Nigeria’s Hydroelectric Resources

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Introduction

Hydroelectricity is a renewable energy resource. It is a mature technology used all over the world. In addition to low cost electricity supply, it provides energy storage as well as ancillary services such as grid balancing, which contributes to a more efficient management of the electricity supply system. Since 1969, hydroelectricity has been an integral part of the power generation mix in Nigeria, due to the abundance of precipitation, rivers and mountains.

According to the *Hydropower & Dams World Atlas and Industry Guide*\(^1\), Nigeria has a gross theoretical hydropower potential of 42,750 GWh/year and a technically feasible potential of 32,450 GWh/year both evaluated in 1975 and 1980. The economically feasible potential, evaluated in 1980, is 28,800 GWh/year according to the guide. So far, Nigeria has developed 26 per cent of the technically feasible potential. As at 2015, 2040 MW of hydro capacity was in operation in the country.

Based on figures released by the Transmission Company of Nigeria\(^2\), hydro production in 2014 was about 5,345 GWh, of a total of 30,126GWh. That represented about 18 per cent of the total. The percentage of generation contributed by hydropower declined considerably due to the increased generation from recent thermal capacity additions especially the NIPP plants.

Hydropower Development in Nigeria: the Beginning

The development of large hydroelectric power generation in Nigeria, started in the early 1960s after hydrological surveys commissioned to study the energy potential of Nigeria’s river system, by the Federal and the Northern Regional governments, acting separately in the preceding decade. The initial surveys took place in the Niger River and its tributary, the Kaduna River. This is because the Niger and its tributaries drain more than 50% of the country.

The surveys led to the establishment of the Niger Dams Authority, NDA, to develop the Kainji Dam and to run the power station as well as to oversee all future development of hydropower in the country. According to the initial plans, Kainji was associated with a national grid. The Authority planned it to be sufficient until 1980 when other dams, namely Jebba on the Niger and Shiroro on the Kaduna rivers would complement it. Jebba was to come in ten years later and Shiroro after that, to bring total hydro capacity to 1730 MW.

By 1990, hydropower capacity in Nigeria was about 1900 MW. The NDA Commissioned Kainji in 1969 with an initial installed capacity of four 80-MW Kaplan sets. Later, it installed four more sets and by 1978, the installed capacity was 760 MW. NEPA planned new plants at Jebba and Shiroro. However, political and economic circumstances delayed them and they could not come
on stream in quick succession to meet fast growing demand, as NEPA had planned. The 540 MW Jebba scheme came on line in 1985. NEPA commissioned Shiroro 600 MW scheme, in 1989.

With the 1972 merger of the Electricity Corporation of Nigeria, ECN, and the Niger Dams Authority, NDA, to form the National Electric Power Authority, NEPA, development of Nigeria’s hydro resources became the responsibility of the NEPA. The decade witnessed generation capacity stagnation, though NEPA had perceived in 1975 that demand was growing at about 20.5% per year.

In a 10-year development plan in 1979 to cover a decade up to 1990, NEPA’s hydro capacity increases were as follows:

- Lokoja 1950 MW
- Shiroro 600 MW
- Makurdi 600 MW
- Jebba 545 MW
- Ikom 400 MW

However, Nigeria’s hydropower development was slow. Between 1979 and 1983, the FGN disclosed that the Lokoja hydro station would not cost less than ₦2000 million. That apart, thousands of people on the banks of the Niger and Benue would be displaced by the project. People on the Benue would feel the effects as far as Makurdi and along the Niger as far as Rabba. Eight Local Governments in Niger, Kwara, Benue and Plateau States would bear the brunt. Despite the hydropower potential, the environmental impact was severe and the FGN suspended the project. In my opinion FGN action lacked courage. Perhaps, they might have acted differently if they understood two facts. First, the country’s energy resource is finite. Secondly, the future of the country’s economic hopes and aspirations depended on energy. Therefore, Nigeria’s politicians might have been more courageous. With hindsight, if they acted differently then, Nigeria would have paid off the debt in her boom years.

NEPA revised its planned capacity additions in 1986:

- Makurdi 1062 MW
- Mambilla 1800 MW
- Zungeru 950 MW
- Lokoja 1870 MW
- Ikom 400 MW
- Gurara 300 MW

In the 1979 NEPA hydropower development plan, Shiroro and Jebba survived. However, since Jebba 1985 and Shiroro 1989, little has happened. The return to democratic rule in 1999
provided a fresh impetus. The FGN now has the issue on the front burner. Of the planned capacities listed above, the FGN is considering Zungeru, downstream of Shiroro on the Kaduna River in Niger State, and Mambilla on the Donga River in Taraba State.

**Latest Developments**

In the short term, the FGN has two critical hydropower projects at Zungeru in Niger State and Mambilla Plateau in Taraba State started, albeit with mixed fortunes. Consultants have significantly revised the installed capacities of both projects. They scaled down Zungeru to 700 MW and scaled up Mambilla to 3050 MW. The other significant project, the 360-MW Gurara Hydropower project on the Gurara River, is under consideration.

In the case of the Zungeru project, the FGN commissioned the French consulting firm Coyne et Bellier, to review the original feasibility studies and the engineering design prepared by Chas T. Main International Inc. of Boston, Massachusetts, USA. Coyne et Bellier, finally recommended an installed capacity of 700 MW compared with the previous capacity of 950 MW. The FGN has since awarded an EPC contract to the Chinese consortium Sinohydro - China National Electric Engineering Co. Ltd (CNEEC), to build a power plant on the Kaduna River, 77 km downstream of Shiroro.

Work on the project started in May 2013. Rated 700 MW, it will comprise 4 x 175-MW Francis turbine generator units. The plant is expected to generate an average energy in excess of 2698 GWh/year. In July 2015, CNEEC awarded a contract to Alstom Hydro China, to supply the electro-mechanical equipment and technical services.

Unlike the Zungeru project, the Mambilla Hydroelectric Project on the Donga River in Taraba State has slowed. After 2005, the FGN only awarded a contract for the design, project management and construction supervision, to a joint venture of the consultancy companies Tractebel Engineering of France and the Nigerian consulting firms of De Crown West Africa and Water & Dam Services Company, in March 2011. Diyam and Binnie & Partners had prepared the feasibility study in 1985. They recommended an installed capacity of 2600 MW. Lahmeyer and Dam Tech reviewed that study in 2006 to produce a feasible study. That latter study by Tractebel and others recommended increase in installed capacity to 3050 MW. The average generation is expected to be 5400 GWh/year. The proposed power cavern will accommodate 12 x 254 MW vertical shaft units driven by Pelton turbines.

It is speculated that the FGN has a funding mechanism for the project in place and that an EPC contract will soon be awarded.

The concept of the 360 MW Gurara Hydropower Project has changed slightly—now identified as a multipurpose project for the complete development of the Gurara River Basin, the project, is now referred to as Gurara II (to distinguish it from the smaller project by the same name upstream). It is located 145 km downstream of Gurara I dam (see the section on small hydro). Upstream of the Gurara Falls in Niger State, it is at the stage of EPC tender documentation. With a reservoir volume of 400 Mm³, it can supply an average annual energy of 1,130 GWh/year with a 360 MW power plant (plant factor 0.35). The project will take advantage of the natural fall of
the river in the area and will allow irrigation of an area up to 10,000 ha downstream of the Gurara Falls via gravity.

All the three projects incorporate a powerhouse design concept that, though well established elsewhere, is something of a novelty in this country. They will each have underground powerhouse. Of course, this adds some complication to project execution, but the positive spin-off is the higher level of security it guarantees for the infrastructure.

**Small Hydropower**

There is yet no clear-cut definition of what constitutes small hydro, but consultants, developers and governments seem to agree that it varies enormously. It ranges from a few hundred kilowatts up to 30 megawatts\(^6\). However, they agree with the great potential of small hydro as suitable for generating power for rural communities and isolated properties. In its simplest form, it involves the exploitation of a river’s hydro potential, without significant damming and its negative effects that can arise. That is a potential that has not been harnessed in Nigeria.

The best example of the impact of the power of small hydro is the privately-owned British company, Nigerian Electricity Supply Company, NESCO. Established in 1922 in the Jos Plateau, the company built a couple of small hydro stations. One of them is the Kurra Falls Power Station. It consists of three hydraulically coupled plants with a total installed capacity of 18.4 MW. The plant was to supply the tin mines.

That installation was the first hydroelectric power station in Nigeria. NESCO built it to supply the mines, over an area of 1554 square kilometres. It served ECN and its successors for power supply to Bukuru 1936, Jos 1937, and Vom 1944.

The peak load was 12 MW with an annual load factor of 60%. The total capacity of the NESCO plants in operation currently (2015) is 26 MW. NESCO supplies 43.8 GWh/year to Jos Electricity Distribution Company. For any private investor intent on capturing the Nigerian electricity market, this pioneering example clearly demonstrates what great potential success is possible for small hydro projects.

Governments have lately appreciated the benefits of small hydro and there is renewed activity at various sites of our multi-purpose dams that were built primarily for irrigation and water supply. The activities relate to harnessing the hydropower potentials of those dams.

In 2001\(^7\), the Kano State Government commissioned the installation of a 2 x 3.5 MW plant at the Challawa Gorge Dam and a plant of the same capacity for the Tiga Dam. The government expects 30 GWh/year and 35 GWh/year, respectively, to be generated, and supplied in bulk, to the national grid. However, there is divided opinion on that issue. Where does the optimal benefit lie – direct interconnection to the grid or as embedded generation, considering the size of the plants? Should direct connection to the grid, be affirmed, a tripartite agreement would be necessary for any power purchase agreement (PPA) as the ownership of the Challawa Gorge Dam, has since been transferred to the Hadejia-Jama’are River Basin Development Authority (HJRBDAB).
There is news that on the same project, the Kano State Government signed an agreement in 2013 with India’s Skipper Group. They are to redevelop the project at the two sites. Up-rated to a total generating capacity of 35 MW, there is no information to suggest when or whether the initial feasibility study of the energy potential at the sites has been revised to account for the proposed increase in installed capacity. However, U. O. Aliyu$^8$ has estimated that 149 MW generating capacity, can be exploited from the Hadejia-Jama’are River Basin.

The Dadin Kowa Dam in Gombe State in the Upper Benue River Basin Development Authority (UBRBDA) is another site. There the necessary civil engineering infrastructure to accommodate generating equipment, has been provided. This dam on the Gongola River, irrigates 35,000 hectares and impounds sufficient water for the generation of 146 GWh/year. All works for the hydroelectric component of the project stopped at the site after 1983. The powerhouse building has been exposed to the elements over the years. It has suffered significant damage due to flooding.

In 2004, hydropower equipment manufacturer VA TECH HYDRO of Austria carried out an assessment of the requirements for powering the dam and suggested that the original planned capacity should increase from 30 MW to 40 MW. Resumed in 2005, the FGN awarded Mabon Energy Limited the concession to complete and operate the plant on a build-operate-transfer basis, for 25 years. Reports indicate that work has reached about 70 percent completion stage and the 2 x 20-MW generating units will be ready for commissioning in the first quarter of 2016.

Small hydropower development is receiving some attention. Gurara and Kashimbilla are successful small hydro projects. Gurara is a collaborative effort between the Federal Ministry of Water Resources and the Federal Ministry of Power. Located on the Gurara River, the FGN had conceived it as a multipurpose dam for water transfer to the Lower Usama Dam to boost potable water supply to the Federal Capital territory. The FGN also wanted to develop 20,000 hectares of irrigable land downstream, as well as the 30 MW power plant. Work on the plant is completed; it consists of 3 x 10 MW turbine-generator units to generate 115 GWh/year. An 80-km 132-kV power evacuation line to Kaduna has been completed, but generation is being delayed until the completion of the associated substation at Kudenda.

Kashimbilla multipurpose dam is located between the towns of Kashimbilla and Gamovo on River Katsina-Ala, in Takum Local Government Area of Taraba State. Conceived as a buffer dam, it will check the threat of flood from the structurally weak volcanic Lake Nyos, upstream on the Bamenda Plateau in the Cameroon.

The hydropower plant has an installed capacity of 40 MW comprising 4 x 10 MW turbine-generator units. They are equipped with Kaplan type turbines. Power evacuation will be by means of a 65-km double circuit 132-kV line to Takum. The transmission line will extend to Wukari via a 75-km double circuit 132-kV line and thence to Yandev via a 105-km double circuit 132-kV line for interconnection to the national grid. The project is due for completion in the last quarter of 2015$^9$. 
For a small hydropower project, the project incorporates one of the most elaborate power evacuation components. The project developers might have attached greater attention to reliability by proposing this mode of connection, which in itself, is commendable for its maximum impact. Projects of this size would give greater benefit to the local environment if despatched as embedded generation in the local 33-kV network.

**Choice of Technology**

The choice of an appropriate hydropower technology is site-specific. Hydroelectric plants fall under three general classifications based on construction: run-of-the-river hydro, storage (or pondage) hydro and pumped storage hydro. Nigeria’s hydro plants fall almost exclusively under the storage hydro classification.

The type of turbine used in a hydroelectric plant depends primarily on the design head for the plant. By far the largest number of hydroelectric projects uses reaction-type turbines. Only two types of reaction turbines are now in common use. For medium heads (that is, in the range from 20 to 300 metres), the Francis turbine is used exclusively. Shiroro Power Station with a design head of 97 metres falls into this category. For the low-head plants (that is, for design heads in the range of 3 to 20 metres), the propeller turbine is used. The more modern propeller turbines have adjustable pitch blading (called Kaplan turbines) to improve the operating efficiency over a wide range of plant head. The plant at Kainji Power Station comprises both Kaplan and the fixed propeller turbines. Typical turbine performance results in an efficiency at full gate loading of between 85 to 90%. The Francis turbine and the adjustable propeller turbine may operate at 65 to 125% of rated net head as compared to 90 to 110% for the fixed propeller. Shiroro Power Station maintains an operating policy at 93 to 113% of rated head.

High-head plants (typically over 300 metres) use impulse or Pelton turbines. In such turbines, the water is directed into spoon-shaped buckets on the wheel by means of one or more water jets located around the outside of the wheel. As we have already noted, the proposed Mambilla hydroelectric project, which will operate under a net head of 927 metres, will be equipped with Pelton turbines.

Once a choice of hydropower technology is made, it can be used with advantage to adapt to the service requirements expected from the plant. Where the main requirement especially for plants with a relatively higher capacity factor is to operate for much of the period in a year to serve a base load, the Francis turbine offers the advantage. If on the other hand the plant is to be deployed for “peak lopping” duty most of the time, the Kaplan turbine, will be the obvious choice.

However, apart from the basic functions of producing and delivering electric energy and power to customers, generating companies are required to pay equal attention to the issue of security and reliability of supply. In order to satisfy this requirement, generators nowadays, have to fulfil both the commercial obligations in the Power Purchase Agreements, PPAs, as well as the technical requirements that are prerequisites for connection to the grid, as set out in the Grid Code. These are ancillary services. They enable the System Operator to keep the system’s supply and demand in balance by keeping the voltage and the frequency at the right level and preventing
system collapse as well as restarting the system after collapse. In order to cope with this onerous duty, selecting the right turbine and generator is a priority. That gives stable operation over the full range of plant head and loading condition.

The above considerations informed the philosophy of the selection of the turbines at Kainji Dam. The initial installation of 4 x 80 MW units was equipped with Kaplan turbines which in addition to supplying the national demand at the time, also had the flexibility to control frequency and thus provide the required ancillary services. Conversely, the 2 x 100 MW and 2 x 120 MW units installed in the subsequent phases of the project, were equipped with the fixed propeller type turbine which provided the station with the much needed capability to supply the system base load, for most of the time.

At Shiroro, the generator can operate as a synchronous condenser to provide the system with increased voltage support, by generating or absorbing reactive power. Considering the position Shiroro occupies in the network, this utility is of great value especially during the dry season period in the year, when energy production is reduced from the plant, with severe consequences to voltage profile in the northern part of the country. Together with its black-start capability, that forms the nucleus of the ancillary services the plant renders to the national grid.

For small hydropower schemes, especially below 30 MW, there are wide varieties of options for turbine arrangement. The costs, operating efficiency, maintenance and flexibility differences are large and need careful consideration.
Environmental Issues

Ensuring appropriate environment is part of what every hydroelectric energy project considers. The greatest concern expressed by communities is about flooding from operations and management of hydroelectric reservoirs. Another issue albeit not to the same degree in Nigeria, is the need to provide fish with a way of accessing spawning grounds upstream of the dam. Many new schemes elsewhere, provide fish ladders at project sites. It will surprise no one if people raise voices here, for provision of fish ladders and the incorporation of fish-friendly turbine designs, in our future hydro developments.

It would appear that no matter how much we point out the social and economic benefits of dams - electric power, irrigation/water supplies and flood control - dams remain controversial. Many believe that adverse impacts, such as the burden of foreign debt, forced displacement of people, perceived irreparable damage to the environment and inequitable sharing of costs and benefits of the facility are often greater than the benefits. This is easily the greatest challenge facing hydroelectric plants and their future.

There is now a legal framework for environmental impact assessment and management, which is a policy of the Federal Ministry of Environment. That policy is in accordance with the World
Bank’s new policy on water resources management, with special reference to Environmental Impact Assessment, EIA.

FGN has now sought to address through legislation, the environmental concerns due to the operation of our dams and reservoirs. It ratified the Hydro Power Producing Areas Development Commission, HYPPADEC, Act in 2010. HYPPADEC is responsible for curbing of ecological problems facing communities brought on by construction and other activities related to hydroelectric power projects, among other things. HYPPADEC is also to establish a governing council for management, advisory and monitoring committees. The headquarters is to be at Minna, the Niger State capital.

One does not know the details of scope of HYPPADEC’s activity, but one hopes that it will encompass a comprehensive ‘Environmental Management Plan’. That would ensure maximum benefits from its intervention projects. Communication that will make all information available for public participation is important. It will be easier then, to find solutions that are acceptable to the human populations affected by the dams. As elsewhere in the world, the plan must include epidemiology as well as public health management and sanitation, which will cater for the concerns of communities near the dams and provide them with primary health care.

The FGN has applied that sort of intervention. That was right at the beginning of the Kainji hydroelectric project. The FGN sought to address the environmental concerns that arose from the building of the dam. It established the Kainji Lake Research Project in 1968. That metamorphosed into the Kainji Lake Research Institute and its objective was to carry out a comprehensive development of the manmade lake resource, through research and surveys. The functions of the Institute were executed through the agency of the Food and Agriculture Organisation of the United Nations until 1975. Now, it has the responsibility to conduct research specifically, into:

a) the limnology, behaviour and characteristics of the Kainji and other manmade lakes as well as their effects on the fish and other aquatic life;

b) the abundance, distribution and biological characteristics of species of fish and practical methods of their rational exploitation, in the said lakes and major rivers in Nigeria;

c) the behaviour and characteristics of wildlife and their conservation as well as range ecology in the Kainji Lake area;

d) the public health problems arising from the construction of the dams and the resettlement of people around them;

e) the development of irrigated crops around the lakes;

f) the socio-economic effects of the construction of the lakes on their neighbouring rural populations, and

g) any other related matter.

In terms of both resettlement for the host community and solution to the environmental impact problem, Kainji has been a huge success and should serve as a useful model to HYPPADEC.
Hydropower Development and the Power Sector Reform

With the implementation of the power sector reform programme, which lead to the privatisation of the generation and distribution assets of the defunct NEPA in November 2013, people ask about the fate of hydropower development in the country, considering that it is capital-intensive.

It is appropriate to say here that in carrying out the recent privatisation exercise the model the FGN used for divesting the hydro plants is different to the wholesale privatisation model adopted for the thermal plants. The nation’s three hydro plants were given out on concession for a specified period, with the FGN retaining ownership of the facilities. The North South Power Company was granted the concession to operate the Shiroro Power Station, while Mainstream Energy Solutions was granted the concession to operate both Kainji and Jebba Power Stations, which are situated on the River Niger.

There is understandable pessimism that hydropower development in the country would be stifled if government should completely cut-off financing new projects. Hydro projects require huge capital outlays and long lead-in times before realisation. However, percipient governments know the role of cheap electric power in a country's economy. It understands the long-term and multiple benefits of hydroelectric plants and recognise them, as the optimum economic choice among alternatives.

Brian Sadden\(^\text{12}\) in an article on hydropower development in southern and southeastern Asia, analysed some of the pressures militating against the development of hydro plants. “One of the difficulties with attracting private investment and finance to hydro projects,” he says, “is the need for a higher return on equity than was traditionally sought by utilities and multilateral agencies. This had led to a system where debt leveraging is essential. The large size of power sector investments and the shorter-term outlook of private investors also affect the nature of the projects that might be undertaken in the private sector.”

In order to attract finance, Sadden outlined some of the controlling factors in the development of power generation, and particularly of hydro. They are:

- **Scale of the capital investment**
- **Possibility for an attractive return on equity and minimum feasible debt service characteristics**
- **Security of project revenue during debt service**
- **Management of the major project risk factors.**

According to Sadden, the “bankable” projects or those considered desirable by private investment are as follows:

- **High head, so that minimal amounts of water are needed, and Pelton wheels (i.e., simple and easily maintained equipment) can be used** (High head also tends to require less reservoir area, which can reduce environmental impacts and approvals procedures.)
- **Run of river, so that diversion structures are small and storage is minimized, again keeping costs low and reducing the environmental impacts associated with large reservoirs**
- Surface-based configuration to minimize the construction and geological risks associated with underground power house caverns;
- Compact, so that the smallest stretch of river is affected;
- Appropriate size to minimize exposure to potential future slowdown in the regional electricity demand;
- Short development cycle and debt repayment.

Project developers often use the levelised cost of electricity (LCOE) as a means for directly comparing the lifetime cost of electricity of different projects to decide on investment priorities. According to the latest report released by the World Energy Council\textsuperscript{13},

\textit{While all hydropower projects have the same financial profile of high capital cost, low operation and maintenance cost, no fuel cost and typically steady sustained revenues, the scale of the project plays a major role in the LCOE. Small-scale hydropower (installed capacity of less than 10 MW) may cost between $2000-4000/MW, while a larger scheme of 300 MW and greater is likely to cost significantly less at approximately $2000/MW, which considerably enhances the return to the investor. It is important to note that hydropower's revenue stream is steady only when long-term power purchase agreements (PPA) or feed-in tariffs exist. There is a substantial price risk in liberalised power markets, when no such mechanisms are in place, although this is the case for all energy technologies and is not specific to hydropower. In such cases, hydropower operators will make generation decisions on the basis of shorter-term electricity prices, which can in many cases, bring higher returns relative to long-term PPAs. However, spot markets also bring an element of risk to the hydropower operator, which must be considered.}

In a purely deregulated market, the foregoing considerations would be the sole determinant of our hydropower development strategy. However, given government's admission of about 40% access to electricity and per capita usage of about 188 kWh (based on an estimated population of 160 million by 2014), figures very low by world standards, this strategy cannot be the basis for bridging the existing power generation-demand gap, let alone building a strong self-reliant economy. If Nigeria must build the generating capacity that can power her industrialisation, she needs a disciplined and phased programme that develops her durable base-load plants and load-looping plants calculated and located to support them.

Power supply economics was something of a conundrum, which experts battled hard to solve. Thanks to them, a service that is costly to produce and must be made affordable to its customers, is affordable in Nigeria, but is it? It is to meet the objectives of availability to all that institutions such as the Nigerian Electricity Regulatory Commission (NERC) was set up. Design of electricity tariff is both science and an art. Does NERC understand that? We have to recognise that Nigeria's electricity market is still evolving. It is struggling to raise even the baseline revenues to support its operations. Some of the key ingredients that will make it work are either missing or are ineffective. The bulk trader does not appear to be sufficiently capitalised to intervene to balance the electricity market. The PPAs are extortionate and NERC itself appears to lack the ability to assert the authority of the Commission. Above all, the issue of the massive
capital injection required to build up capacity to the level of market and operational stability that can sustain the industry is still left in the air.

What is the way forward? The answer to this can only be some form of hybrid solution relevant to our specific situation. It can be Government alone, or Government/Private Sector or Government/PPP or any combination of these or indeed some other initiative provided the desired objective will be achieved. Perhaps it is because government appreciates the difficulties that it decided among other reasons to adopt the concession model in the privatisation of the hydro plants, which will allow it to continue to fully support and finance hydropower development.

Under the current deregulated environment, a sustainable generation portfolio for Nigeria could be conceived as being grouped into essential and attractive to private investment on the one hand and essential but unattractive to private investment on the other. Hydropower development falls into the latter category. As is generally known, hydro though cheaper to run (has zero fuel cost) is capital-intensive to construct. Typically, the plant cost of conventional hydro (i.e., storage hydro) is 1700 $/kW compared to 350 $/kW and 600 $/kW for simple cycle and combined cycle gas turbine plants respectively (all based on 1990 dollar). Its construction lead-in time is also longer.

Recently, the FGN made two affirmations. First, it is committed to uphold the power sector reform programme, of the last administration. Secondly, it pledges to further strengthen and make it work. These will boost investor confidence and empower the private sector to play an effective role in building the economy. However, the FGN should balance deregulation with national needs especially in key sectors such as power generation. It should create the enabling environment, for the private sector to concentrate on developing fast-track gas turbine and combined cycle thermal plants. These fall into the other category of generation portfolio defined earlier. The FGN, either by itself or by means of some suitable financing mechanism, should continue to play a leading role in developing our large hydropower potentials.

**Future Outlook**

The government has recently rolled out what it calls a Renewable Energy Master Plan, REMP. According to REMP, FGN seeks to increase the supply of renewable electricity - wind, solar, biomass and small hydro - from 13% of total electricity generation in 2015 to 23% in 2025 and 36% by 2030. By December 2014, generation from hydro was about 18% of the national total.

The Energy Commission of Nigeria, ECN, has estimated the total capacity of the country’s hydropower potential as 11,500 MW and 3,500 MW for large and small hydropower systems respectively. ECN gave a breakdown of hydropower supply projections in the short, medium and long terms based on different growth scenarios as follows:
<table>
<thead>
<tr>
<th>Type</th>
<th>Supply Projection (MW)</th>
<th>Scenario</th>
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<tbody>
<tr>
<td></td>
<td>Short Term</td>
<td>Medium Term</td>
</tr>
<tr>
<td>Large Hydro</td>
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<td>320</td>
<td>760</td>
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</tbody>
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ECN envisions that with the appropriate policy and regulatory and institutional framework to stimulate demand and attract investors, these targets are possible by the horizon year 2030. Although ECN has identified the institutions to fund the support services to actualise the target, it has not indicated the level of funding required for the development of the generating capacity and the extent of government support for the development.

The Federal Ministry of Power has identified small hydropower projects around the country. The total capacity is 102 MW. It includes the 40 MW Itisi project in Kaduna State. The study for the project, including the EIA, has been completed. FGN is seeking a suitable financing mechanism for the development. Full details are available at the ministry’s website at [www.power.gov.ng](http://www.power.gov.ng)

Similarly, the Presidential Task Force on Power, PTFP, has listed 19 sites, where up to 227 MW of small and medium hydropower capacity could be developed. The task force also developed a programme for captive power generation for remote and off-grid locations in the country.

**Conclusion**

With only 26% of the country’s technically feasible hydropower potential exploited, the future holds great promise for the exploitation of this important renewable energy resource. To make a success of it, the right policies and a favourable environment must be in place. The recent power reform programme should be the catalyst for positive change especially in the area of small hydropower development.

Hydropower development in Nigeria has been at a snail’s pace with no capacity addition since Shiroro came on stream in 1989. For the country to take full advantage in harnessing this cheap and renewable source of energy, she needs to implement the development programmes set out in the new National Energy Master Plan, with a lot more vigour.

The REMP is heavy on where to go but light on how to get there. What are the other projects apart from Zungeru and Mambilla that will make Nigeria achieve the targets? Has she identified other large hydro potential sites since NEPA released the last development plan in 1986? What is happening to Makurdi? If the FGN decides to go ahead and develop the proposed sites at Makurdi, Gurara, and Ikom, they will add only about 1,800 MW to the country’s resource. Add Zungeru and Mambilla and the country, will have just enough to meet the long-term target, based
on the 7% GDP growth rate scenario. There is an urgent need to rethink Lokoja and to investigate new potential sites for Nigeria’s power development.

Nigeria should borrow from the example of Ethiopia. She was in a similar situation as Nigeria. Faced with crippling energy shortages and a rising population, she took a positive step. Aggressively, she pursued a hydropower development programme. She quickly boosted her generating capacity from 850 MW in 2010 to 2178 MW by 2014. Other projects to bring capacity additions to 10,365 MW are on course for completion in the closing part of this decade. That includes the massive 6,000-MW Grand Ethiopian Renaissance Dam on the Blue Nile.

The two projects at Zungeru and Mambilla are currently at different stages of development. Construction goes on steadily at Zungeru although there are challenges. Mambilla will probably take off soon. President Buhari’s declaration of support for the project is reassuring. By virtue of location within the Nigerian power system, the Mambilla hydroelectric project assumes operational significance. Apart from being the only source of voltage support in that part of the network, Mambilla will in future, serve as the gateway for the interconnection of power from the African Union inspired 40,000 MW Grand Inga hydroelectric project in the Democratic Republic of Congo. We need to execute these two projects post haste.

I conclude with a comment on Nigeria’s approach to small hydropower development. Small hydro is accepted as a proven technology for cost-effective power supply to isolated areas and rural communities. The success story of NESCO is Nigeria’s evidence of that. Fixation with the idea of being “connected to the national grid” appears to have resulted in the smallest hydro project, being connected to the national grid. From Challawa Gorge to Tiga, Gurara, Dadinkowa, with capacities ranging from 30 to 40 MW have been connected to the national grid using expensive evacuation 132-kV power lines.

I acknowledge the merit of HV line connection in the reduction of I^2R losses, but there is the problem of reactive power requirement and the demand for line charging. In a 132-kV line, that could be as high as 3.25 MVA, 4.86 MVA and 6.46 MVA for 60-km, 90-km and 120-km HV line respectively. Serving that demand can be quite onerous for a small plant.

Apart from adding high cost to the project, this mode of evacuation introduces delays and right-of-way issues, which increases the cost payable by the consumer.

Besides, the mode as conceived in many cases is incompetent. Take the case of Gurara I. The installed capacity is 30 MW. The station will not operate at full capacity all year round. Based on approximately 44% capacity factor, it will operate for only a fraction of the time during the peak inflow period. Technically speaking, for most of the year, it will generate an average of 13 MW. Effectively that 13 MW will be transmitted to Kaduna via the 80-km 132-kV line for synchronisation to the national grid at Kudenda.

However, Kaduna’s demand is 330 MW approximately. Compared to the national demand of 3900 MW, that is a modest burden for the Nigerian system. However, it is unlikely that the NCC will increase electricity availability to Kaduna for that reason. Wouldn’t it have been more
beneficial then, if this 13 MW was dedicated to serve essential loads such as hospitals, water works, prisons, street lighting and several other essential loads?

Besides, there are water management issues to consider too. These dams are multipurpose dams primarily for irrigation and water supply. Power generation is a spin-off and should be seen as that.

I hope that the foregoing points will influence future decisions in similar projects. The programme designed by the Presidential Task Force on Power for these types of projects is the right approach.

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About the Author

Engr. Daudu Abdul-Aziz works with the North-South Power Company as Chief Operating Officer, Shiroro Hydroelectric Power Station in Niger State, Nigeria.

He was born on 27\textsuperscript{th} May 1957 in Hadejia, Jigawa State. He holds a Bachelor of Engineering degree in electrical engineering from Ahmadu Bello University and is a graduate of the Power Systems Engineering Course conducted by GE Power Systems, Schenectady, New York, USA.

Before joining North South Power in May 2014, Engr. Abdul-Aziz had worked with the defunct National Electric Power Authority (NEPA) for 30 years and rose to become Chief Executive Officer of Shiroro Hydroelectric PLC in 2008. While with NEPA later PHCN, he became a member of the Board of the Presidential Task Force on Power (PTFP). He was seconded to the PTFP secretariat as a Senior Performance Monitor for Generating Plants as well as Senior Special Assistant to the President on Power Generation from 2010 to 2011. He contributed to the Generation chapter of the Roadmap for Power Sector Reform which was launched by the President in August 2010.

He received the NEPA Employee Merit Award in 1992 and the NEPA MD/CE’s special commendation in 2005 for leading different teams that repaired Shiroro Generators no. 2 & no. 3 in-house, in 2004 and 2009 respectively.

One of his most significant achievements as CEO, Shiroro Hydroelectric PLC has been the initiation, procurement and overall supervision of the turnaround maintenance of three of the station’s 4 x 150-MW turbine-generating units which effectively restored the station’s available capacity to 100\% and added 300 MW of generating capacity to the national grid.

Engr. Abdul-Aziz is a fellow of the Nigerian Society of Engineers, a senior member of the Institute of Electrical and Electronics Engineers and a member of CIGRE (the International Council on Large Electric Systems). He is registered with COREN. He is also a member of the Nigerian national committees of the following international professional associations and standards bodies: the International Network on Small Hydropower, the International Commission on Large Dams, the World Energy Council and the International Electrotechnical Commission.