International Journal of Advance Studies in Engineering and Scientific Inventions
Volume 3 Number 1, JULY 2015. ISSN (Print): 1741-8763 ISSN (Online):1741-8771

RENEWABLE ENERGY TECHNOLOGY FOR RURAL ELECTRIFICATION IN NIGERIA: CURRENT TRENDS AND EMERGING ISSUES

[1]Diji, C.J, PhD & [2]Bassey Anam PhD
[1]Department of Mechanical Engineering
University of Ibadan, Ibadan
[2]Institute of Public Policy and Administration
University of Calabar, Cross Rivers State

Abstract
In general, a rural area is a geographical area that is located outside a city or town; with mainly agriculture and activities around agricultural services as the main occupation. The major distinction between rural communities and urban centers is that while urban centers are large, impersonal and complex in social structure; rural areas are small, intimate and simple in organization. The problem of access to modern energy services, especially electricity is a major developmental issue confronting rural communities globally, particularly in Asia and sub Saharan Africa. According to IEA (2009) worldwide 1,456 billion people do not have access to electricity, of which 83% live in rural areas. In sub Saharan Africa less than 10% of the rural population have access to electricity. Currently in Nigeria, it is estimated that over 70% of the population live in rural areas with less than 15% of them having access to electricity. This study takes a critical look at the use of renewable energy technology for rural electrification in Nigeria. The study examined the policy trends, institutions and challenges, as well as the current problems and constraints of rural electrification in Nigeria. The study appraises identified cost of investment in renewable energy technology, financial constraints, lack of community participation and faulty institutional arrangements as major challenges to rural electrification in Nigeria. The study concludes by highlighting the emerging issues that need to be examined to guarantee the successful implementation of the Nigerian rural electrification policy.

Keywords: *Rural areas, Renewable energy, Electricity, Policy, Nigeria*

http://internationalpolicybrief.org/journals/international-scientific-research-consortium-journals/intl-journal-of-engineering-vol3-no1-july-2015

Background to the Study

In general, a rural area is a geographical area that is located outside a city or town. They are usually large and isolated areas of an open country with low population density, with mainly agriculture and activities around agricultural services as the main occupation. The major distinction between rural communities and urban centres is that while urban centres are large, impersonal and complex in social structure; rural areas are small, intimate and simple in organization.

The problem of access to modern energy services is a major developmental issue confronting rural communities globally, particularly in Asia and sub Saharan Africa. Modern energy services are benefits derived from modern energy sources such as electricity, natural gas, clean cooking fuels and mechanical power, that contribute to human well being (Modi et al, 2005). According to IEA (2009) worldwide 1,456 billion people do not have access to electricity, of which 83% live in rural areas. In sub Saharan Africa less than 10% of the rural population have access to electricity. Currently in Nigeria, it is estimated that over 70% of the population live in rural areas with less than 15% of them having access to electricity.

Globally, the problem of providing modern energy services to rural areas have been addressed by two major strategies: grid extension to electricity services in the urban centres and deploying of Renewable Energy Technologies (RETs)to meet the needs of the rural population. The objective of this presentation is to highlight the current status, as well as the challenges and constraints of the Nigerian government in the provision of modern energy services to the rural areas of the country, through the development and deployment of RETs.

The presentation is divided into five sections. The first section is the introduction, while the second section gives an overview of current renewable energy technologies that have been deployed for rural electrification and development in Nigeria. The third section discusses rural electrification and all the FGN institutions and agencies involved in the provision of modern energy services, to the rural areas. Section four discusses the challenges and constraints confronting the deployment of RETs for universal rural energy access in Nigeria. The section also discusses how the current challenges can be turned into opportunities. Section five concludes.

Objective to the Study

To highlight the current status and challenges faced by the Nigerian government in the provision of modern energy services to the rural areas, through the development and deployment of renewable energy technologies (RETs)

Literature Review

RETs are energy-providing technologies that utilize energy sources in ways that do not deplete the Earth's natural resources and are as environmentally benign as possible. The resources are sustainable in that they can be managed to ensure they can be used indefinitely without degrading the environment (Renewable Energy Association, 2009). By exploiting these energy sources, RETs have great potential to meet the energy needs of rural societies and sustainable way, albeit most likely in tandem with conventional systems. The decentralized nature of some RETs allows them to be matched with the specific needs of different rural areas.

RETs can be divided into two categories: those used to provide *energy for domestic use* (predominantly cooking and heating) and those used to supply *electricity*. RETs used to produce energy for domestic use tend to do so by exploiting modern fuels or by utilizing traditional fuels in new and improved ways. RETs that generate electricity can do so either as part of a stand-alone (or off-grid) system or as a grid-based system, by way of connection to a mini-grid or the national grid. Table 1 lists renewable energy sources, as and corresponding RETs that provide modern energy services and electricity, while Table 2 outline the present investment costs of Power technologies without BOS.

Common RET options for providing energy in rural areas utilize wind, solar, small-scalehydro power and biomass resources. Wind energy is used for pumping water and generating electricity. Solar photovoltaic (PV) systems convert sunlight into electricity and solar heaters use sunlight to heat stored water. Small-scale hydropower plants are used to generate electricity and vary in size (mini, micro and pico, in descending size).

Many small-scalehydro systems are “run-of-the-river” schemes, meaning that the main energy-carrying medium is the natural flow of water. In these cases, dams are small and there is very little storage of water. As a result, they are cheaper and less demanding on the environment, although they are less efficient and heavily dependent on local hydrological patterns. Technologies that utilize biomass include improved cook stoves for efficient burning of traditional energy sources or biogas. Biogas can also be used in small power plants to generate electricity (Alazraque-Cherni, 2008; World Bank, 2004).

Decentralized RETs are particularly suitable for providing electricity services in rural areas. It has been argued that decentralized systems can provide local power and so can be locally designed (Havet *et al.*, 2009). Generally they also have low up-front costs (though often higher costs per kW installed than centralized technologies), and can help avoid the high costs associated with transmission and distribution grids (Alazraque-Cherni, 2008; Steger,2005). They operate at smaller scales (kWh), appropriate to local needs and are accessible in remote locations as they are situated close to users (Kaundinya *et al.*, 2009).

Table 1: Renewable Energy Sources and Corresponding RETs

Energy Sources		RETs	
Type	Description	Energy for Domestic use	Electricity
Elemental Renewables	Solar	Solar pump, solar cookers	Solar PV
	Water(including wave/tidal)		Micro and Pico hydroelectric generating plant
	Wind		Wind turbine generator
	Geothermal		Geothermal generating plant
Biological Renewables	Energy Crops		Biomass generating plant
	Standard crops (including by products)		Biomass generating plant
	Forestry and forestry by products	Improved cook stoves	Biomass generating plant
	Animal by – products	Biogas digester, improved cook stove	Biogas digesters

Source: Renewable Energy Association, 2009.

Also, the possibility of adopting RETs is particularly important in the light of the limited success of conventional national grid-based rural electrification programmes to reach small, dispersed rural communities in developing countries (Goldemberg, 2000;Alazraque-Cherni, 2008).

Greater access to energy for domestic use and electricity using RETs can have a significant impact on livelihoods in rural areas. Cleaner use of traditional fuels can significantly improve health by reducing acute respiratory infection and conjunctivitis, commonly caused by indoor pollution. Wider health benefits can occur too; cooking with more efficient technologies can make dietary choice and boiling of water more affordable or more likely. Women and children in particular will have more time for education, leisure and economic activity (Murphy, 2001).

Access to electricity can significantly reduce the time required to devote to household activities. Electric water pumps, for example, can provide clean water, reducing the effort needed for collection. Electricity can make possible the refrigeration of vaccines and operation of medical equipment in rural health clinics. Access to radio and television can improve educational opportunities and provide entertainment. Electric lighting provides higher quality illumination than kerosene lanterns, improving opportunities for extended work and study time as well as better security, comfort and safety (World Bank, 2004; World Bank, 2001).

Method and Source of Data Research Design

The study adopts a descriptive research design. Data is drawn largely from secondary sources. Data obtained is significant in explaining the trends and emerging issues affecting the implementation of renewable energy technology for rural electrification in Nigeria.

Table 2: Investment Costs of Power Technologies

S/N	Technology	Year on Line	Cost ($/kw)
1.	Advanced open cycle turbine	2008	398
2.	Conventional open cycle turbine	2008	420
3.	Diesel generator (sound proof)	2010	555
4.	Advanced oil/gas combined cycle	2009	594
5.	Conventional oil/gas combined cycle	2009	603
6.	Distributed generation (base load)	2009	859
7.	Distributed generation (peak load)	2008	1032
8.	Advanced combined cycle with sequestration	2010	1185
9.	Wind	2009	1208
10.	Coal –fired plant with scrubber	2010	1290
11.	IGCC	2010	1490
12.	Conventional Hydropower	2010	1500
13.	Biomass	2010	1869
14.	Geothermal	2010	1880
15.	Advanced Nuclear	2011	2081
16.	IGCC with carbon sequestration	2010	2134
17.	Solar thermal	2009	3149
18.	Fuel cell	2009	4520
19.	Solar photo voltaic (PV)	2008	4751

Improved health and education, combined with more time to undertake non-energy related activities, are important goals in themselves. However, access to modern energy services also have the added value of helping local populations to engage in income-generating activities. Demand for services associated with RETs can help generate local economic activity based on these technologies, in addition to the means to power local industry.

Applications of RETs for productive activities vary from mechanical wind-powered water pumping to motorize milling machines for grinding grain. Radio services can provide farmers and fishermen with weather forecasts and telecommunication services can provide growers with information on crop prices (World Bank, 2004). As noted by Steger (2005), these applications can lead to job creation and improved livelihoods, both of which can contribute to significant increases in productivity in rural areas.

Rural Electrification in Nigeria

Rural electrification is the process of bringing electrical power to rural communities. Electricity is at the top of the energy ladder and is highly efficient and convenient for some specialized cooking appliances, such as rice cookers and microwave ovens. But for many years to come, electricity is unlikely to be practical for general cooking in most rural areas of the developing world. Nevertheless, for lighting, communication, refrigeration, and motor applications, electricity is essential for a satisfactory quality of life. Moreover, electricity is key to improving agricultural productivity through mechanization and is essential for many rural industrial activities. Considerable progresshas had been made in rural electrification programmes in Nigeria designed to extend electricity services to isolated villages.

Brief History of Rural Electrification in Nigeria

In 1981, the Federal Government of Nigeria initiated the Rural Electrification Programme with the primary objective of connecting all existing local government headquarters in the country to the national grid. By connecting the headquarters, several small towns and communities between them will benefit from the programme, and ultimately bring power to the vast majority of rural dwellers.

The defunct National Electric Power Authority (NEPA) was mandated to execute the programme on behalf of the Federal Government. Due to political patronage, procurement problems and poor funding, progress was slow and came at high financial costs. In 1987 the federal government negotiated an agreement with Bulgaria and Germany to supply $75 million worth of necessary imported materials, while those materials that could be produced locally wooden cross-arms, reinforced concrete poles, tie straps, stay blocks, etc. were purchased on the local market.

In 1989, the programme was restructured according to geographical accessibility to grid connecting points and facilities and a common procurement of offshore components and the federal government inaugurated an Implementation Committee on Rural Electrification (ICRE), comprised of officials from NEPA, the Federal Ministry of Power& Steel, and the Electrical Inspectorate Services Department. RE projects were monitored by the 15 zonal offices of the Ministry, and NEPA's RE Department handled project supervision and evaluation. Despite the partnership between local communities, state governments and the federal government on this programme, progress was painfully slow. Again, political interference, poor funding, planning and mismanagement of the overall electricity sector impeded growth in national access rates.

Between 1989 and 1999, a period of ten years, only about 300 projects were completed and connected to the national and a total of 800 projects were abandoned by the outgoing military regime for the incoming civilian administration in May, 1999. With renewed commitment and political will between 1999 and 2001, additional 189 projects were completed and by the end of 2003, over 600 local government headquarters out of the 774 headquarters were connected to the national grid.

However, in view of the critical nature of electricity to overall national development, the rural electrification programme was ripe for reform. The reform of the RE sector was anchored on a broader power sector reform and restructuring process. The reform of the sector was thus captured in the Electric Power Sector Reform Act (EPSRA) of 2005 part IX sub section 88 90. The EPSRA created the Rural Electrification Agency (REA) as the main government agency to drive RE in Nigeria. The Act provided for funding for the entire electricity sector and including funding for the rural electrification programme.

The new electricity power policy is expected to enable the entire electricity supply industry to:

1. Meet all current and prospective economically justifiable demands for electricity throughout the country.
2. Modernize and expand its coverage.
3. Support national economic and social development.
4. Provides an enabling framework to work out innovative approaches to rapidly expand access to rural areas in an economically efficient, socially equitable and environmentally sustainable manner.

Deployment of RETs in Rural Electrification in Nigeria

In 2003, the Federal Executive Council (FEC) approved an overall National Energy Policy (NEP), which articulates for the use of all viable energy sources for sustainable national development and with the active participation of the private sector in line with government's economic policy. Renewable energy is one of the energy types articulated in the policy. The policy also covers energy efficiency and conservation, amongst many other issues.

The NEP and indeed the renewable energy component, has amongst other things, five broad objectives:

1. To enhance energy security in the nation through diversifying the energy supply mix.
2. To increase energy access especially in the rural and semi urban areas;
3. To facilitate employment creation and empowerment; and
4. To protect the environment and mitigate climate change.
5. To build local capacity.

In 2005, the Energy Commission of Nigeria (ECN) produced the Renewable Energy master Plan (REMP) as a roadmap for the planned implementation of the renewable energy component of the NEP. The REMP is basically structured into the following programmes with short, medium and long term targets. The programmes are: National biomass energy programme; national solar energy programme; national hydropower programme; national wind energy programme; emerging energy programme and framework programme for renewable energy promotion. Based on a 13% GDP growth rate, the REMP projects the contribution of renewables to the electricity supply for the country (Table 3)

Table 3: Summary of Renewable Energy Targets for Electricity Supply (MW)

S/N	RESOURCES	SHORT	MEDIUM	LONG
1.	Hydro (large)	4,000	9,000	11,250
2.	Hydro (small)	100	760	3,500
3.	Solar PV	300	4,000	30,005
4.	Solar Thermal	300	2,005	10,000
5.	Biomass	5	30	100
6.	Wind	23	40	50
All renewable		4,628	15,835	54,905
All Energy Resources		21,238	85,668	270,068
% of Renewables		22%	18%	20%

Note: short 2015; Medium 2020 and Long - 2030

Also, in 2006, the International Centre for Energy, Environment and Development (ICEED) prepared a renewable electricity policy for the Federal Ministry of Power These enabling policy provisions provided the impetus for the Federal Ministry of Power and Steel to embark on the development of National Policy Guideline for Renewable Electricity and Renewable Electricity Action Program. This document pertains to the National Policy Guidelines on Renewable Electricity. The overall objective of this Policy Guideline is to expand the role of renewable electricity in sustainable development through effective promotional and regulatory instruments.

The bio-fuels specific policy initiated by the renewable energy Division of the Nigerian National Petroleum Corporation (RED NNPC) was approved by the FEC in 2007, with the primary objectives of establishing a thriving bio-fuels industry utilizing agricultural products as a means of improving the quality of automotive fossil based fuels in Nigeria.

Institutions and Agencies Involved in Rural Electrification in Nigeria

Currently the following institutions and agencies are involved in the deployment of rural electrification in Nigeria. They are: Rural Electrification Agency (REA); Energy Commission of Nigeria (ECN) and the National Agency for Science and Engineering Infrastructure (NASENI).

Rural Electrification Agency (REA)

The Rural Electrification Agency (REA) was established in 2006, via section 88 (1) of the Electric Power Sector Reform (EPSR) Act, 2005. The act established the Electrification Agency and the Rural Electrification fund. REA adopted the following three methods in providing electricity service. These are: Expansion of the main grid to rural areas; Development of Isolated and Mini-grid systems and Renewable Energy generation.REA commenced operations in August 2006, with all its projects centered on grid expansion to rural areas, via funding from the Federal Government annual budgetary allocation. The Rural Electrification Fund was entrusted to a Fund Trustee.

Approximately 2,000 grid expansion projects at various level of completion were taken over by the Agency from the Federal Ministry of Power's National Rural Electrification program. New grid expansion projects were initiated by the REA between 2008 and 2009. Currently a total of 1,964 Distribution Expansion Projects are currently at various stages of completion and the agency intends to use renewable energy as part of the electricity supply mix to remote off-grid communities (capturing the uncompleted REA projects) in Nigeria in a sustainable and commercially viable manner. These communities are typically found in:

1. The coastal areas of the Niger-Delta
2. The highlands of the South-West, up the border with the Republic of Benin
3. The mountainous regions of the South-East, up to the border with Cameroun
4. The far North-East and far North-West, up to the border with Niger Republic

Particularly the agency is interested in developing market incentives for the deployment of efficient private sector driven solutions. While the Federal Government, will provide the enabling environment and support for the successful deployment of renewables in remote areas. Also, the agency seeks to leverage on the capabilities of the private sector, for technical appraisal, engineering design, project management and delivery of projects. There are various program delivery models contemplated, i.e. under a B.O.O. (Build, Own, and Operate) basis and other potential public private partnerships (PPP).

Energy Commission of Nigeria (ECN)

The Energy Commission of Nigeria (ECN) is the major institution that has been promoting the development of renewable energy technology, rural energy and electricity deployment in Nigeria. The ECN was established by Act No. 62 of 1979, as amended by Act No. 32 of 1988 and Act No. 19 of 1989, with the statutory mandate for the strategic planning and co-ordination of national policies in the field of energy in all its ramifications. By this mandate, the Commission which is the apex government organ is empowered to carry out overall energy sector planning and policy co-ordination. The ECN carries out its mandate through various energy centres that were established across the nation. The Renewable energy projects which are currently being coordinated by ECN are shown in Table 4.

National Agency for Science and Engineering Infrastructure (NASENI)

The National Agency for Science and Engineering Infrastructure (NASENI) was established in 1992 by The Federal Government of Nigeria. The Nigerian Ministry for Science and Technology is responsible for overseeing the activities of NASENI. NASENI, by its mandate and scope of operation is the Nigerian all-purpose built Agency designed to conduct developmental work in the areas of manufacturing and as such, it is capable of coordinating the proliferation of technologies developed either within or outside of its Centers including patents obtained.

Technologies developed in the areas of spares, components and systems engineering are to be transferred to Entrepreneurs for the production of goods and services. NASENI operates mainly through her Development Institutes. Each of the Institutes has a unique mandate of engineering infrastructural development. The major institute associated with the power sector and by extension rural electricity development is Power Equipment and Electrical.

Table 4: Renewable Energy Projects managed by the ECN

S/N	Renewable Energy Type	Project Description
1.	Hydro Power	Reactivation of existing three large hydropower plants at Kainji (760MW), Jebba (540MW) and Shiroro(600MW) to deliver optimum power
		30MW Gurara I hydropower plant completed and power evacuation network being put in place
		300MW Gurara II hydropower plant under planning
		40MW hydropower plant across river Katsina Ala in Taraba state, 55% execution to be completed by 2014
		700MW Zungeru hydropower plant – contract signed with a Chinese Firm 2012 & to be completed in 48months.
		2,600MW Mambilla hydropower plant- feasibility & environmental impact assessment(EIA) studies done
		30 MW SHP NESCO, Jos- operational and the oldest
		2x75kW Waya Dam SHP in Bauchi completed
		1x30kW Ezioha – Mboro Dam SHP, Enugu completed
		2x200kW Tunga Dam SHP, Taraba State – Machines on site
		34MW Dadin Kowa Dam, Gombe State, Hyropower plant concessioned to private sector but yet to commence operation.
2.	Wind	Electronic Wind Map (WIS) development for wind resources assessment
		10MW Wind farm in Lambar Rimi Katsina – Contract awarded in 2009 & to be completed 2013
		2x215kW wind turbines at UDUS by SERC
		70x3kW wind turbines in Zamfara State by the State Government.
3	Solar Energy	Solar street lights, water pumping systems, mini-grids, solar refrigerators etc.- about 15MW dispersed installations in the country.
		7.5MW solar PV modules manufacturing plant, Karshi, Abuja
		500kW solar PV plant in Katsina
		30MW solar PV plants in Katsina, Gombe and Bauchi by German-Nigeria energy partnership
		50kW solar PV plant in Kaduna
		20 MW solar PV plant in Yola
		Solar water heaters, cookers, dryers, distillers etc.(R&D outputs)
4.	Biomass	Biofuel development – E10 & B20 permitted for use (NNPC, Research Institutes, private sector).
		5MW rice husk fired power plant in Ebonyi state – feasibility completed
		Biogas digesters @ R&D stages

(i) Small Hydro Power Project

The objective of the NASENI small hydro power project includes:

1. To develop local manufacturing capacity on Small Hydropower equipment.
2. To midwife the establishment of local manufacturing companies for electromechanical equipment / component parts for Small Hydro Power (SHP) Plants.
3. To midwife the establishment of Small Hydropower Equipment Development Institute.
4. To survey the possibility of integrating Small Hydro Power plants in the large number of dams in Nigeria, currently used for water supply and irrigation only.

Currently under this initiative, the following have been achieved.

1. In the late 2007, UNIDO selected NASENI as the host agency for the local manufacturing of Small Hydro Power Equipment in the African region.
2. Cross flow Turbine were selected for the first production involving Nigerian engineers and using local technology. The first phase of the project is expected to produce and test prototype of Cross flow turbine within 12months from takeoff.
3. The next phase is to mass produce the turbines which will be used to establish pilot SHP plants in selected African countries and eventually to service the SHP equipment demand for the African Sub-Region.
4. Ten (10) sites have been selected from the Six Geopolitical Zones and the Federal Capital Territory. The selected sites are shown in Table 5.

Table 5: Selected Sites for Pilot Small Hydro Plants (SHP) in Nigeria

S/N	Site/Community	State/Geo – Political zone	Capacity (kW)
1.	Ketti	AMAC / FCT	10kW
2.	Kwaita	KWALI / FCT	10kW
3.	Kurmu Daudu	BWARI / FCT	10kW
4.	Eboji	ABAJI / FCT	10kW
5	Obudu Cattle Resort	CROSS RIVER	30kW
6	Ta Hoss Community	PLATEAU	100kW
7	Ikeji-Ile Ijesha	OSUN	15kW
8	Iguoriakhi Farm Settlement	EDO	75kW
9	Sabke-Mai ¡dua	KATSINA	About 150kW
10.	Kiri-Numan	ADAMAWA	About 300kW

(ii) Wind Project

The main objective of NASENI Wind Energy Project (NAWEP) is to develop capacity for the aerodynamic design, fabrication and installation of wind turbine blade that can give optimum performance in our vast but low wind speed region with long durational harvest specifically for electricity generation. The project which is part of NASENI's effort at developing capacity in renewable energy arose because imported blades cannot perform optimally in this country since they are built to operate at the speed of at least $8ms^{-1}$ and above whereas the wind speed in Nigeria is between 3-5 m/s. In recognition of this fact which has been a major setback to wind powered electricity generation in Nigeria, NASENI is undertaking the development of wind turbine blades for optimal wind energy conversion in Nigeria.

So far the aerodynamic design of the blade has been carried out; first approximation performance test has been carried out using steady state air flow from wind tunnel and theoretical performance analysis using Blade element / momentum method. Presently, the blade is being subjected to advanced aerodynamics analysis using the necessary fluid dynamic equations formulated for modeling and simulation in COMSOL Multiphysics software acquired by NASENI headquarters for related modeling and simulation analysis.

Results so far obtained are very impressive, however further tests are still ongoing before actual construction starts. NASENI is also making effort to acquire a complete set of wind turbine for the purpose of reverse engineering of other components like tower, control system and the power conversion unit.

The local fabrication of the blade and reverse engineering of the other standard components are proposed to be carried out at HEDI, Kano. Hydraulic Equipment Development Institute (HEDI) is one of NASENI Development Institutes that is equipped with facilities for related fabrication. It is going to serve as the test bed for the project. The institute also has an outstanding experience in wind pump project which is also part of the Agency's effort in wind energy utilization.

(iii) Solar Panel Manufacturing Plant

NASENI is establishing a 7.5MW solar panel manufacturing plant at Karshi, Abuja through a joint venture project with a foreign partner. The establishment of the solar cell manufacturing plant in Nigeria will lead to the following applications amongst others: domestic use, street lighting, water pumping for irrigation purposes, power of repeater stations and telecommunication booster station, powering of traffic lights, small scale processing of farm products, and other applications in off-grid areas. The required facilities for this project have been imported and a building / workshop for the operation of the plant are already in place.

(iv) Pole Mounted Transformer

The provision of adequate and sustainable power is vital for the growth and development of Nigeria; thus power is one of the seven point agenda and the vision 2020 of the present administration. To this end, NASENI through one of its institutes, Power Equipment and Electrical Machinery Development Institute (PEEMADI), Okene serves as a strategic

intervention to meet the urgent foundations needed to transform to a truly developed technology society. To this end, PEEMADI is dedicated to the design, prototype development, construction, manufacture, testing and production of maintenance devices, Pole-Mounted Transformers amongst others, to support the electric Power Industry.
Other activities include the Design, Prototyping, Construction, Manufacturing and the mass production of Equipment such as Low Loss Power Distribution Transformer, Circuit Breaker, Relays and Voltage Regulator etc.

Challenges and Constraints of Deploying RETs for Rural Electrification
The major challenges and constraints confronting the deployment of RETs for rural electrification include:
1. Cost of Investments in Renewable Energy Technologies
The current investment cost of renewable energy technologists as shown in Table 2 is a major constraint to the widespread deployment of RETs for rural electrification in Nigeria. This situation is also worsened by the fact that majority of the population is predominantly engaged in peasant agriculture and allied activities and their income streams are inadequate to meet their basic needs.

2. Financing Constraint
The Nigerian government is currently the major financier for the provision of rural electrification in Nigeria. Confronted with budgetary constraints and the pressure to finance new power plants as part of the power sector reforms; this has made government investment in the rural electricity sector very minimal. Mobilizing financial resources to expand rural electricity service delivery is essential to a sustainable energy and economic future in Nigeria. In this context, Public Private Partnerships (PPPs) provide an important mechanism to overcome government budgetary constraints for widening rural access to energy services.

3. Viable Business Model
The Nigerian rural electricity sector, based on RET is currently not viable because it is not supported by any viable business model. A number of examples have shown that even when the technology is viable, the success of a renewable energy based rural electrification programme could be hindered by inadequate effort to create and demonstrate a viable model for further diffusion or the necessary structure for maintenance, financing and continued operation (Martinot et al., 2002). The set of solar home system programs funded by Global Environment Facility (GEF) is a case in point. While these projects implemented in individual countries have been successful in providing solar home systems to thousands of households, they have not become self- sustaining and replicable, despite some resources being put towards institutional strengthening. Each additional set of installations requires international donor funding and coordination, and the scale of installations remains small compared to the need (Zerriffi, 2007).

4. Community ownership, capacity building and training
One of the major limitations of renewable energy based rural electrification in Nigeria is the lack of community ownership of such projects and lack of capacity building and training to operate, maintain and repair of the RET when deployed. Community involvement in the

operations and management of RET based rural electrification requires time and information in education, training and trust- building of the communities (Valencia and Caspary, 2008). Even when they are involved for day-to-day operations and management, lack of capacity building and proper training inhibits the projects to have a substantive impact. However, there is now a realization that community buy- in and their active involvement right from the planning stage is pivotal to ensure the success of any project.

5. Institutional arrangements

Another significant challenge encountered in several energy access projects is the absence of robust institutional mechanisms (Barnes 2005; Aldover, 2007). There are several institutional shortcomings in delivering the energy services to remote locations. Rural energy access and rural energy development in most developing countries does not have any specific institutional support. Rural energy access programs are usually managed by energy supply-focused government institutions, but energy access is also a demand side issue. Both supply and demand side issues should be incorporated in the institutional framework for delivering universal rural electricity access in Nigeria.

Conclusion

The study has examined the trend and challenges involved in the development of RET based rural electrification in Nigeria. The study examined the trends in the development of rural electrification, the institutions involved in the process and their current activities. The paper identified cost of investments in rural electrification, financial constraints, lack of viable business models and lack of community participation and ownership as major challenges militating against the accomplishment of the rural electrification policy in Nigeria. Based on the trends, the paper recommended various emerging issues to reverse the current trend.

Recommendations

Based on the identified trends and challenges in the development of RET based rural electrification, the following emerging issues must be addressed for the success of the rural electrification in Nigeria

1. There is a need for a new institutional arrangement with a strong public private sector perspective. This new institutional arrangement should involve effective community ownership and participation.
2. There is an urgent need to mobilize funds from various sources including Federal, state and local governments, as well as other private and foreign sources to complete the many abandoned rural electrification projects and initiate new ones.
3. Another major consideration concerns risks associated with investment to strengthen rural electricity supply. These are in four dimensions: economic, socio-political, technological and environmental (methane leaks, post-Kyoto protocol requirements and climate change compatibility, nuclear accidents spills). Optimal sharing of these risks among the three principal actors in the electricity market, namely, consumers, investor/producers and the government is essential to guarantee efficient allocation of resources to the rural electrification in Nigeria.

4. There is also the human resource requirement of robust and reliable energy supply system which is fundamental to sustainable rural electricity future in Nigeria. The demand on local and foreign skilled workers will be immense. However, as in the telecom industry, having the appropriate incentive structure is essential given the globalized, regional and national demand for electrical, mechanical, computer engineering and other skills needed to support a vibrant industry at the Centre of Nigeria's energy map.

References

Alazraque, C. J (2008), "Renewable Energy for Rural Sustainability in Developing Countries." Bulletin of Science, Technology & Society. Vol. 28, No. 2 (April).

Barnes, D. & Floor, W. (1996), "Rural Energy in Developing Countries: A Challenge for Economic Development." Annual Review of Energy & Environment, No. 21.

Barnes, D., (2005), "Meeting the Challenge of Rural Electrification." Washington, D.C.: ESMAP Report. World Bank,

Caven, B. (1998). "Optimization of the Reliability of Electricity Power Supply in Nigeria." A Working Paper Presented in NEPA Headquarters. Vol. 1, pp: 39-41

Chaurey A, Ranganathana M & Mohanty P (2004). "Electricity access for geographically disadvantaged rural communities technology and policy insights." Energy Policy, No. 32.

Energy Commission of Nigeria (2002), "National Energy Policy." Abuja: August.

Energy Commission of Nigeria (2005), "Renewable Energy Master Plan." Abuja: November.

Goldemberg, J. (2000). "Rural Energy in Developing Countries." Chapter 10 in Goldemberg J (Ed.), World Energy Assessment: Energy & the Challenges of Sustainability. New York: United Nations Development Programme

Havet I, Chowdhury S, Takada M & Cantano A (2009), "Energy in National Decentralization Policies". New York: United National Development Programme

International Energy Agency (IEA) (2011), "Energy poverty: The missing Millennium Development Goal", 1March2011. / http: / / www.iea.org / index_info.asp?ID=1847S. International Energy Agency. World Energy Outlook 2009 Paris

Kaundinya D, Balachandra P & Ravindranath N (2009), " Grid-connected versus stand-alone energy systems for decentralized power: A review of literature." Renewable & Sustainable Energy Reviews" No. 13.

Martinot, E. & Chaurey, A., et. Al., (2002), “Renewable Energy Markets in Developing Countries.” AnnualReviewofEnergyandEnvironment27,309348.

Modi, V, McDade, S, Lallement, D & Saghir, J, (2005), “Energy Services for the Millennium Development Goals.” World Bank and UNDP, Washington, DC and New York 2005

Murphy, J.T. (2001), “Making the energy transition in rural East Africa: Is leapfrogging an alternative?" Technological Forecasting and Social Change, No. 68.

Ranjit, L. & O'Sullivan, K. (2002). “Energy.” Chapter 21 in Klugman J (Ed.) A Sourcebook for Poverty Reduction Strategies. Vol. 2. Washington DC: World Ban

World Bank (2003). “Making services work for the poor people.” World Development Report 2004. Washington DC: The World Bank & Oxford University Press.

World Bank (2009). “World Development Indicators.” Washington D.C.

World Bank, (2011). “India: Biomass for Sustainable Development - Lessons for Decentralized Energy Delivery Village Energy Security Programme.” World Bank, Washington, DC.

Zerriffi, H., (2007). “Making Small Work: Business Models for Electrifying the World.” /http://iisdb.stanford.edu/pubs/21983/WP63,_Zerriffi,_Making_Small_Work_20070926.pdfS(accessed16.11.2011).