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Small Hydropower Development in North-Central of Nigeria: An Assessment

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Abstract – *This paper focuses on small hydropower development in North-Central and electrification, which are given high priority in the government's efforts to increase the standard of living in rural areas, reduce rural-urban migration trends, and realize other development objectives. However, the three key challenges for rural electrification are: how to provide sustainable energy (electricity) services to the poorest of the poor, who have no purchasing power to pay for the services? How to offer the most cost-effective, clean and reliable electricity to those who are currently spending a significant share of their income on energy? How to set up commercial infrastructure to provide these services? In North-Central zone where rivers, waterfalls and streams with high potentials for small hydropower (SHP) development is abundant, where harnessing these hydro resources leads to decentralized use and local implementation and management, thereby making sustainable rural development possible through self-reliance and the use of local natural resources. This can be the most affordable and accessible option to provide off-grid electricity services. Based on zone's level of hydropower development, small hydropower station is defined as follows: Small = installed capacity between 2 MW and 10 MW; Mini ≤ 2 MW; and Micro ≤100 kW. In recent studies carried out in other zones and four (4) river basins, over 78 unexploited SHP sites with the total potential of 734.3 MW were identified. However, SHP potential sites exist in virtually all parts of the zone with an estimated capacity of 3,500 MW.*

Keywords: Hydropower, power, potential, renewable

1.0 INTRODUCTION

Nigeria is characterised with a large expanse of land with remote, isolated communities located at long intervals whose inhabitants are often peasant farmers living below subsistence level. These areas are marked by lack of basic infrastructures like road network, telecommunication, water supply, electricity and others.

Electricity in the zone is supplied through centralized generating station (hydro and thermal) with high capacities (above 100MW). The major operators in the Nigerian electric power station is the National Electric Power Authority (NEPA), now known as the Power Holdings Company of Nigeria (PHCN), was created in 1972 after the merging of the then Electricity Corporation of Nigeria (ECN) and the Niger Dams Authority by Decree NO. 24 of 27th June 1972. The supply is about 80% of the total electricity consumption in the country, with about 6,000MW installed capacity from three (3) large hydropower stations, Shiroro, Jebba and Kainji, with the other five (5) thermal power stations, hence its maximum suppressed demand is about 3,500MW. The demand for electricity is shared between residential, industrial and commercial/street lighting in the proportions of 50:30:20. 2 to 5% of the capacity of the national grid is contributed by private sector –IPP (NESCO, Shell, AES-Lagos, Bayelsa state

gas turbine and Ajaokuta Steel company). All these private producers sell power to PHCN for transmission and distribution to consumers, while the other balance of power demand in the country is been supplied by private generating sets [1].

About two-third of Nigeria lies in the watershed of the Niger River, which empties into the Atlantic at the Niger Delta, with its major tributaries; The Benue in the Northeast, the Kaduna in the North Central, the Sokoto in the Northwest, and the Anambra in the Southeast. The Niger is African's third longest river and fifth largest in terms of discharge. Several rivers of the watershed flow directly into the Atlantic, notably the Cross river in Southeastern Nigeria and the Ogun, Osun and Oyan in the Southwest [1-3].

Several rivers of Northeastern Nigeria, including the Komadugu Gana and its tributaries, flow into Lake Chad. The lake rests in the centre of a major drainage basin at the point where Nigeria, Niger, Chad and Cameroon meet. Kainji Lake was created in the late 1960s by the construction of the Kainji Dam on the Niger River in Nigeria. The Zne's topography ranges from lowlands along the coast and in the lower Niger valley to high plateau in the North and mountain along the eastern border. Most part of the zone is linked with productive rivers which are scattered virtually all over the zone. In North-Central, electricity is seen as an essential infrastructure in the same category as road, telecommunication and water. In fact, it is the lifeblood of the national development and industrial growth. Although electricity is treated as an essential social service slightly after over 100 years ago, the industry is still characterized by the erratic supply of inadequate coverage in terms of geographical spread covering less than 40% of the population and a record of low per capita consumption [4].

In North-Central of Nigeria, the economy became private sector-driven from the inception of the democratic dispensation in 1999. This paved way for the approval of a number of policy frameworks to improve energy supply infrastructure in order to cope with the fast growing population. Among these frameworks are the national energy policy, the passage of the electric power sector reform Act and the establishment of the Nigerian Electricity Regulatory Commission. Through these, complete government control of power generation and distribution was removed while the activities of all stakeholders and issuance of operating licenses to various parties in the power sector were better managed.

Hydropower was the type in use in North-Central before the discovery of crude oil. However, there was a shift in the attention towards fossil fuels due to the vast deposits in the country, hence leading to the decay of the hydropower sector. The result was that the existing hydro plants in the North-Central; Kainji, Jebba and Shiroro were neglected to the extent that they performed well below the expected capacity. For many centuries, water is a resource that has been exploited for various purposes. Hydropower is the leading source of renewable energy, providing more than 97% of all electricity generated by renewable sources and approximately 22% of the world's electricity production, most of which is small hydropower <10MW. Small hydropower represents the highest density resource and stands in the first place in electricity generation from renewable sources throughout the world among all the non-conventional renewable energy sources. It has no internationally agreed definition and its classification is based only on a country's level of hydropower development as shown in Table 1.

Table 1: Small hydropower definition and classification in some selected countries and organizations [5]

Country	Micro (kW)	Mini (kW)	Small (kW)
IN-SHP	<100	101–500	501–10,000
UNIDO	<100	101–2000	2001–10,000
ESHA	-	-	<15,000
China	<100	101–500	501–25,000
Philippines	-	51–500	<15,000
Sweden	-	-	101–15,000
USA	<500	501–2000	<15,000
Nigeria	≤500	501–1000	1001–10,000
United Kingdom	<1000	-	-
Zimbabwe	5–500	501–5000	-
Canada	-	<1000	1001–1500
France	<500	501–2000	-

The global installed capacity of small hydropower is around 47,000MW against an estimated potential of 180,000MW. China, on the other hand, has over half of the world's developed small hydro capacity in about 42,000 stations with an installed capacity of over 35,000MW. According to Solanke, about 19,000 micro- and 19,606 mini-hydropower plants with total installed capacities of 687 and 7171MW respectively were constructed between 1994 and 2004. Meanwhile, Nigeria has large SHP potentials considering her numerous rivers and dams which can be economically tapped for many applications in remote, off-grid communities and grid-based power generations [2].

2.0 SMALL HYDROPOWER IN NORTH-CENTRAL

Nigeria is ranked ninth in hydropower potential in Africa with technical hydropower energy at 32,450 GWh/yr as revealed in Table 1. She used 21.5% (6986 GWh/yr) of her potential for the year 2011. The situation in other African countries with respect to the exploitation of their respective hydropower potentials was similar.

Nigeria has a gross exploitable large hydro potential of 14,750MW, of which 14% amounting to 1930MW is harnessed, contributing approximately 30% of the total installed grid connected electricity generation [6-7].

It was also established through a 1980 survey of some states in the zone that small hydropower potentials of 734MW was available in 277 sites; however, a 2004 estimation indicated a total

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small hydropower capacity of 3,500MW, representing 23% of the nation's hydropower potential if the remaining states were surveyed [8].

The projected power demand for small hydropower as shown in Figure 1 reveals that the country needs 190, 490, 1280 and 3,315MW for 2000, 2010, 2020 and 2030 respectively and yet, only 30MW capacity is being harnessed, representing approximately 16% of the 2000 demand, indicating a wide disparity and deficiency in supply relative to demand. In view of this, small hydropower potential is underexploited in North-Central even though the potential exists to meet the projected 2030 demand if other sites are fully harnessed [11].

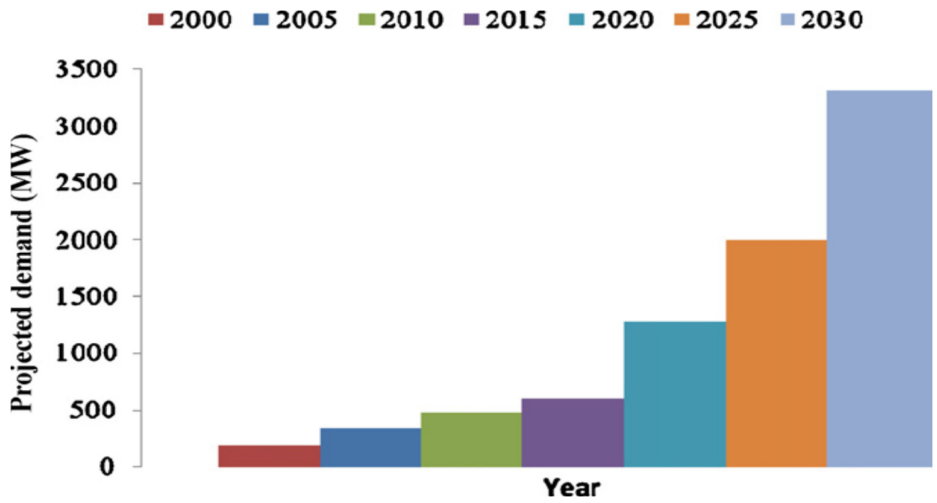

Figure 1: Projected demand of Small Hydropower in MW of North-Central [11]

In 1976, Nigeria was divided into 11 river basins (Figure 2) through the establishment of River Basins Development Authorities for the purpose of irrigation, water supply, navigation, hydroelectric power generations, fisheries and recreational facilities, and accomplished through the construction of small, medium and large dams to impound surface waters. North-Central has a good topography which ranges from lowlands along the coast and in the lower Niger valley to high plateaus and mountains in the Plateau, as well as along the Benue with elevation ranging from 600 m to 2,042 m. Most of the rivers and dams are favoured with good elevation for various small hydropower utilizations. The large hydropower plants comprising Kainji (760MW), Jebba (570MW) and Shiroro (600MW) were constructed on the Kainji and Shiroro rivers while Zungeru, a proposed project on the Kaduna river and currently under construction, has a capacity above 400MW. All of these rivers and dams have several adequate heads for small hydropower development.

The electric power sector reform Act provides the vertical and horizontal unbundling of electricity companies into separate and competitive entities, the development of a competitive electricity markets, setting out of a legal and regulatory framework for the sector, a framework for rural electrification, a framework for the enforcement of consumer rights and obligations, as well as the establishment of performance standards.

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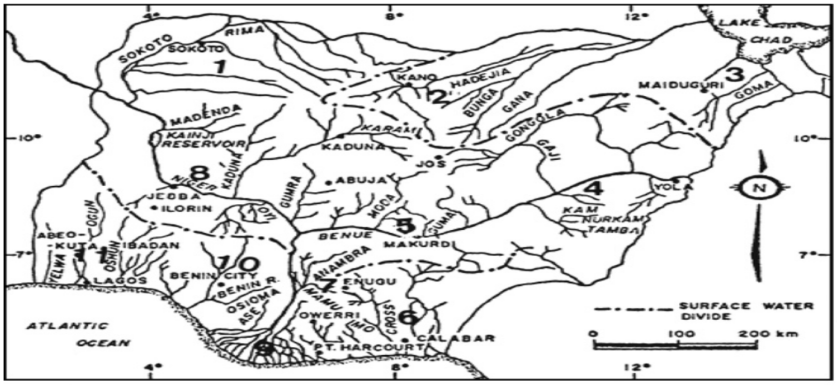

Figure 2: Map of Nigeria showing major rivers and hydrological basins [4].

Table 2: Small hydro scheme in existence in North-Central [4]

State	River	Installed capacity (MW
Plateau	Bagel	1
Plateau	Bagel II	2
Plateau	Ouree	2
Plateau	Kurra	8
Plateau	Lere	4
Plateau	Lere	4
Niger	Zungeru	10
Niger	Gurara	6
Kwara	Niger	13
Total		50

The reform broke the monopolistic framework in the power sector, thereby allowing: (a) private operators to apply for and obtain a license through the Nigerian electricity regulatory commission to build and operate a power plant with aggregate capacity above 1MW, and (b) the establishment of the rural electrification agency together with an independent rural electrification fund whose major objective is to fully incorporate renewable energy in the energy options. There is still little awareness of the benefits and opportunities of small hydropower as a power generation source if the quantity exploited with the existing potentials are compared, while at the same time a current and extensive hydrological database is not in existence for prospective investors. So far, private sector participation in renewable energy

implementation in the country is in the area of importation and marketing of components. With full private sector involvement in hydro generation, especially in the form of investment towards the maximum utilization of small hydropower potential as encouraged by national energy power policy and national energy policy, Nigeria's economically feasible hydropower potential is expected to exceed 29,800 GWh/yr, which is calculated before the enactment of national electric power policy.

3.0 SMALL HYDROPOWER - A SUSTAINABLE ENERGY TECHNOLOGY

Secure supply of energy is generally agreed to be necessary, but not sufficient requirement for the development within a society. Sustainable development within a society requires a supply of energy resources that, in the long term, is readily and sustainably available at reasonable cost and can be utilized for all required tasks without causing negative societal impacts [1]. Small hydropower projects are generally considered to be more environmentally favourable than both large hydro and fossil fuel powered plants because they do not involve serious deforestation, rehabilitation and submergence.

Table 3: Small hydro potential in surveyed states of North-Central [9].

State (Pre-1980)	River basin	Total sites	Total capacity (MW)
Niger	Niger	30	117.6
Kwara	Niger	12	38.8
Plateau	Lower Benue	32	110.4
Benue	Lower Benue	19	69.2
Kaduna	Niger	19	59.2

Small-scale hydropower is economically competitive with small-scale fossil fuel/steam-electrical plants particularly if the hydro sites are located near electricity demand centres and are truly sustainable in the sense of being able to fully account for their environmental and social costs. In North-Central, the emission factor for gas-based heat and electricity generation is 430 g CO2/kWh. Hence, an assumed operating time of 5,000 h/year of hydro plant will result in annual savings of about 8,300 tons CO2 emissions/year while an anticipated lifetime of 25 years will result in savings of approximately 218,000 tons CO2 emissions using the hydro plant. It is clear from the above facts that the adoption and development of small hydropower in North-Central will be a renewable source for sustainable development.

4.0 FINANCING SMALL HYDROPOWER

Previous researches have shown that one of the main obstacles to implement renewable energy projects in Africa is not the technical feasibility of the projects, but the absence of low-cost and long-term financing. This is further complicated by the competition for limited funds by the diverse projects which become critical if the country is operating under unfavourable macro-

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economic conditions [9]. Through the reform programme, competition in the power industry is promoted in a bid to meet the growing electricity demand. However, since fossil fuels have not been able to resolve the persistent energy challenge of the country, despite the abundance, the need for electricity generation through renewable energy sources has been constantly expressed. This explains why zone plans to add a cumulative 735MW renewable electricity generating capacity within a 10 year targets of 2007-2016 to the grid, together with the following energy contributions to the economy: (a) 5% contribution to the total electricity generation, excluding large hydropower, (b) 5 TWh of energy, (c) 2 million new connections to the grid, (d) 1 million solar home systems, (e) 2,000 rural school electrification, (f) 2,000 rural solar clinic electrification, (g) 10,000 solar street lights, (h) 100 billion Naira renewable electricity industry and (i) 1.2MT CO2 emission reduction [13].

A special fund called the renewable electricity trust fund has been established by the government to accelerate the expansion of renewable electricity in North-Central. The renewable electricity trust fund which shall be managed under the rural electricity fund according to the 2005 electric power sector reform Act shall be to promote, support and provide renewable electricity through private and public sector participation [12]. As electricity generation via renewable sources is becoming popular in the zone, special funding seems inevitable. The zone will also benefit from a number of international grants for renewable energy projects. An examination of the initial capital cost of some renewable energy sources shows that small hydropower is the cheapest choice of the renewable sources in zone [16[. The low cost further supports small hydropower investments in North-Central in Nigeria by individual, indigenous private and foreign organizations [17].

6.0 OPPORTUNITIES

6.1 Industrial and Economic Development

There is a historical positive relationship in the zone between power availability and industrial and economic development, which shows the decline or stagnation of the manufacturing sector in North-Central after the late 1990s. A faster pace of industrial development is expected when IPP begin producing and supplying additional cheap power. Normally, 40% of the power generated goes to industrial development. In rural areas, agro-based SME is most likely to develop. Nearly 200,000 employees get direct employment and the same number gets indirect employment. Similarly, converting the SHP sites for tourism development and fish farming can create employment opportunity [15].

6.2 Clean Power Development

This zone will suffer if its sustainable hydropower potential is not tapped, since hydropower is its only easily harnessed indigenous power source. It is also one of the very few competitive advantages for the zone, since land, labour and other inputs to industrial development are costlier in the zone compared to other zones. The development of SHP projects reduces the usage of diesel and kerosene for generating electricity in the off-grid area for the high-income group. This will also reduce the transportation cost for transporting fuel from cities to the rural areas. Another aspect to be noted is the destruction of trees from the forest area for lighting and cooking. Moreover, SHP projects can be developed as a multipurpose project; the same can be used for flood control, drinking water purpose, irrigation, fish farming, and for tourism development.

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6.3 Improved Availability and Quality of the Power Supply

Reliable and adequate electric power will reduce the costs and losses currently suffered from inadequate power, and increase productivity, effectiveness and the quality of output, reduce hardships, inconveniences and disrupted services due to power interruptions, and reduce the expenditures made by businesses and households to compensate for inadequate power. Since the zone is facing power shortage during the peak hours, this additional capacity will help in improving the voltage in the distribution network.

6.4 Economic Growth and Employment

Poverty is clearly related to unemployment. The lack of electricity is an important constraint that works against employment, generating economic growth and contributes to the under-utilization of human and natural resources, resulting in widespread unemployment and poverty. Although the poor generally do not qualify for new jobs in the industrial and manufacturing sectors, they can benefit from the multiplier effects of economic growth, such as new construction and increased expenditure in the informal sector. These types of unskilled jobs, however, tend to be low-paid, temporary and/or insecure. This has been demonstrated from experience, where income from the Gulf countries facilitated the increase of wage rates, not only in the construction sector, but also in agriculture, because of linkages in the labour market [17]. The availability of power would also enhance public services and infrastructure facilities such as communications, which are necessary for the growth of industries and activities in the service sector.

6.5 Accessibility

Forty-five percent of total households in Nigeria do not have access to electricity. Availability of electricity is critical for household work. Sufficient power throughout the day and evening will allow women to complete their domestic tasks more easily, quickly and effectively, and involve in other income generating additional activities, with benefits for all the family. If we are adding 732.0 MW from SHP, a major portion nearly 37 MW will go to domestic consumers, thereby providing electricity for additional 3,700 new consumers.

6.6 Benefits for Women

Human development of the populace depends not only on economic growth, but also on the quality of life in homes. Women have the major responsibility for maintaining and enhancing the well-being of their families and their quality of life. Policies and services support their productivity, health and creativity, benefit and support the entire family. Women, children and the aged are positively affected more than men by the availability of electricity because more of their time and their work are carried out in the homes.

7.0 CHALLENGES IN HYDROPOWER DEVELOPMENT IN NIGERIA

7.1 Huge Financial Investment

Very expensive equipment or overhead cost in undertaking hydropower scheme especially on dam construction penstock, turbine and generator amongst others and in line with economic level in the country and any other developing countries in world this is really serving as a great challenge in the development of hydropower stations.

7.2Poor Revenue Collection

Based on the fact majority of North-Central of Nigerians are in the rural areas, which account about 70% of the zone's population, and also in view with electricity in Nigeria is regarded as essential commodities like road and water, it is always hard to get people paying their tariff regularly also to couple with the interrupted nature of power supply in the zone, which results to poor revenue collection.

7.3 Significant Environment Damage

Major problems in this case are desertification, deforestation, erosion, massive water impoundment and poaching, and settlements within the potential areas really contribute to a very significant environmental damage in the zone.

8.0 CONCLUSION

Small hydropower is considered a viable solution to the power challenges of the North-Central (Zone) especially in the rural areas of the zone and to the restrictions posed by the rising cost of conventional or traditional energy. In this paper, the role of small hydropower in meeting the electricity challenges is discussed. Also, consideration has been given to the factors affecting developments in the small hydropower sector, and efforts have been made to ensure capacity building for renewable energy, stimulation of the private sector, developing the markets for small hydropower, obtaining the necessary finance for small hydropower projects and the assistance of multilateral institutions in advancing small hydropower in the zone.

REFERENCES

[1] O. Adeoti, B. Oyewole, T. Adegboyega, Solar photovoltaic-based home electrification system for rural development in Nigeria: domestic load assessment, Renewable Energy 24 (20011) 155-161.

[2] National Climatic Data Center. Global historical climatology network (PHCN),Version [online], (updated 12 Sep 2012), Available from, http://www.worldclimate.com/; 1990.

[3] J.A. Duffie, W.A. Beckman, Solar Engineering of Thermal Process. New York: Wiley Interscience, (1980)

[4] A.A. Solanke, Research and Development in Renewable Energy: Usage and Conversion Technologies. A paper presented at the public lecture organized by the Nigerian Society of Engineers Minna Branch. 2008.

[5] ESAP, Energizing rural Nigeria-Energy Sector Assistance Programme: A Decade of Experience in Delivering Clean, Sustainable and Renewable Energy Solutions. Alternative Energy Promotion Centre, Abuja, Nigeria (2013).

[6] N.R. Karki, D.K. Jha, A.K. Verma, Rural energy security utilizing renewable energy sources: challenges and opportunities. In: Proceedings of the IEEE Region 10 Annual International Conference, Proceedings/TENCON, 551-556 (2010).

[7] C.T. Gaunt, Meeting electrification's social objectives in South Africa, and implications for developing countries, Energy Policy 33 (2005) 1309-1317.

[8] M.M. Muhammadu, Design, Fabrication and Performance Evaluation of Solar water Pump, Master of Engineering thesis, Department of Mechanical Engineering, Federal University of Technology, Minna, Nigeria (2008).

[9] A.B. Hassan, M.M. Muhammadu, Design, Construction and Performance Evaluation of Solar Water Pump, IOSR Journal of Engineering 2 (2012) 711-718

[10] A. Nasir, M.M. Muhammadu, Renewable energy technology: a technology for helping to actualize the vision 20:2020, Proceeding of 22nd AGM and International Conference of the NIMechE, Osun 2009.

[11] O. Iloeje, Renewable energy development in Nigeria: status & prospects. In: Proceedings of a national workshop on energizing rural transformation in Nigeria: Scaling up electricity access and renewable energy (2002).

[12] International Energy Agency (IEA). Measuring progress towards energy for all: power to the people? In: World energy outlook. Paris, France: Organization for Economic Co-operation and Development 2012.

[13] F.D. Bamidele, Clean energy investment in Nigeria – the domestic concept. International Institute for Sustainable Development (IISD) 2008.

[14] J.O. Makoju, Small Hydro Power Construction: Techno-Economic Analysis, ECN/UNIDO Trainers Workshop on SHP Planning and Development, Owerri 2012.

[15] A.A. Esan, Hydroelectric Power in Nigeria, the Nigerian Engineer, 16 (2001).

[16] Senate Committee on Power and Steel, Brief on Tour of NEPA Installations (2010).

[17] A.A. Esan, Preparedness on Development Green Energy for Rural Income Generation-Nigeria's Country Paper UNIDO, INSHP/IC SHP, Hangzhou, China June 19-23, (2013).