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Hydro Power Energy Resources in Nigeria

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Abstract: Energy is one commodity on which the provision of goods and services depend. Its availability and consumption rate is an economic index to measure the development of any community. In Nigeria, there is a limitation to power supply from the National grid which has adversely affected the economic and social development of the populace. This really necessitates the need for decentralized power source as a viable alternative to which hydro power schemes readily fits in. Major rivers and dam's development provide an enviable energy potential for the exploitation of hydro energy in Nigeria. This study presents analysis of hydro power as renewable energy resource potentials in Nigeria with the status of the database including its adequacy and gaps. A detailed analysis of the technical and technological assessment, present demand and supply situation is also made.

Key words: Energy potentials, power supply, hydro power, database, Nigeria

INTRODUCTION

Hydropower is derived from the potential energy available from water due to the height difference between its storage level and the tail water to which it is discharged. Power is generated by mechanical conversion of the energy into electricity through a turbine, at a usually high efficiency rate. Depending on the volume of water discharged and height of fall (or head), hydropower can be large or small.

Although, there may not be any international consensus on the definition of small hydropower, an upper limit of 30 Megawatts (MW) has been considered. Thus, 30 MW has been adopted as the maximum rating under this dispensation. Small hydro can further be subdivided into mini hydro (<1 MW) and micro hydro (<100 kW). Thus, both mini and micro hydro schemes are subunits of the Small Hydro Power (SHP) classification (Raghunath, 1986).

HYDRO RESOURCE SITUATION

Globally, hydropower is a very significant contributor to energy systems. Nigeria is endowed with abundant water resources. Annual rainfall decreases from a high of 3400 mm depth in the south central shores of the Niger Delta to 500 mm over the northern boundaries of the country, with a perched increase to 1400 mm over central Jos Plateau region. Similarly, the eastern ranges of Adamawa and Cameroon boundaries experience elevated precipitation as high as 2,000 mm relative to contiguous low areas of the country.

Rainfall duration is longest in the south and decreases progressively northwards. In the southern areas, precipitation lasts over 8 months of the year, whereas, at the extreme north annual rainfall duration can be <3 months.

It is clear that the country is blessed with a huge hydropower potential (Okoro, 2006). The most attractive areas would be the southern, Plateau and southeastern regions of the country, where rainfall is highest and of long duration and local topography provides appropriate drops and necessary hydraulic heads. It is also evident that the run-of-the-river SHP is unlikely to operate year round, except in the south and south-eastern areas where, river and stream flows are perennial. In the northern and Jos Plateau regions where stream flows are substantially ephemeral, the SHP would require flow regulation via storages and reservoirs. All the same, small hydropower can essentially be developed in virtually all parts of the country.

ESTIMATED RESOURCE BASE

From National Electric Power Authority's (NEPA) most recent estimate, the country's outstanding total exploitable hydro potential, are shown in Table 1 currently stands at 12,220 MW. Added to the 1930 MW (Kainji, Jebba and Shiroro), already developed the gross hydro potential for the country would be approximately 14,750 MW. Current hydropower generation is about 14% of the nation's hydropower potential and represents some 30% of total installed grid connected electricity generation capacity of the country.

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From a 1980 survey of 12 of the old states of the federation, namely; Sokoto, Katsina, Niger, Kaduna, Kwara, Kano, Borno, Bauchi, Gongola, Plateau, Benue and Cross River, it was established (Table 2), that some 734 MW of SHP can be harnessed from 277 sites. The potential would of course increase when the rest of the country is surveyed. It is presently estimated by the Inter-Ministerial Committee on Available Energy Resources (Technical Committee on Quantification of Energy Resources, 2004) that the total SHP potential could reach 3,500 MW representing 23% of the country's total hydropower potential.

Table 1: NEPA estimate of current exploitable hydro power sites in Nigeria installed potential

Location	River	Install potential capacity (MW)
Donka	Niger	225
Zungeru II	Kaduna	450
Zungeru I	Kaduna	500
Zurubu	Kaduna	20
Gwaram	Jamaare	30
Izom	Gurara	10
Gudi	Mada	40
Kafanchan	Kongum	5
Kurra II	Sanga	25
Kurra I	Sanga	15
Richa II	Daffo	25
Richa I	Mosari	35
Mistakuku	Kurra	20
Korubo	Gongola	35
Kiri	Gongola	40
Yola	Benue	360
Karamti	Kam	115
Beli	Taraba	240
Garin Dali	Taraba	135
Sarkin Danko	Suntai	45
Gembu	Dongu	130
Kasimbila	Katsina Ala	30
Katsina Ala	Katsina Ala	260
Makurdi	Benue	1060
Lokoja	Niger	1950
Onitsha	Niger	1050
Ifon	Osse	30
Ikom	Cross	730
Afokpo	Cross	180
Atan	Cross	180
Gurara	Gurara	300
Mambilla	Danga	3960
Total		12220

Small hydro schemes under operation in the country are shown in Table 3. As indicated, the projects are developed only in 3 states of the federation, namely; Plateau, Sokoto and Kano. Of the total 30 MW installed capacity, 21 MW (or 70%) is generated from 6 sites in Plateau State by the Nigerian Electricity Supply Corporation Ltd. (NESCO).

As indicated in Table 4, NESCO projects were completed between 1923 and 1964 and have continued to provide virtually uninterrupted power to not only supply the Jos metropolis and meet local consumption, but also feed into the national grid. NESCO operations are a clear example of a very successful Independent Power Production (IPP) that should be replicated in other parts of the country.

Table 2: Small hydro potential in surveyed states of Nigeria

State (Pre 1980)	River basin	Total sites	Total capacity (MW)
Sokoto	Sokoto-Rima	22	30.6
Katsina	Sokoto-Rima	11	8.0
Niger	Niger	30	117.6
Kaduna	Niger	19	59.2
Kwara	Niger	12	38.8
Kano	Hadeija-Jamaare	28	46.2
Borno	Chad	28	20.8
Bauchi	Upper Benue	20	42.6
Gongola	Upper Benue	38	162.7
Plateau	Lower Benue	32	110.4
Benue	Lower Benue	19	69.2
Rivers	Cross River	18	258.1
Total		277	734.2

Table 3: Existing small hydro schemes in Nigeria

River	State	Installed capacity (MW)
Bagel I	Plateau	1
Bagel II	Plateau	2
Ouree	Plateau	2
Kurra	Plateau	8
Lere	Plateau	4
Lere	Plateau	4
Bakalori	Sokoto	3
Tiga	Kano	6
Total		30

Table 4: NESCO small hydro projects in plateau state

Items	Kwali	Ankwil I	Ankwil II	Kurra	Jekko I	Jekko II
River	Tenti	Tenti	Tenti	Tenti	Sanga	Sanga
Reservoir						
Area (km^2)	0.14	5.1	0.23	4.8	0.4	0.02
Capacity (MCM) $\times 10^6$	0.63	31	1.16	17	1.4	1.4
Discharging (m^3 sec^{-1})	271	228	343	571	685	685
Dam						
Height (m)	9	27	9	19	9.75	6
Crest length (m)	274	708	203	1,067	128	23
Volume (MCM)	90,500	521,240	46,578	348,654	6,000	700
Altitude (ASL)	1,068	1,274	1,274	1,172	870	674
Type	Earth fill	Earth fill	Earth fill	Earth fill	Concrete	Concrete
Spillway	Ogee	Underflow	Underflow	Broad crested weir	Ogee	Ogee
Power plant						
Output (MW)	2	1	2	8	4	4
Year of completion	1923	1964	1963	1929	1937	1950

Nigerian Electricity Supply Corporation Ltd. (NESCO), Jos

STATUS OF DATABASE

The database on small hydro in Nigeria is quite limited, incomplete and substantially obsolete. Only 12 sites were surveyed some 20 years ago and to date no new surveys have been conducted to either confirm/verify earlier data or extend the work over the uncovered states, which, incidentally, occupy the most promising south-western and southeastern regions of the country where, precipitation is high and most streams and rivers are perennial.

Every effort should be made to complete the survey over the entire country developing new data and verifying existing information. Data can be assembled through the River Basin Development Authorities, State and Local Governments, NEPA, State Rural Electrification Boards and relevant Non Governmental Organization's (NGO) under the responsibility of the Energy Commission of Nigeria (ECN, 2004). Data thus, generated should be organized in appropriate reports and stored in other suitable formats for easy retrieval and application. For each potential small hydro site, data to be assembled should cover, among other items: rainfall depths and duration; river and stream systems including flow rates and duration; seasonal and long-term variation of flows; local topographical features; suitability of site for reservoir development; geology; demographic characteristics; community trades and employment; land use; status of power supply in the area; developable small hydro capacities; cost of schemes; project feasibility and requirements for hydro system implementation.

RESULTS AND DISCUSSION

Technical assessment

Overview of technology: A relatively simple technology, SHP depends on the availability of water flow or discharge and a drop in level over the river course. For the run-of-the-river scheme, where there is no impoundment, computation of the hydropower only requires a determination of the magnitude of the discharge and the head or vertical distance of the waterfall (Jack, 1984). The flow can be measured by the bucket method, which simply determines the time taken to fill a bucket of a known volume. Discharge can also be determined by the velocity method, where a weighted float is timed over a longitudinal flow path and stream depths are measured across the flow section to determine the cross-sectional area.

Where, the topography permits the hydro yield is firmed up by the construction of a small dam, which creates a reservoir. The storage provides additional head and flow regulation, thereby increasing power output and extending power generation over low-flow periods. Other components of the small hydro include the penstock, a turbine which transforms the energy of flowing water into rotational energy, an alternator which converts rotational energy into electricity, a regulator which controls the generators and wiring which delivers the electricity to the end users. In many systems, an inverter is incorporated to convert the resulting low-voltage Direct Current (DC) into 220 or 240 V Alternating Current (AC) compatible with existing national power systems.

Sometimes excess power is stored in batteries for use during periods of low flow or water scarcity. While, the bulk of small-hydro requirement and accessories are import-based during early stages of development, it is believed that with appropriate government incentives and support, virtually all basic components of the systems can be manufactured locally. This would also facilitate system maintenance and repairs.

To date, small hydro technology is still at its infancy in Nigeria. As shown in Table 2, the schemes are operated in only three of the 36 States of the Federation and only the NESCO complex in Plateau State, whose first unit went on stream some 80 years ago, has developed some form of local technology in its facility operation and maintenance.

Technical characteristics: Power output from the small hydro plant is dependent on the characteristics of its key components namely: the penstock, turbine, generator, regulator, inverter and cabling. Penstock piping should be selected to reduce flow friction and hydraulic losses by using smooth piping materials and limiting the number of joints, bends and transitions.

Turbines are preferred over waterwheels, because they are more compact have fewer gears and require less material for construction. As shown in Table 5, several types of turbines are available for the small hydro. The impulse turbines, which have the least complex design and rely on flow velocity to move the wheel or runner are the most commonly used for the high head SHP systems. The most common types of impulse turbines are the Pelton and Turgo wheels.

With the Pelton wheel, water is funneled into a pressurized pipeline via a jet existing from a nozzle and striking double buckets attached to the wheel. The resulting impact creates a force that rotates the wheel at a high efficiency rate of 70-90%. The system is particularly suited for low-flow high-head conditions.

The Turgo impulse wheel is an upgrade of the Pelton. Using the same spray concept, the Turgo jet is about half the size of the Pelton, but its spray hits three buckets simultaneously. Thus, the Turgo wheel is less bulky and

Table 5: Types of turbines and parameters for small hydro schemes

Type	Head (n)	Discharge (m sec^{-1})	Speed (rpm)	Rating (kW)
Cross flow	7.5-100	0.15-5.0	100-1000	50-1000
Bulb (package)	5-18	4-25	187-500	150-4500
S-type (tubular)	3-18	1.5-40	120-750	50-5000
Vertical tubular	5-18	2-20	300-750	300-750
Horizontal francis	20-300	0.6-17	300-1000	500-5000
Impulse	75-400	0.3-3	120-000	100-5000

National energy plan vision 2010 for small hydropower technology (March, 2004)

moves almost twice as fast the Pelton version. It also, needs few or no gears and generally operates trouble free under low-flow conditions, requiring medium or high head. The Turgo wheel therefore, achieves even higher efficiency than the Pelton wheel.

In reverse action, conventional pumps, which are mass produced and relatively less expensive, can operate as turbines. Reasonable pump performance, however, requires generally constant head and flow, not usually achievable under the small hydro concept. Pumps are also less efficient and more prone to damage than turbines.

The generator, regulator and inverter are generally standard equipment with fixed but lower than turbine efficiencies. Thus, whereas the turbine efficiency can be as high as 90%, overall efficiency of the small hydro composite unit is in the range of 53%. Achievement of this level of efficiency requires regular and proper system maintenance.

Since, the hydro plant has only few moving parts and operates at ambient temperatures, its life span can be quite long. While, thermal power plants require very large operation and maintenance costs and must be replaced every 5-7 years, the hydropower system can operate for as long as 20 years under generally inexpensive operation and maintenance requirements before there is need for major rehabilitation. As shown in Table 6, the lifetime of the small hydro facilities is 20-30 years, compared with 8-10 years for diesel engine generators. Long service life is therefore, another important attraction of the small hydro system.

Parts of SHP plants are readily available in the economy. Other than the turbine, which may be import based, other components of the system can be purchased virtually anywhere in the general market. Development and support of the small hydro can thus, be easily achieved within the Nigerian economy.

Economic competitiveness: Although, the small hydro may require a moderately high capital cost (Table 7), its low operation and maintenance (O and M) requirements (Table 8) coupled with long life spans are its major advantage over other prospective sources of power to small and medium sized local communities and settlements. The petrol/diesel generators which may be installed at a relatively moderate cost are prone to such serious limitations as unreliability of fuel supply, frequent breakdown, high O and M requirements, short service lives, noisy operation and environmental pollution.

Table 6: Lifetimes of off-grid renewable energy technologies

Technology	Lifetime (Years)
Engine generators	8-10 (diesel)
Micro hydro	20-30
Photovoltaic	20-30
Wind turbines	15-25
Batteries	3-5

Table 7: Initial capital costs of electricity generating systems

Technology	Size (kW)	Initial capital cost ($/kW)
Engine generator	-	-
Gasoline	4	760
Diesel	20	500
Micro hydro	10-20	1000-2400
Photovoltaic	0.07	11200
Photovoltaic	0.19	8400
Wind turbine	0.25	5500
Wind turbine	4	3900
Wind turbine	10	2800

Costs are as of 1990, national energy plan vision 2010 small hydropower technology (March, 2004)

Table 8: Operating and Maintenance (O and M) and fuel costs for different technologies

Technology	O and M costs (cents/kWh)	Fuel costs (cents/kWh)
Engine generator	2.0	20
Micro hydro	2.0	0
Photovoltaic	0.5	0
Wind turbines	1.0	0

The economic value of small hydro schemes would be further enhanced when more units come on stream, local service areas are established and system components are predominantly locally sourced. Training facilities would need to be set up in different states, particularly in areas of high SHP potential and/or development. Prospective operators and managers can also, be trained in higher institutions throughout the country. Economic competitiveness of the SHP would increase with more use and improvements.

Benefits and limitations: Several benefits are derived from the small hydro development, among which are provision of a basic tool for rural development, very low operation and maintenance costs, no fuel costs, kick-starting and support for cottage industries, access to remote and often neglected communities, competitive economic and supply advantage over other power systems, environmentally friendly and emission free power generation (Table 9), poverty alleviation, general upliftment of the social structure of the community, provision of rural employment, economic empowerment of the community, reduction of rural-urban migration and opportunity to tap substantial unutilized energy resources of the country.

Table 9: Comparison of environmental effects of power generating plants

Types of plant	Multipurpose	Emissions	Radioactive radiation	Social impact	Earthquake prone
Hydro	Yes	No	No	Yes	Yes
Small hydro	Yes	No	No	Yes	No
Fossil fuel	-	Yes	No	Less	µ
Nuclear	-	Yes	Yes	No	No
Solar	-	Yes	No	Yes	No

National energy plan vision 2010 small hydropower technology (March, 2004)

Despite its obvious benefits, the small hydro has its limitations. Power can usually be generated only during the rainy season when sufficient flow would be available. Even where, a reservoir is integrated as a component of the scheme, it is still unlikely that power is produced over an appreciable period of the dry season or drought. Small hydro plants are usually sited in remote, sometimes rugged and virtually inaccessible locations from where, it is difficult at times to bring the power to populated areas and load centers. Other SHP limitations include: long project development periods and high *in situ* investment costs; administrative bottlenecks relating to organization, awarding the contract and construction of projects involving complex coordination of tendering, construction and supervision; water right problems where water is diverted from areas with prior rights; the absence of technical standards, which leads to utilization of substandard equipment, resulting in low efficiency and poor system reliability; insufficient financial resources for necessary O and M for sustained operation of SHP, the bulk of which is produced for consumptive residential use; there are no real models for companies to finance and operate SHP on a private development basis; financial institutions may be reluctant to finance non-traditional (power) projects and land acquisition could lead to social and cultural controversies.

Market situation

Present demand and supply situation: From a projection of overall energy demand for the Country, electricity demand for households and industry, the principal consumers of the SHP are projected to grow at annual rates between 8 and 9% under the high growth scenario and between 3 and 5% for a low growth pattern. It is projected that the demand for SHP will grow at a faster pace and could reach an annual rate of 10%. Based on year 2000 Nigerian population of some 110 million and per capita power requirement of about 30 W, the 2000 year demand for the small hydropower is estimated to be 190 MW. Corresponding future demands, as set out in Fig. 1, are projected to reach approximately 490 MW in year 2010, 1280 MW in 2020 and 3315 MW by 2030.

Sufficient SHP potential exists to meet the national demand over the next 30 years. There is a need for government to be fully committed to developing these

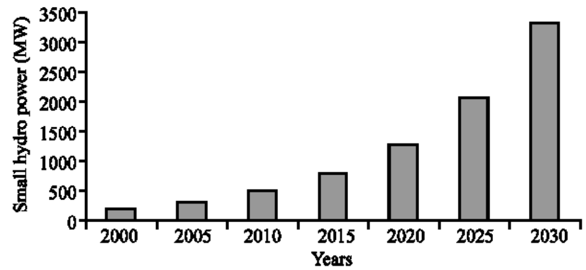

Fig. 1: Projected Nigerian small hydro power demand

sites. Overall national power requirements indicate substantial deficiency in supply relative to demand. In year 2000, for example, only 30 MW of the 190 MW demand was generated leaving a supply shortfall of 160 MW or some 84%. Without additional developments, the supply gap would increase further over time and could exceed 90% in the next 20 years. At the estimated demand of 3315 MW, the year 2030 requirement just about matches the estimated national potential of 3500 MW. It means therefore that full realization of the nation's small hydro potential will be achieved in 30 years if available sites are developed in line with the projected growth in national demand.

Key drivers for the SHP market: Population growth creates the demand and market for small hydropower development. Population pressure leads to demographic changes, which result in settlement over remote areas usually near sources of water. These settlers provide the demand and market for the SHP.

Such government sponsored programs as rural electrification, water resources development, cottage industries, rural enterprises, agriculture, poverty alleviation programs and health care services constitute important activities that can draw from the small hydro scheme.

Diversification of community trades and services would also provide ready markets. The high cost of fuel, O and M and related expenses associated with diesel based generator sets together with the unreliability of fuel supply promote a justification for the SHP option.

So, does the remoteness of the rural areas as well as the absence of national power grid. Improved community awareness through individual and general public education including interaction with other communities is also an important driver for the SHP market.

Gaps and barriers to small-hydro market development: As noted in Nigeria's Vision 2010 National Energy Plan, the following barriers face implementation and marketing of renewable energy, including small hydro:

implementation requires significant initial investment with generally low rate of return while, there is very limited level of consumer awareness on the benefits and opportunities of SHP development. The economic and social system of energy services is based on centralized development around conventional sources of energy, specifically electricity generation, thus, making a level playing field impossible. Financial, legal, regulatory and organizational barriers need to be overcome in order to implement the projects and develop new energy markets. There is an absence of a framework for power purchase agreement between owners of small hydro plants, the grid and other users. There has also been a lack of assessment of the market potential and the structure necessary to harness the SHP potential.

RECOMMENDATIONS AND CONCLUSION

Integration of renewable energy and systems: Different renewable energy technologies offer different services depending upon the availability of potential resources.

Therefore, there is need for adopting an integrated approach to overcome technical challenges related to fluctuations and intermittency of energy supply provided by different renewable energy systems.

Technology acquisition and development: Nigeria lacks manufacturing capacity for renewable energy technologies and so most of the technologies used in the country are imported. There is an urgent need to develop regional, sub regional and national strategies to develop requisite R and D capacity and skills for adaptation and strengthening of the manufacture base.

Human and regulatory development environment: The renewable energy markets in Nigeria are seriously constrained by lack of coherent policy and regulatory environment, which can create level playing field for renewable energy technologies. Therefore, the country needs to establish policy and regulatory environment that will facilitate the promotion of renewable energy technologies.

Financing options: New and additional mechanism of targeted investment need to be developed to finance both grid-connected and stand alone renewable energy projects.

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