A Buyer’s Guide”. Natural Resources Canada: Ontario.

8. National Development and Reform Commission. 2005. *Beijing Declaration on Renewable Energy for Sustainable Development*.

9. National Population Commission Report. 2007.

10. Smail Khennas and Andrew Barneth. 2000. “ITDG Practical Answers to Poverty”. Department for International Development: London, UK.

11. The British Hydropower Association. 2005. *A Guide for UK Mini Hydropower.* BHA: London, UK.

ABOUT THE AUTHORS

Roland Uhunmwangho was born at Benin, Nigeria on March 10th, 1960. He received a B.Sc. Electrical Engineering at the Technical University of Iasi, Romania in 1983, an M.Tech., and a Ph.D. from the Rivers State University of Science and Technology, Port Harcourt, Nigeria in 1988 and 2003 respectively. He lectured with the Bendel State University Ekpoma, Nigeria from 1994 till date he is with University of Port Harcourt, Port Harcourt, Nigeria. He is currently on leave of Absence with an engineering company (Income Electrix Limited) Electrical Power. The company is involved in the Construction of Electrical Transmission and Distribution lines.

E.K. Okedu is a researcher in the Department of Electrical/Electronic Engineering, University of Port Harcourt, Nigeria with research interests in hydropower and energy systems.

SUGGESTED CITATION

Uhunmwangho, R. and E.K. Okedu. 2009. “Macro- and Micro-Hydropower: An Option for Socioeconomic Development. Case Study – Agbokim Waterfalls, Cross River State, Nigeria”. *Pacific Journal of Science and Technology.* 10(2):529-534.

Pacific Journal of Science and Technology