FEDERAL MINISTRY OF POWER AND STEEL

FEDERAL REPUBLIC OF NIGERIA

Renewable Electricity Action Program (REAP)

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iceed
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Abbreviations and Acronyms

BPE	Bureau of Public Enterprises
CDM	Clean Development Mechanism
CET	Central External Tariff
CHP	Combined Heat and Power
CIDA	Canadian International Development Agency
ECN	Energy Commission of Nigeria
EPSR	Electric Power Sector Reform Act 2005
ETF	Education Trust Fund
FMPS	Federal Ministry of Power and Steel
FMW	Federal Ministry of Works
FMWR	Federal Ministry of Water Resources
GEF	Global Environmental Facility
GW	Gigawatt
GWh	Gigawatt hour
KW	Kilowatt
KWh	Kilowatt hour
MDGs	Millennium Development Goals
MW	Megawatt
MWh	Megawatt hour
NEEDS	National Empowerment and Economic Development Strategy
NEP	National Energy Policy
NEPA	National Electric Power Authority
NEPP	National Electric Power Policy
NERC	Nigerian Electricity Regulatory Commission
NM	Net Metering
NPIRD	National Policy on Integrated Rural Development
PBF	Public Benefit Fund
PHCN	Power Holding Company of Nigeria
PV	Photovoltaic
REA	Rural Electrification Agency
REAC	Renewable Electricity Advisory Committee
REAP	Renewable Electricity Action Program
REF	Renewable Electrification Fund
REMP	Renewable Energy Master Plan
REP	Rural Electrification Policy
RPS	Renewable Portfolio Standard

Energy Units Conversion

To / From	Joule	Gigajoule	Tetrajoule	Toe	kWh	Gwh
Joule	1	10^{-9}	10^{-12}	$2.4x10^{-12}$	$2.8x10^{-7}$	$2.8x10^{-13}$
Gigajoule	10^{9}	1	10^{-3}	$2.4x10^{-2}$	278	$278x10^{-6}$
Tetrajoule	10^{12}	10^{3}	1	24	$2.8x10^{5}$	$2.8x10^{-1}$
Toe	$42x10^{9}$	42	$42x10^{-3}$	1	$12x10^{4}$	$12x10^{-3}$
kWh	$36x10^{5}$	$36x10^{-4}$	$36x10^{-7}$	$8.3x10^{-6}$	1	10^{-6}
GWh	$36x10^{11}$	$36x10^{2}$	$36x10^{-1}$	83	10^{6}	1

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1.0 Background

1.1 Introduction

The Federal Government of Nigeria's vision of renewable energy in the power sector is the achievement of accelerated sustainable development through affordable access to reliable renewable electric power.

Access to electricity services is critical to achieving economic and social development targets outlined in the National Economic Empowerment and Development Strategy (NEEDS) and the Millennium Development Goals (MDGs). The Federal Government of Nigeria is committed to reaching these sustainable development targets through the full mobilization of the electricity sector. Renewable energy presents unique opportunities to scaling up access to electricity services and meeting NEEDs targets and the MDGs. In the pursuit of these objectives, the Federal Government seeks the establishment of a ten-year Renewable Electricity Action Program (REAP).

The REAP provides the framework to implement the Renewable Electricity Policy and Regulatory Guidelines.

1.2 Electricity situation in Nigeria

Nigeria is endowed with sufficient energy resources to meet its present and future development requirements. The country possesses the world's sixth largest reserve of crude oil. It is increasingly an important gas province with proven reserves of nearly 5000 billion cubic meters. Coal and lignite reserves are estimated to be 2.7billion tons, while tar sand reserves represent 31 billion barrels of oil equivalent. Identified hydroelectricity sites have an estimated capacity of about 11,000MW. Nigeria has significant biomass resources to meet both traditional and modern energy uses, including electricity generation. The country is exposed to a high solar radiation level of 3.5 – 7.0kWh/m2/day. Wind resources in Nigeria are however poor - moderate, and efforts are yet to be made to test their commercial competitiveness.

The current installed capacity of grid electricity is about 6000MW, of which about 67 percent is thermal and the balance is hydro-based. Between 1990 and 1999, there was no new power plant built and the same period witnessed substantial government under-funding of the utility for both capital projects and routine maintenance operations. Generating plant availability is low and the demand – supply gap is crippling. Poor services have forced most industrial customers to install their own power generators, at high costs to themselves and the Nigerian economy.

Table 1.0: Nigeria's energy reserves/potentials

Resource	Reserves	Reserves Billion toe	% Fossil
Crude oil	33 billion bbl	4.488	31.1
Natural gas	4502.4 billion m^3 (159 trillion scf)	3.859	26.7
Coal & Lignite	2.7 billion tones	1.882	13.0
Tar Sands	31 billion bbl oil equiv.	4.216	29.2
Sub-Total (Fossil Fuels)		**14.445**	**100.0**
Hydropower, large scale	10,000MW		
Hydropower, small scale	734 MW	Provisional	
Fuelwood	13,071,464 has (forest land 1981)	Estimate	
Animal waste	61million tones/yr	" "	
Crop Residue	83million tones/yr	" "	
Solar Radiation	3.5-7.0kWh/m^2-day		
Wind	2-4 m/s (annual average)		

Source: Renewable Energy Master Plan (2006).

By 2005, the transmission network consisted of 5000km of 330 kV lines, and 6000km of 132 kV lines (PHCN, 2005). The 330 kV lines fed 23 substations of 330/132 kV rating with a combined capacity of 6,000 MVA or 4,600 MVA at a utilization factor of 80%. In turn, the 132 kV lines fed 91 substations of 132/33 kV rating with a combined capacity of 7,800 MVA or 5,800 MVA at a utilization factor of 75%.

Table:1.1: Commercial Power Generation in Nigeria

Source of power	Capacity in MW	%
Afam	986	
Egbin	1320	
Sapele	1020	
Delta	912	
Thermal	***4238***	69
Kainji	760	
Shiroro	600	
Jebba	570	
Large Hydro	***1930***	31
Total	**6168**	100

Excerpts from Agagu, O.(2002) Developments in the electric power sector, May 1999 - 2002.

The distribution grid consisted of 23,753 km of 33 kV lines and 19,226 Km of 11 kV lines. In turn, these fed 679 substations of 33/11kV rating and 20,543 substations of 33/0.415 and 11/0.415 kV ratings. In addition, there were 1,790 distribution transformers and 680 injection transformers (ECN, 2004).

The transmission network is overloaded with a wheeling capacity less than 4,000 MW. It has a poor voltage profile in most parts of the network, especially in the North, inadequate dispatch and control infrastructure, radial and fragile grid network, frequent system collapse, exceedingly high transmission losses.

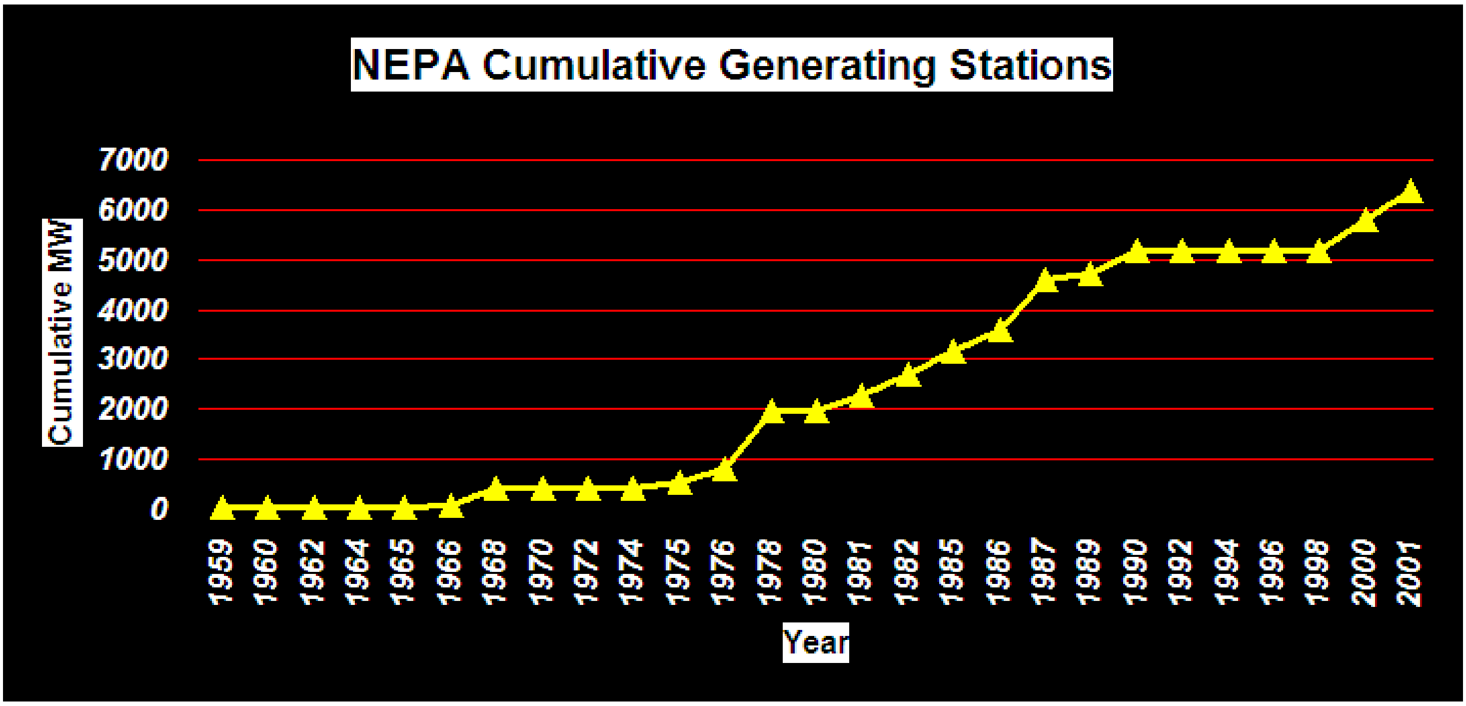


Figure 1.0: NEPA Cumulative Generating Stations

PHCN's business operations are inefficient. The system suffers from chronic under-investment, poor maintenance, un-recorded connections and under- billing arising from a preponderance of un-metered connections. The utility's financial performance, as well as its ability to serve customers satisfactorily has been consistently poor.

Access to electricity services is low in Nigeria. About 60 percent of the population – approximately 80 million people are not served with electricity. Per capita consumption of electricity is approximately 100kWh against 4500kWh, 1934 and 1379 in South Africa, Brazil and China, respectively. Under a business-as-usual scenario, the proportion of Nigerians without access to electricity services will continue to increase over time. The Rural Electrification Program began in 1981 focuses exclusively on grid extension; costs per connection remain high and annual rate of connection is low. With the chronic shortage of available generating capacity and low tariffs for rural areas, there is little incentive for PHCN to champion an expansion program. In all, rural electricity capital assets continue to deteriorate through neglect, vandalism and theft.

The Federal Government is undertaking comprehensive reforms to address the electricity situation in the country. The enactment of the Electricity Power Sector Reform Act (2005), establishment of the Nigerian Electricity Regulatory Commission, Rural Electrification Agency and the unbundling of PHCN are concrete legal, regulatory and institutions steps that will begin to address the challenges of the sector. Presently, a new wave of investments in the power generation championed both by the government and the private sector has commenced.

1.3 The Role of renewable electricity

Increased power generation from conventional sources and grid extensions alone will not achieve access expansion targets rapidly and cost-effectively. Accelerating rural electrification coverage will require an aggressive deployment of multiple supply options and business delivery systems. Consistent with the provisions of the EPSR Act, the Federal Government will seek to meet national electricity access targets through the following strategies:

- Grid-based extension for proximate areas;
- Independent mini-grids for remote areas with concentrated loads where grid service is not economic or will take many years to come; and
- Solar Photovoltaic (PV) systems for remote areas with scattered small loads.

Non-conventional renewable energy is a key element in the overall strategy of the Federal Government in rapidly expanding access to electricity services in the country. Beyond large hydropower, the total contribution of renewable energy in Nigeria’s electricity industry is about 35MW composed of 30MW small hydropower and about 5MW solar PV. This represents about 0.06% of total electricity generating capacity in the country.

The first independent power producer (IPP) in Nigeria was the Nigerian Electricity Supply Company, NESCO, a British-owned company supplying hydroelectric power to the growing tin mining industry. In 1930, NESCO took over the 2 MW hydroelectric power plant at Kwa falls in the Jos Plateau from the Nigerian Power and Tin Fields which had earlier commissioned the plant in 1923. NESCO increased its generating plants to five hydro-electric and one diesel plants serving both the tin industry and Jos and its environs.

In Evboro II village of Ovia South West Local Government Area in Edo State, a 3KW pico hydro scheme constructed under a culvert by an individual has been in existence. This scheme has for several years served 20 homes in the community.

1.4 Definition of renewable electricity

“Renewable electricity” refers to electric energy sources that do not result in the depletion of the earth’s resources. Renewable electricity also includes energy sources and technologies that have minimal environmental impacts, such as less intrusive hydro and certain biomass combustion. These sources of electricity normally will include solar energy, wind, biomass co-generation and gasification, hydro, geothermal, tide, wave and hydrogen. Based on the resource situation and the technological base of the country, the Policy Guideline focuses on hydropower, biomass co-generation, solar PV and wind energy for electricity production.

Small, Mini and Micro Hydropower – Small hydropower is defined by the Renewable Energy Master Plan as all hydroelectricity schemes below 30 MW, mini below 1MW, micro below 100kW and pico below 1kW.

Biomass electricity – Green plants converting sunlight into plant material through photosynthesis produce biomass energy. Biomass cogeneration is the predominant process of producing both thermal energy and electrical energy from biomass-fuelled boilers, with excess steam above that required for electricity being used for other purposes such as process heat, district heating and cooling plants, or even sold off to third parties requiring such services.

Solar energy – Electricity is generated from solar energy through photovoltaic materials (cells or modules) that converts sunlight directly into electricity. Solar thermal electricity technologies also are available whereby solar energy could be concentrated unto boilers to produce steam which could then be used in a conventional steam power plant. In Nigeria, solar photovoltaic technologies are used for small-scale power supply in some rural electrification programs of some States of the federation.

Wind energy – The energy contained in the movement of air in form of wind is used to turn the blades of windmills or wind turbines which in turn could be used to drive electrical generators to produce electricity. Large modern wind turbines operate together in “wind farms” to produce electricity for utilities, while small turbines are used to meet localized and small energy needs.

1.5 Objectives of the program

The overall objective of the Renewable Electricity Action Program is to establish a framework for achieving the objectives of the Renewable Electricity Policy and Regulatory Guidelines by setting measurable targets, strategies and implementation plan for the contribution of renewable electricity to the national economy.

The program has the following specific objectives:

- To provide an overview of renewable energy resources, technologies and market situations;
- To set achievable targets for renewable electricity;
- To develop sets of strategies for reaching the targets;
- To establish funding and program management framework
- To provide a mechanism for monitoring and evaluation of the program.

Chapter 2: Renewable energy resources, technologies and markets

2.0 Introduction

This chapter first considers the renewable energy resource potentials in Nigeria, the status of the database including its adequacy and gaps. The technical and technological assessment section follows with an overview of the various technologies in each renewable energy sub-sector. Finally, the chapter surveys the market situation providing comparative international experience as appropriate. A detailed analysis of present demand and supply situation is then made for each sub-sector followed by a consideration of the key drivers for each renewable energy sub-sector. Finally, the gaps and barriers to the development of each renewable energy technology market are outlined and analyzed. The order of consideration of the sub-sectors is as follows: Hydro Power, Solar Energy, Biomass Energy and Wind Energy. In the various reviews of resources, technologies and markets, emphasis is placed on specific technologies being promoted under the REAP.

2.1 Hydro power

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

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

Hydro Resource Situation

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

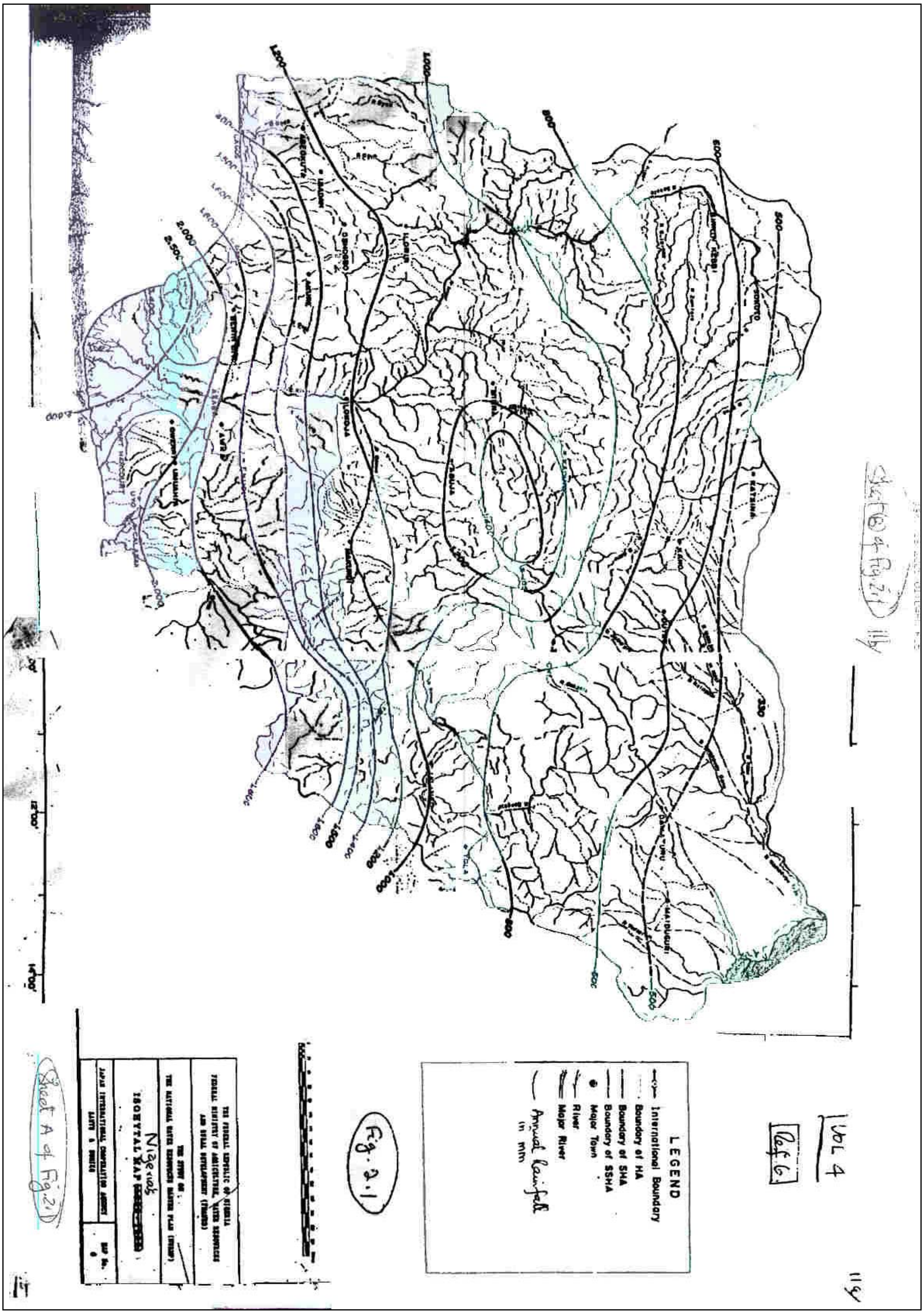


Figure 2.0: Nigeria's Isohyetal Map

Rainfall duration is longest in the South and decreases progressively northwards. In the southern areas, precipitation lasts over 8 months of the year, whereas at the extreme north annual rainfall duration can be less than 3 months. From the isohyetal and river system map shown in Fig. 2.0 it is clear that the country is blessed with a huge hydropower potential. The most attractive areas would be the southern, Plateau and Southeastern regions of the country, where rainfall is highest and of long duration and local topography provides appropriate drops and necessary hydraulic heads.

It is also evident that the run-of-the-river SHP is unlikely to operate year round, except in the South and South-eastern areas where river and stream flows are perennial. In the northern and Jos Plateau regions where stream flows are substantially ephemeral, the SHP would require flow regulation via storages and reservoirs. All the same, small hydropower can essentially be developed in virtually all parts of the country.

Estimated Resource Base

From NEPA's most recent estimate, the country's outstanding total exploitable hydro potential, listed in Table 2.0 currently stands at 12,220 MW. Added to the 1930 MW (Kainji, Jebba and Shiroro), already developed, the gross hydro potential for the country would be approximately 14,750 MW. Current hydropower generation is about 14% of the nation's hydropower potential and represents some 30% of total installed grid-connected electricity generation capacity of the country.

Table 2.0: NEPA Estimate of Current Exploitable Hydro Power Sites in Nigeria

Location	River	Potential Capacity MW
Donka	Niger	225
Zungeru II	Kaduna	450
Zungeru I	Kaduna	500
Zurubu	Kaduna	20
Gwaram	Jamaare	30
Izom	Gurara	10
Gudi	Mada	40
Kafanchan	Kongum	5
Kurra II	Sanga	25
Kurra I	Sanga	15
Richa II	Daffo	25
Richa I	Mosari	35
Mistakuku	Kurra	20
Korubo	Gongola	35
Kiri	Gongola	40
Yola	Benue	360
Karamti	Kam	115
Beli	Taraba	240
Garin Dali	Taraba	135
Sarkin Danko	Suntai	45
Gembu	Dongu	130
Kasimbila	Katsina Ala	30
Katsina Ala	Katsina Ala	260
Makurdi	Benue	1,060
Lokoja	Niger	1,950
Onitsha	Niger	1,050
Ifon	Osse	30
Ikom	Cross	730
Afikpo	Cross	180
Atan	Cross	180
Gurara	Gurara	300
Mambilla	Danga	3,960
Total		**12,220**

From a 1980 survey of 12 of the old States of the Federation, namely; Sokoto, Katsina, Niger, Kaduna, Kwara, Kano, Borno, Bauchi, Gongola, Plateau, Benue and Cross River, it was established (Table 2.1), that some 964 MW of SHP can be harnessed from 277 sites. The potential would of course increase when the rest of the country is surveyed. It is presently estimated by the Inter-Ministerial Committee on Available Energy Resources (2004) that the total SHP potential could reach 3,500 MW, representing 23% of the country's total hydropower potential.

Table 2.1 Small hydro potential in surveyed states of Nigeria

S/No	State (pre-1980)	River Basin	Total Sites	Total Capacity (MW)
1	Sokoto	Sokoto-Rima	22	30.6
2	Katsina	Sokoto-Rima	11	8
3	Niger	Niger	30	117.6
4	Kaduna	Niger	19	59.2
5	Kwara	Niger	12	38.8
6	Kano	Hadeija-Jamare	28	46.2
7	Borno	Chad	28	20.8
8	Bauchi	Upper Benue	20	42.6
9	Gongola	Upper Benue	38	162.7
10	Plateau	Lower Benue	32	110.4
11	Benue	Lower Benue	19	69.2
12	Rivers	Cross River	18	258.1
		Total	**277**	**964.2**

Listed in Table 2.2 are the small hydro schemes under operation in the country. As indicated, the projects are developed only in three states of the federation, namely; Plateau, Sokoto and Kano. Of the total 30 MW installed capacity, 21 MW (or 70%) is generated from 6 sites in Plateau State by the Nigerian Electricity Supply Corporation Ltd. (NESCO).

Table 2.2: Existing small hydro schemes in Nigeria

S/No	River	State	Installed Capacity (MW)
1	Bagel I	Plateau	1
	Bagel II	Plateau	2
2	Ouree	Plateau	2
3	Kurra	Plateau	8
4	Lere I	Plateau	4
	Lere II	Plateau	4
5	Bakalori	Sokoto	3
6	Tiga	Kano	6
Total			**30**

Table 2.3: NESCO small hydro projects in Plateau State

S/No	Items	PROJECTS					
		Kwali	**Ankwil I**	**Ankwil II**	**Kurra**	**Jekko I**	**Jekko II**
1	**River**	Ouree	Tenti	Tenti	Tenti	Sanga	Sanga
2	**Reservoir**						
	Area (sq km)	0.14	5.1	0.23	4.8	0.4	0.02
	Capacity (MCM) x 10^6	0.63	31	1.16	17	1.4	1.4
	Discharging (m3/sec)	271	228	343	571	685	685
3	**Dam**						
	Height (m)	9	27	9	19	9.75	6
	Crest Length (m)	274	708	203	1,067	128	23
	Volume (MCM)	90,500	521,240	46,578	348,654	6,000	700
	Altitude (ASL)	1,068	1,274	1,274	1,172	870	674
	Type	Earthfill	Earthfill	Earthfill	Earthfill	Concrete	Concrete
	Spillway	Ogee	Underflow	Underflow	Broad Crested Weir	Ogee	Ogee
4	**Power Plant**						
	Output (MW)	2	1	2	8	4	4
5	**Yr of Completion**	**1923**	**1964**	**1963**	**1929**	**1937**	**1950**

Source: Nigerian Electricity Supply Corporation Ltd (NESCO), Jos

As indicated in Table 2.3, NESCO projects were completed between 1923 and 1964 and have continued to provide virtually uninterrupted power to not only supply the Jos metropolis and meet local consumption, but also feed into the national grid. NESCO operations are a clear example of a very successful independent power production (IPP) that should be replicated in other parts of the country.

Status of Database

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

Every effort should be made to complete the survey over the entire country developing new data and verifying existing information. Data can be assembled through the River Basin Development Authorities, State and Local Governments, NEPA, State Rural Electrification Boards and relevant NGO's under the responsibility of the Energy Commission of Nigeria (ECN). Data thus generated should be organized in appropriate reports and stored in other suitable formats for easy retrieval and application.

For each potential small hydro site, data to be assembled should cover, among other items: rainfall depths and duration; river and stream systems including flow rates and duration; seasonal and long-term variation of flows; local topographical features; suitability of site for reservoir development; geology; demographic characteristics; community trades and employment; land use; status of power supply in the area; developable small hydro capacities; cost of schemes; project feasibility and requirements for hydro system implementation.

Technical Assessment

Overview of Technology

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

Where the topography permits the hydro yield is firmed up by the construction of a small dam which creates a reservoir. The storage provides additional head and flow regulation, thereby increasing power output and extending power generation over low-flow periods.

Other components of the small hydro include the penstock, a turbine which transforms the energy of flowing water into rotational energy, an alternator which converts rotational energy into electricity, a regulator which controls the generators, and wiring which delivers the electricity to the end users. In many systems, an inverter is incorporated to convert the resulting low-voltage direct current (DC) into 220 or 240 volts alternating current (AC) compatible with existing national power systems. Sometimes excess power is stored in batteries for use during periods of low flow or water scarcity.

While the bulk of small-hydro requirement and accessories are import-based during early stages of development, it is believed that with appropriate government incentives and support, virtually all basic components of the systems can be manufactured locally. This would also facilitate system maintenance and repairs.

To date, small hydro technology is still at its infancy in Nigeria. As shown in Table 2.2, the schemes are operated in only three of the 36 States of the Federation, and only the NESCO complex in Plateau State, whose first unit went on stream some 80 yrs ago, has developed some form of local technology in its facility operation and maintenance.

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

Turbines are preferred over waterwheels, because they are more compact, have fewer gears and require less material for construction. As listed in Table 2.4, several types of turbines are available for the small hydro. The impulse turbines, which have the least complex design and rely on flow velocity to move the wheel or runner, are the most commonly used for the high head SHP systems. The most common types of impulse turbines are the Pelton and Turgo wheels.

Table 2.4 Types of Turbines and Parameters for Small Hydro Schemes

Type	Head, n	Discharge, m/s	Speed, rpm	Rating, kW
Cross flow	7.5 – 100	0.15 – 5.0	100 – 1000	50 – 1000
Bulb (package)	5 – 18	4 – 25	187 – 500	150 – 4500
S-Type (Tubular)	3 – 18	1.5 – 40	120 – 750	50 – 5000
Vertical Tubular	5 – 18	2 – 20	300 – 750	300 – 750
Horizontal Francis	20 – 300	0.6 – 17	300 – 1000	500 – 5000
Impulse	75 – 400	0.3 – 3	120 – 000	100 – 5000

Source: National Energy Plan Vision 2010 for Small Hydropower Technology (March, 2004)

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

The *Turgo* impulse wheel is an upgrade of the Pelton. Using the same spray concept, the Turgo jet is about half the size of the Pelton but its spray hits three buckets simultaneously. Thus, the Turgo wheel is less bulky and moves almost twice as fast the Pelton version. It also needs few or no gears and generally operates trouble free under low-flow conditions, requiring medium or high head. The Turgo wheel therefore achieves even higher efficiency than the Pelton wheel.

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

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

Since the hydro plant has only few moving parts and operates at ambient temperatures, its life span can be quite long. While thermal power plants require very large operation and maintenance costs and must be replaced every 5 to 7 yrs, the hydropower system can operate for as long as 20 yrs under generally inexpensive operation and maintenance requirements before there is need for major rehabilitation. As shown in Fig. 2.0, the lifetime of the small hydro facilities is 20 – 30 years, compared with 8 – 10 years for diesel engine generators. Long service life is therefore another important attraction of the small hydro system.

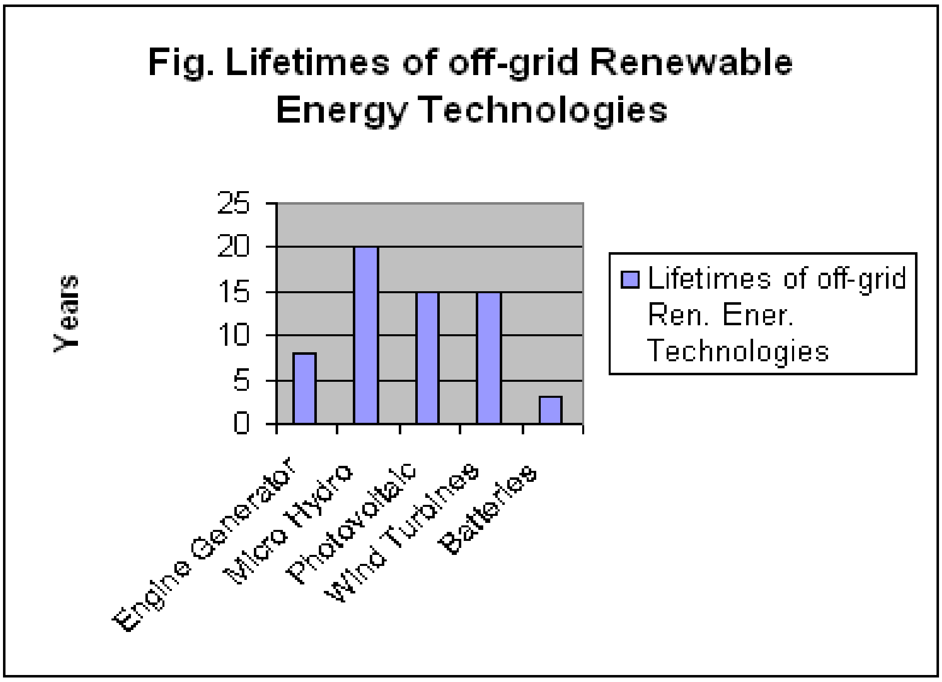


Fig. 2.1: Lifetimes of off-grid Renewable Energy Technologies

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

Economic Competitiveness

Although, the small hydro may require a moderately high capital cost (Fig. 2.1), its low operation and maintenance (O & M) requirements (Fig. 2.2) coupled with long life spans are its major advantage over other prospective sources of power to small and medium sized local communities and settlements. The petrol/diesel generator sets which may be installed at a relatively moderate cost, are prone to such serious limitations as unreliability of fuel supply, frequent breakdown, high O & M requirements, short service lives, noisy operation and environmental pollution.

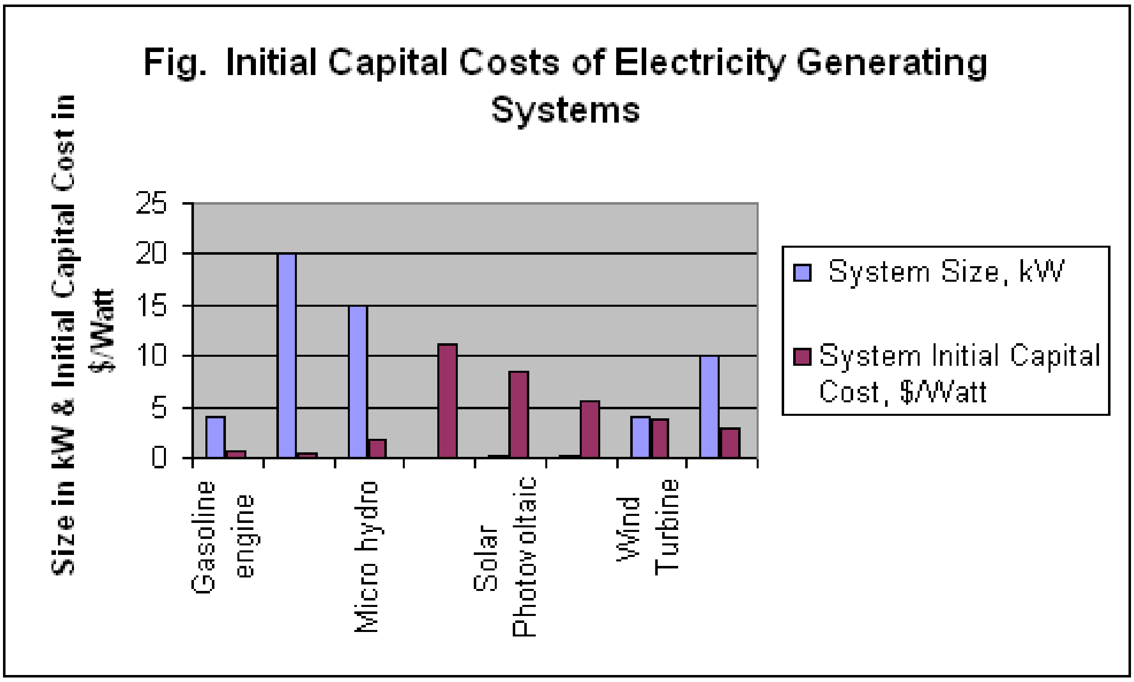
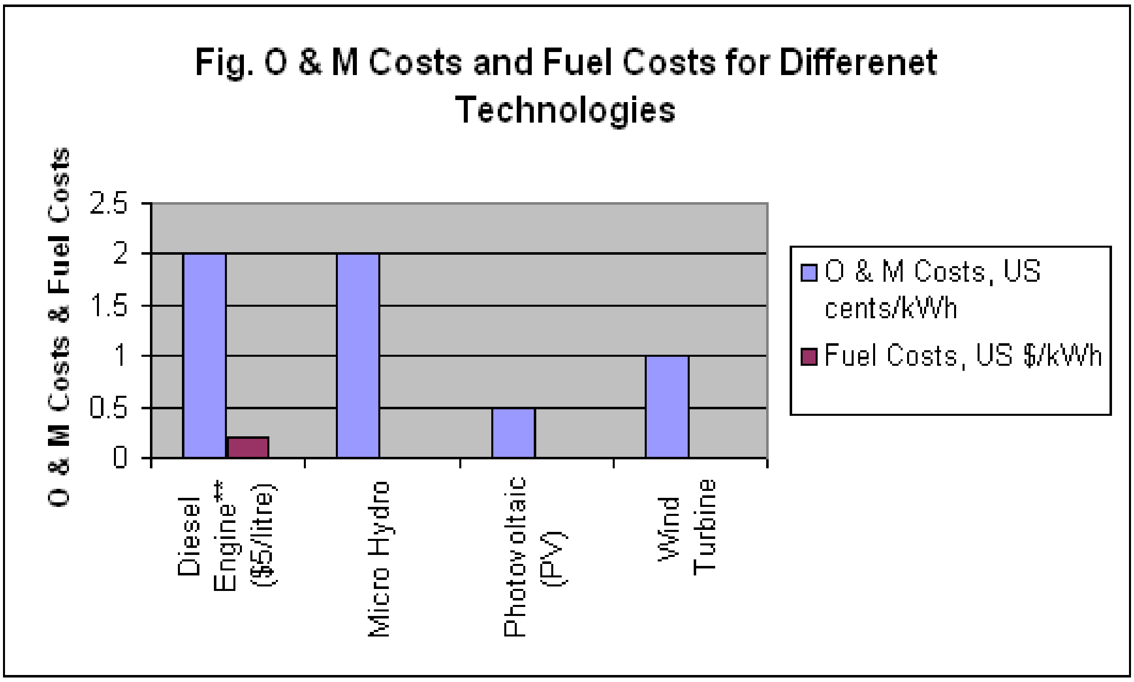


Fig. 2.2: Initial capital costs of electricity generating systems
Costs are as of 1990
Source: National Energy Plan Vision 2010 Small Hydropower Technology (March, 2004)

Fig. 2.3: Operating & Maintenance (O & M) and Fuel Costs for different technologies



Source: National Energy Plan Vision 2010 Small Hydropower Technology (March, 2004)

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

Benefits and Limitations

Several benefits are derived from the small hydro development, among which are: (i) provision of a basic tool for rural development; (ii) very low operation and maintenance costs; (iv) no fuel costs; (v) kick-starting and support for cottage industries; (vi) access to remote and often neglected communities; (vii) competitive economic and supply advantage over other power systems; (viii) environmentally friendly and emission free power generation (Table 2.1.6); (ix) poverty alleviation; (x) general enhancement of the social structure of the Community; (xi) provision of rural employment; (xii) economic empowerment of the community; (xiii) reduction of rural-urban migration and (xiv) opportunity to tap substantial unutilized energy resources of the country.

Table 2.5: Comparison of Environmental Effects of Power Generating Plants

Types of Plant	Multipurpose	Emissions	Radioactive Radiation	Social Impact	Earthquake Prone
Hydro*	Yes	No	No	Yes	Yes
Small Hydro	Yes	No	No	Yes	No
Fossil Fuel	-	Yes	No	Less	µ
Nuclear	-	Yes	Yes	No	No
Wind*	-	No	No	Yes	No
Solar*	-	Yes	No	Yes	No
					No

* Require vast areas away from large cities in sparsely populated regions in Nigeria.

Source: National Energy Plan Vision 2010 Small Hydropower Technology (March, 2004)

Despite its obvious benefits, the small hydro has its limitations. Power can usually be generated only during the rainy season when sufficient flow would be available. Even where a reservoir is integrated as a component of the scheme, it is still unlikely that power is produced over an appreciable period of the dry season or drought.

Small hydro plants are usually sited in remote, sometimes rugged and virtually inaccessible locations from where it is difficult at times to bring the power to populated areas and load centres. Other SHP limitations include: Long project development periods and high in-situ investment costs; administrative bottlenecks relating to organization, awarding the contract and construction of projects involving complex coordination of tendering, construction and supervision; water right problems where water is diverted from areas with prior rights; the absence of technical standards, which leads to utilization of substandard equipment, resulting in low efficiency and poor system reliability; insufficient financial resources for necessary O & M for sustained operation of SHP, the bulk of which is produced for consumptive residential use; there are no real models for companies to finance and operate SHP on a private development basis; financial institutions may be reluctant to finance non-traditional (power) projects; and land acquisition could lead to social and cultural controversies.

Market Situation

Present Demand and Supply Situation

From a projection of overall energy demand for the Country, Electricity demand for households and industry, the principal consumers of the SHP, are projected to grow at annual rates between 8% and 9% under the high growth scenario and between 3% and 5% for a low growth pattern. It is projected that the demand for SHP will grow at a faster pace and could reach an annual rate of 10%.

Based on Yr 2000 Nigerian population of some 110 million and per capita power requirement of about 30 W, the 2000 Yr demand for the Small hydropower is estimated to be 190 MW. Corresponding future demands, as set out in Fig. 2.1.5, are projected to reach approximately 490 MW in Yr 2010, 1280 MW in 2020 and 3315 MW by 2030.

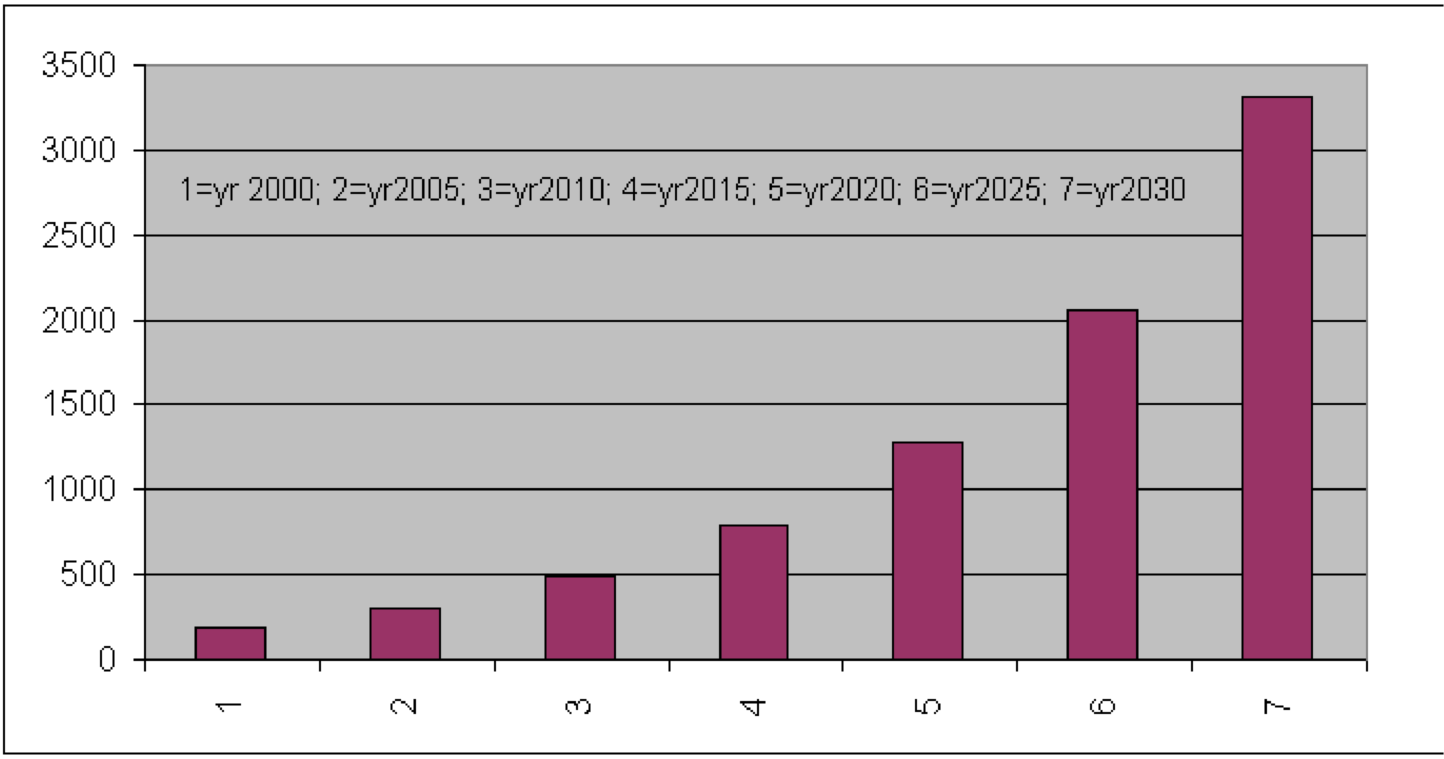


Fig. 2.3: Projected Nigerian small hydro power demand

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

Key Drivers for the SHP Market

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

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

Diversification of community trades and services would also provide ready markets. The high cost of fuel, O & M and related expenses associated with diesel based generator sets together with the unreliability of fuel supply promote a justification for the SHP option. So does the remoteness of the rural areas as well as the absence of national power grid.

Improved community awareness through individual and general public education including interaction with other communities is also an important driver for the SHP market.

Gaps and Barriers to Small-Hydro Market Development

As noted in Nigeria's Vision 2010 National Energy Plan, the following barriers face implementation and marketing of renewable energy, including small hydro: implementation requires significant initial investment with generally low rate of return while there is very limited level of consumer awareness on the benefits and opportunities of SHP development. The economic and social system of energy services is based on centralized development around conventional sources of energy, specifically electricity generation, thus making a level playing field impossible. Financial, legal, regulatory and organizational barriers need to be overcome in order to implement the projects and develop new energy markets. There is an absence of a framework for power purchase agreement between owners of small hydro plants, the grid and other users. There has also been a lack of assessment of the market potential and the structure necessary to harness the SHP potential.

2.2 Solar energy and photovoltaic technologies

The solar energy resource situation in Nigeria including the estimated potential and available amount of the resource, are considered in this section. The status of the database is discussed, indicating its degree of adequacy and an identification of the gaps.

Resource Situation

Estimated Resource Base

The National Energy Policy Document states that "Nigeria lies within a high sunshine belt and, within the country, solar radiation is fairly well distributed. The annual average of total solar radiation is varies from about 12.6 MJ/m^2-day (3.5 kWh/ m^2-day) in the coastal latitudes to about 25.2 MJ/ m^2-day (7.0 kWh/ m^2-day) in the far north." Assuming an arithmetic average of 18.9 MJ/ m^2-day (5.3 kWh/ m^2-day), Nigeria therefore has an estimated 17,459,215.2 million MJ/day (17.439 TJ/day) of solar energy falling on its 923,768 km^2 land area. The above arithmetic average may be interpreted as the application of each of the above radiation values to approximately half the area of the country, thus giving a total of (12.6 + 25.2) x (923,768/2) which gives the same value as before. Annually, the above average solar intensity is 6898.5 MJ/m^2-year or 1934.5 kWh/m^2-year, a value that can be used to calculate the available solar energy.

Thus, over a whole year, an average of 6,372,613 PJ/year (≈1,770 thousand TWh/year) of solar energy falls on the entire land area of Nigeria. This is about 120 thousand times the total electrical energy generated by the National Electric Power Authority for the whole country for the year 2002. This then is an estimated potential solar thermal energy resource base. Part of this resource falls on agricultural and forest lands and of course is useful for photosynthesis processes; others fall on developed areas most of which could be harnessed for power generation through roof- and building-integrated solar conversion devices (solar water heaters, solar photovoltaic -PV- claddings, etc.); others fall on roads and waterways some of which are useful or useable, e.g. for drying agricultural products by rural dwellers. Thus, this total resource is largely useable or harness-able.

Alternatively, the solar resource could be considered from the standpoint of the area required to generate the total national energy consumption through this solar energy. Thus, the NEPA total electricity generation of 14.68 TWh in the year 2000 could have been provided by the average solar energy intensity of 1934.5 kWh/m^2-yr (6898.5 MJ/m^2-yr) falling on an area of 7.66 km^2 if a 100% efficient conversion device were used, or an area of less than 100 km^2 if a conversion device having an efficiency of only 10% were used.

How much of the total solar resource of 6,372,613 PJ/year is actually available depends on what fraction of the nation's land area could be dedicated to energy production among other competing needs such as agriculture, river and road networks, etc. Dwellings have been deliberately left out of this analysis since both roofs and walls could easily be used for energy production as earlier discussed. Two scenarios are considered: worst case of only 10% and a conservative best case of 20% of the land area of Nigeria dedicated to energy production by using solar energy. These percentages derive from the biomass resource assessment chapter in this report, where 28.5% of the total land area of Nigeria is composed of forest, woodland, developed and other land besides agricultural land and water bodies. Further, we assume solar energy conversion devices with a very conservative overall thermal efficiency of 10%. The available solar energy resource estimate therefore becomes 17,702 TWh/yr (63,726 PJ/yr) and 35,403 TWh/yr (127,452 PJ/yr) respectively for the two scenarios. This available resource is about 23 times the ECN projection of total final energy demand for Nigeria in the year 2030 and just under 200 times of the demand for the year 2010 for the best case scenario. For the worst case scenario, the available source is about 12 times the year 2030 demand and just under 100 times the year 2010 demand.

Status of Database, including adequacy and gaps

The solar radiation measuring stations of the Nigerian Meteorological Agency earlier discussed are mostly airport and aerodrome weather stations which were originally set up to aid civil aircraft navigation. Thus, the stations themselves cover only about thirty localities. To obtain a good solar radiation database there is need to set a lot more radiation measurement stations all over the country, particularly in the northern areas where the radiation belt is very high. Radiation studies done have relied on the data from the meteorological stations to develop equations applicable to either zones of the country or to the whole country which are useful for solar equipment manufacturers and designers. Such studies need to be validated with much more data evenly spread all over the country.

Most of the solar radiation data taken at the meteorological stations are for the total or global solar radiation. A programme on gathering data on other components of solar radiation such as diffuse radiation, normal radiation, and spectral radiation also needs to be instituted as such data find use in equipment design. Furthermore, although the meteorological stations were in isolated aerodromes far from development at the time they were built over four decades ago, almost all the stations are now in built up areas with high probability of shading effects on the instruments. There is a need for new, purpose-built stations designed to fill knowledge gaps in a solar radiation mapping programme for the country.

The largest solar radiation and other climatological database available in Nigeria reside with the Nigerian Meteorological Agency (NIMET) obtained from their weather stations located widely throughout the country. The data from the various stations are collated centrally at the headquarters in Oshodi, Lagos, where climatological data upwards of30 years are available. Many of the stations are airport or aerodrome weather stations. Another source of localized solar radiation data is the International Institute of Tropical Agriculture, lITA, Ibadan, Oyo State, which has agro-climatological stations at its headquarters and at its agricultural substations or outstations. Very good solar and other climatic database upwards of 20 years can be readily found at lITA.

The National Building and Roads Research Institute (NBRRI) in Lagos and the National Energy Research Centres at the University of Nigeria, Nsukka, the Obafemi Awolowo University, Ile-Ife and Usmanu Danfodiyo University, Sokoto, also provide a valuable source of solar radiation and other climatic information. Less consistently collected are data from some tertiary institutions nationwide, where individual energy researchers work on various energy projects. The annotated references listed in the bibliography contain selected relevant work from some of these institutions. Some international and multinational companies similarly have climatological stations where solar and other climatic data have been collected for decades.

Technical Assessment of Solar Energy Technologies

The two broad classifications of Solar Energy Technologies are Solar Thermal Energy technologies and Solar Photovoltaic (PV) technologies. The following will provide an overview of solar PV technologies.

Solar Photovoltaic (PV) Technologies

A Photovoltaic system consists basically of the module which converts the solar energy to direct current (DC) electricity, the battery which stores the DC electricity for use when the solar radiation is either poor or non-existent, the charge controller which regulates the charging and discharging of the battery to preserve its life, the inverter which converts the DC from the modules or battery into alternating current (AC), wires, switches, relays mounting structures etc. The following PV cell/module technologies have been commercialized: Crystalline Silicon Technologies; Thin-film Technologies and Amorphous Silicon Technologies.

(a) *Crystalline Silicon technologies*

Silicon is the most widely used and best characterized semiconductor material. Silicon technologies have, since the beginning of the industrial activities in the PV field, been the leading technologies. In 2003, the worldwide production of cells and modules from crystalline silicon was estimated at 667MW out of which mono-crystalline silicon accounted for 200MWp, polycrystalline silicon 460MWp, and ribbon silicon 7MWp. Crystalline silicon technologies accounted for 89.6% of the total crystalline cell production of 734 MWp. There have been strong improvements in crystalline silicon technologies over the last decade, in terms of cell efficiencies, material and wafer quality, module performance and reliability, factors which have contributed to an increase of 20%/year of PV module shipments.

(*b) Thin film Technologies*

Thin film technology, as defined, means the large area ($2m^2$) deposition of thin film conductors (TC) and thin film semiconductor (TSC) on a substrate using a patterning technique to achieve an integrated device structure. Usually, the thickness is a few micrometers up to about 20 micrometers.

The process sequence for manufacture of thin film solar modules involves four steps namely, the deposition and patterning of the first electrode, the deposition and patterning of the absorber layer, the deposition and pattering of the second electrode and finally the encapsulation of the module.

The 2003 worldwide production of thin film cells and modules was about 96MWp, a contribution of 13% to the total volume in the year.

For thin film technologies, the differences from one technology to another lie in the steps involved in the deposition of the absorber layer. PV companies involved in module manufacture with C-Si as their major product are already engaged in research and development of cells and modules based on thin materials. The leading companies are Siemens, Solarex and BP Solar which is working on CIS, a-Si and CdTe based materials respectively. Other materials include CdS and CdZnS which, though having the potential for yielding low-cost cells of less than $ 1 per peak watt, are disadvantaged by their low relative efficiencies (4%-6%) and uncertain lifetimes. The low relative efficiency requires the use of larger array areas, increase area related costs such as mountings. The thin film technologies that have achieved some level of market penetration are as follows:

(i) Copper Indium Diselenide (CuInSe2 or CIS) Technologies

This is a compound semiconductor technology that is receiving attention as a prime candidate for PV power generation in view of its promising efficiency and stability of performance. CIS has a very high optical absorption so that very thin layers will absorb sunlight effectively. Its band gap of 1eV is rather low and it is usual to replace indium with an alloy of indium and gallium to increase the energy gap and hence the open circuit voltage.

Because of known weaknesses arising from manufacturing issues such as area uniformity, yield and adhesion problems coupled with the capital intensive nature of the technology amongst others, steps are being taken in following areas: Improvement of adhesion at the Mo/CIS interface; Replacement of CdS transparent layer by Cd-free buffer layer such as ZnO, ZnSe, for reason of environmental considerations; Sourcing of less hazardous Se vapour source to replace H_2Se gas; Achievement of large-area stoichiometric CIS films; Elimination of the wet process in the device fabrication; Development of manufacturing process which will give compositional uniformity and high yields.

(ii) Cadmium Telluride (CdTe) Technologies

Cadmium Telluride has basic properties that make it a very promising candidate for use in thin film solar cells for electrical power generation. Its energy gap of 1.45eV is well adapted to the solar light spectrum, and leads to very high light absorption favourable for thin film solar cells. The compound can be prepared easily in high purity, as the elements Cd and Te can be easily purified. Above 500^oC, the constituting elements have a significantly high vapour pressure than the compound, leaving the compound as stable phase.

(iii) Thin Film Si Technologies

In the past few years, there has been growing interest in combining the approach of interconnected thin film devices on a low cost substrate with a thin layer (<20 μm) of crystalline silicon as the absorber. The inherent stability of C-Si, its potentially high efficiency and advanced materials technology have motivated this interest.

In comparison with the breakthroughs in PV cell and module technologies and Balance of System (BOS) components at the laboratory and production scale in developed countries such as USA, Japan, Germany and United Kingdom, very little work has been done in Nigeria. Some efforts have been made locally to produce cells in the laboratory while most other work have been in the area of thin film deposition by solution growth and their characterization using optical and electrical techniques. A National Committee was set up in 1998 by the Energy Commission of Nigeria to ascertain the level of PV industry activity in Nigeria with a view to establishing the manufacturing capabilities for PV modules and Balance of Systems Components (BOS). Till date, apart from local manufacture of storage batteries and wires and the assembly of refrigerators, all other PV system BOS components are imported.

(c) Amorphous Silicon (a-Si) Technologies

This is the most extensively researched thin film material with the largest manufacturing experience mainly based on low power devices (watches, calculator etc). A lot of investment was put into this technology in the 1980s, yielding remarkable R & D results in the understanding of material properties and in manufacturing. With the large prior investments, there are known paths to scale up manufacturing success already achieved.

Apart from the major low-power applications of a-Si materials, such as in watches and calculators, the modules have started showing remarkable acceptance for building integrated applications in view of their characteristics, these include their size, weight/strength, visual aesthetics, compatibility with conventional construction assemblies, partial visible light transmissivity and excellent heat shading properties. Application in buildings include skylights, curtain walls and roofing.

Economic competitiveness of solar PV technologies

PV systems have been shown in a study to be cost effective in the low power range up to loads effective to 300W on a life-cycle-cost basis when compared with diesel or gasoline generators for use in remote locations requiring national grid extension over a distance of 1.8 kilometers. With the present effort being made to reduce cost through savings in production cost of modules and BOS components, PV systems will become even more cost-competitive in future at higher loads. This is more so, when consideration is given to the present deregulation in the oil industry and the removal of subsidy on petroleum products.

In an ECN survey of business activities in Nigeria, covering existing industrial activities and the state of application of PV technologies, forty four (44) active companies and research centres were involved in the importation and installation of PV system.
On the sources of supply of PV components, USA contributed 49% while German and British makes contributed 13.7% and 12.5% respectively. Holland, India, Denmark and France contributed 5.7%, 4.6%, 3.4% and 2.3% respectively. Eight other Countries, including Nigeria, contributed about 1% each.

The 1.1% contribution by Nigeria were in battery production by Exide Batteries Nigeria Ltd, and Solar-PV refrigerators produced by Solar Electric System of Jos. The battery produced by Exide is shallow-cycle type and not the deep-cycle type of battery recommended for solar PV applications. The PV components which are marketed in the country include modules, batteries, inverters, converters, charge controllers, bulbs/tubes, refrigerators, lighting systems, solar lantern, solar pumps and junction boxes.

Applications, benefits and limitations

Major considerations for the use of crystalline silicon for PV include the availability of the material, its chemical stability and the improvements in the material due to advances in the micro electronics industry. The present scenario puts C-Si in a comfortable position of being at the forefront PV power production in many years to come. The major limitation of crystalline silicon is the high capital cost in growing the crystalline ingots and the wafer saving technologies which are wasteful of material.

Amorphous Silicon technology has the potential for module production at very low cost $1/Wp because of its lower production cost but its major weaknesses include the low efficiencies and light-driven degradation due to the well-known Stabler Wronski effect.
Technologies based on thin films possess the potential for reduction in the cost of PV modules. Photovoltaic systems have proved to be technically feasible for meeting the

electrical energy requirements for a wide range of applications, in rural electrification; street lighting, water pumping; refrigeration; telecommunications and Solar Home Systems.

These applications have positive social and economic impact on the lives of individual users, communities and the nation. The impacts they are currently making and will continue to make towards national development and poverty alleviation cannot be overemphasized. Photovoltaic systems are environmental benign. They do not emit poisonous gases or pollutants into the atmosphere and pose little or no threats to climate change and environmental degradation, as is the case with conventional electricity generation with fossil fuel and nuclear technologies. They are free from mechanical noise as they normally have no moving parts.

However, some limitations exist to the widespread dissemination of PV technologies. The present high initial cost of modules and systems discourages investment in the technology because energy users are usually interested in the initial cost and not in the life-cycle-cost of the energy option they chose. Solar radiation varies with time of day and seasons, thus storage is required in most PV applications. There is a lack of awareness on the viability and applications of PV systems. Government has for many years not shown enough political will to support the incorporation of PV technologies to assume a reasonable share of the energy mix of the Country. Furthermore, there is inertia on the part of government and industry to move from well-known technologies to a relatively new one. Trained manpower base in solar PV is scarce and needs to be considerably increased. There is lack of commercial activity and financing options in the solar PV field. The lack of political stability weakens the enthusiasm of local and foreign investors in PV.

The global market situation for solar PV

Growth rates of 30% or more have become the established trend in the global photovoltaics market. World PV cell and module production reached its highest level in 2003 at 744.08 MW. This represented a 32.4% increase (182MW growth in annual output) over the 2002 figure of 561.77 MW. In both Japan and Europe, production grew by over 40%. Japanese PV cell and module output increased by 45% to 363.91 MW and there was a 43% increase in European production to 193.35 MW. However, there was for the first time a decrease in production in the US, which dropped by 14.6% to 103.02 MW, largely due to the collapse of one of the companies, Astropower.

Production in the rest of the world more than doubled during 2003, increasing by 52.4% to reach 83.8 MW. The trend in world PV production from 1995 to 2003 shows that the bulk of the production is concentrated in the hands of the key players. During 2003, the top ten manufacturers accounted for 85% (634.42 MW) of total production. Japanese companies maintained first and third positions. Shell solar came second followed by BP solar. Sanyo's production of its high-efficiency amorphous silicon/crystal silicon heterojunction continues to remain among the top ten, taking eight place. India, China, Taiwan, Brazil, Australia, Hong Kong, and Malaysia are among the leading producers outside Japan, European Union Countries and the US. Together, these countries contributed 83.80MW of the total module production in 2003.

On the demand side, grid-connected installations have continued to dominate mainly in the key markets of Japan, Germany and the US State of California. This grid-connected residential/commercial sector is estimated to have grown from 270 MW in 2002 to 365 MW in 2003 or 49% of the total world module production in the year. The Japanese, German, United States and European markets for grid-connected systems increased by 200 MW, 120 MW, 38 MW and about 30 MW respectively.

Present local demand and supply situation

From available records, the first PV system in Nigeria was installed in the early 1980's but unfortunately till date, no facilities have been set up for the local production of PV cells and modules. Presently, Nigeria has only acquired the capability for manufacture of non-solar-grade batteries for PV applications and the assembly of Solar-PV refrigerators.

(i) Supply situation
All the PV modules used in the Country are imported. A survey, of business activities in solar PV in Nigeria was conducted by the ECN in 1999. In that survey, the list of number of manufacturers of PV components and systems marketed in Nigeria, as well as the number of countries involved was compiled. By 1999, a total of 44 companies and research Centres were active in the importation and/or installation of PV systems. The distribution of the companies is given below in Table 2.6.

Table 2.6 ECN 1999 Survey results of solar PV businesses in Nigeria

City	Lagos	Kad.	Kano	Jos	Bauchi	Maid.	P H	Nsuk.	Sok.	Total
No. Comp.	30	6	2	1	1	1	1	1	1	44

Kad.; Kaduna; Maiduguri; P.H. – Port Harcourt; Nsuk. – Nsukka; Sok. - Sokoto

Each of the companies was involved in PV business in any or more than one of these activities viz.:- consultants, vendors, contractors or distributors.

Importation of Solar-PV Components

From the 1999 survey, the total capacities of PV system components imported between 1993 and 1998 was 264 kWp. Fourteen companies were involved in the importation of modules, twelve in the importation of inverters and two or three imported converters, solar refrigerators, solar lanterns and lighting systems.

It is recorded that all the imports were made by 14 out of 22 companies involved in PV business at the time. Prior to 1995, the imports were made by only 4 companies. While all the 14 companies imported PV modules, and twelve of them imported inverters as well, only two or three companies imported converters, solar refrigerators, solar lanterns and lighting systems. The import of solar pumps was dominated by two companies and only one company reported the import of junction boxes.

The import situation at the moment in terms of companies involved, may have changed from what was earlier recorded in 1999. It is possible that some companies (e.g.

Siemens) may have stopped business in Nigeria, while some new companies have sprung up. It will require a fresh survey to determine the current level of importation of PV components in the Country and the companies involved in the importation.

(ii) Demand situation
The demand situation can be assessed by the number of installations carried out within a specified period of time. The total module installation for 1999 is estimated to be 264 KWp. Assuming a growth rate of 24% (twice the recorded value of 12% at mid-year) an average growth rate of PV module installation of 46% is established. Using this growth rate, the PV module installation in 2004 is estimated to be 1.74 MWp. The demand for 2005 is estimated to be 800KWp. An exact figure, however, can only be obtained from an up to date survey of the installation carried out by PV companies and research Centre.

Key drivers for solar PV technology market

The major drivers for the PV market in Nigeria include unreliability of grid power supply as the private sector use solar energy as back up; governmental sponsored remote power supply as well as international agencies, NGOs and individuals.

Other drivers are: the unreliability of grid power supply which has created a market for solar energy as back-up for communication companies such as NITEL and several banks. This segment of the market has grown partly through the activities of PV entrepreneurs.

Government sponsorship of remote power supply is another driver. The governments, especially the Federal and State governments, have particularly through their ministries of agriculture, water resources, health, education, power & steel, disseminated several PV systems for irrigation water pumping, water pumping for domestic use, vaccine refrigeration particularly for the expanded programme on immunization, village electrification. Some parastatals of Government e.g the Energy Commission of Nigeria, (ECN) the Agricultural development programme (ADP), the Rural Electrification Boards (REBs), Arid Zone Development Authorities (AZDAs).

Promotion of the dissemination of PV systems in the country by International Organisations, in collaboration with the governments of Nigeria is another driver. Some examples include: contributions to the Alternative Energy Fund of Jigawa State by the United States DOE and the WHO assisted National Programme on Immunisation (NPI). This programme use solar-PV-powered vaccine refrigerators.

Individual promotion by some individuals who can afford it have installed solar PV systems either for remote power supply or as back-ups for poor grid services is another key driver for solar PV market.

2.3 Biomass energy and electricity cogeneration technologies

The biomass resources of Nigeria consist of wood, forage grasses and shrubs, animal wastes arising from forestry, agricultural, municipal and industrial activities as well as acquatic biomass. The primary way to utilize biomass is through direct combustion. Biomass is similar to fossil fuels as it is also made up of hydrocarbons that can burn to release heat.

This vegetative cover is being denuded due to the incursion of agriculture, energy use and other natural and man-made factors.

Resource situation

Previously, biomass dominated Nigeria's energy landscape. It remains a leading source of energy for Nigeria contributing 37% of total energy demand, and the energy of choice for the vast majority of rural dwellers and the urban poor. However, the resource base is under pressure from both human activities and natural factors, such as drought.

Estimated resource base

The biomass energy resources of the nation have been estimated to be 144 million tonnes/year. Nigeria is presently consuming about 43.4 x 10^9 Kg of fuelwood annually. The average daily consumption is about 0.5 to 1.0 kg of dry fuel wood per person. The rate of consumption hardly matches the rate of reforestation.

The total area of Nigeria is distributed among the various uses as shown in Table 2.7 below, where it is seen that Nigeria's total area is 92.4 million hectares out of which 79.4 million and 13.0 million hectares are occupied by land and water bodies respectively. Agricultural land occupies 71.9 million hectares, which are further demarcated as shown in the same table.

The foregoing shows that there is a huge potential for production of agricultural biomass in Nigeria. 94% and 68% of Nigerian households are engaged in crop farming and livestock farming respectively. Table 2.3.2 further underscores Nigeria's potential for the production of manure, which is a key component of agricultural biomass.

Table 2.7: Nigeria's size and land use parameters

Nigeria	Quantity (Million ha)	Percentage (%)
A. SIZE		
Total Area	92.4	100
Land area	79.4	85.9
Water bodies (rivers, lakes etc)	13	14.1
B. LAND USE		
Agricultural land	**71.9**	**77.8**
Arable cropland	28.2	30.5
Permanent cropland	2.5	2.7
Pasture land	28.3	30.6
Forest and woodland	10.9	11.6
Fadama	2	2.2
Other land	7.5	8.1

Source: Federal Ministry of Agriculture

From Fig. 2.4, it can be seen that in 1996 Nigeria recorded an aggregate crop production of about 93.3 million tones for the major crops. This quantity refers to the harvested useful parts of the plants. The discarded parts consisting of roots, leaves, stalks, straws, chaff and other parts of plant shoot (otherwise called crop biomass) would be far in excess of the figures shown in Fig. 2.4. From all the above, it is seen that Nigeria's annual production of agricultural biomass is enormous.

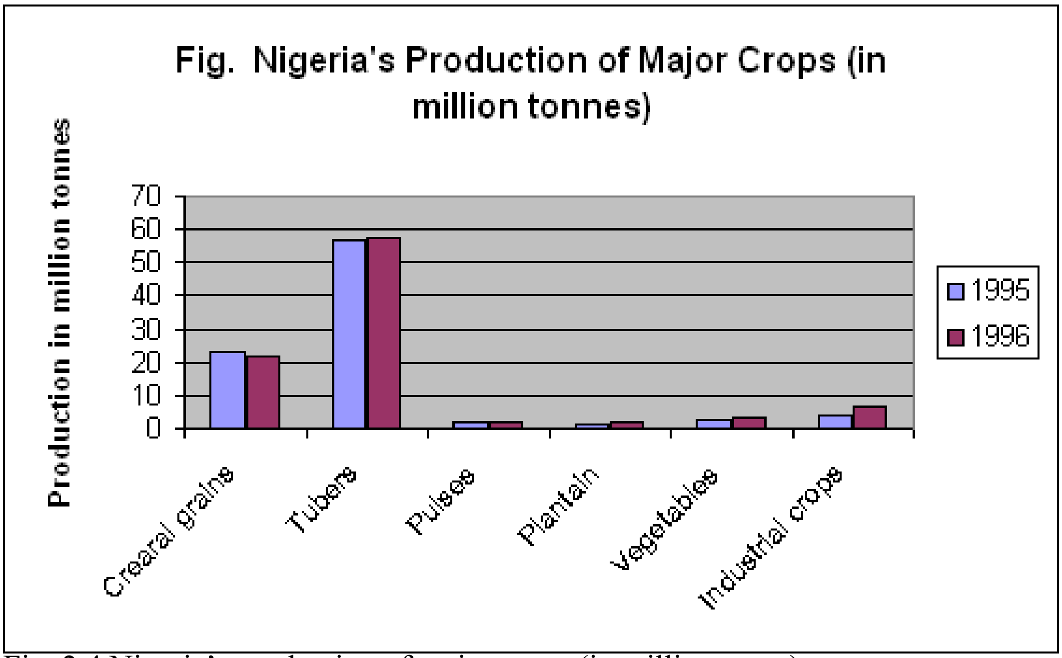


Fig. 2.4 Nigeria's production of major crops (in million tones)

Other relevant biomass resource base includes aquatic plants such as water hyacinth and municipal wastes – both of which constitute major environmental problems. These present opportunities for meeting energy needs sustainably.

Bagasse from Sugarcane in Nigeria

The current consumption of sugar in Nigeria is in excess of 1.2 million tonnes annually, yet the country is heavily dependent on sugar imports. The Nigerian sugar sub-sector is largely underdeveloped with untapped resources and potentials, and the country's existing sugar processing industry has undergone a slow decline over the past decade. The country's four sugar companies, all of which were established by the Federal Government of Nigeria, were characterized by low productivity occasioned by managerial, financial and infrastructural constraints, among others. At present none of these plants are in operation. Currently, most of the sugarcane grown in Nigeria by farmers is chewed for its juice while a small quantity is processed into mazarkwaila and madi products which are of limited acceptability as substitutes for refined sugar. Bagasse is generally discarded and left to decompose, or incinerated as a means of disposal. Nigeria's current dependence on sugar imports draws on the nation's foreign reserves and represents a lost opportunity in terms of employment, revenues, and power generating capacity through bagasse-fired cogeneration.

Table 2.8: Existing sugar plants in Nigeria

S/N	NAME OF COMPANY	LOCATION	NEW OWNERS
1	Savannah Sugar Company	Numan, Adamawa State	Dangote Group
2	Nigerian Sugar Company	Bacita, Kwara State	Joseph & Sons Ltd
3	Sunti Sugar Company	Sunti, Niger State	Privatisation process is on going
4	Lafiagi Sugar Company	Lafiagi, Kwara State	Privatisation process is on going

However, the prospects for Nigeria's sugar industry are now improving as the industry is in a period of transition. Two of the sugar companies formerly owned by the Federal Government of Nigeria have been privatized, while negotiations are ongoing for the remaining two factories. Furthermore, the Federal Government has undertaken measures to support the development of the sugar industry. The National Sugar Development Council (NSDC), established by Decree 8 in 1993, has now set the target of achieving the production of 70% of the country's sugar requirement by the year 2010. The ultimate goal is to reach self-sufficiency. In 2000, the National Sugar Development Council conducted a survey of Nigeria's potential for sugarcane production[1]. The survey identified 29 states in Nigeria as potential sugarcane growing sites, amongst which Kogi State was identified as having approximately 950,000 hectares potentially available for sugarcane production. These sites have excellent climate and soil for production of quality sugarcane.

Bagasse Cogeneration Technologies

Cogeneration (Combined Heat and Power or CHP generation) is a fully mature, proven, competitive and environmentally benign technology. Such claims arise from its relatively much higher efficiency and its ability to use wastes effectively, whether such wastes be biomass and biomass wastes, municipal or industrial wastes. It is applicable as a distributed power generation source in applications that require both heat energy and electrical power. Cogeneration is the simultaneous production of electrical power and heat energy in applications where both are used preferably on the generation site, or excess of either is sold to a third party such as the utility grid (for excess electricity) or a district heating or cooling systems (for excess heat energy). In conventional power plants on the other hand, up to 70% of the thermal energy used for production of electricity is lost in cooling towers or in condensers cooled by river, lake or sea water.

Cogeneration systems on the market range from as low as about 1 kW_e (Stirling-engine-based systems for domestic applications) to unit sizes up to hundreds of MW_e (for gas turbine-based industrial applications). Obviously, the choice of prime mover strongly influences the heat quality and the heat-to-power ratios achievable by a cogen system. The turbine exhaust gases temperature (TET) in a simple gas turbine for example is

[1] National Sugar Development Council, 2000.

around 500°C, from which it is possible to raise high-pressure steam for on-site use. On the other hand, the heat recovered from a reciprocating engine is a lower grade heat at a temperature of about 120°C, which can be used to produce only hot water at 70 – 85°C, depending on the effectiveness of the heat exchanger used. To maximize savings, the system will be designed to cover on-site heat demand, with the electricity as the by-product. Typical heat-to-power ratios for low-temperature heat demand (in residential and district heating/cooling applications) will be about 3:2, while a ratio of 1:1 is typical for high-temperature heat demand in industrial applications.

Cogeneration using agricultural wastes is a growing industry worldwide, including several countries in Africa. Typical wastes include: bagasse by sugarcane industries, wood shavings, saw dust, and wood chips by sawmills and wood processing plants, groundnut shells, palm kernels shells, etc. by oil mills. These enterprises are often able to generate energy in excess of their demands and the excess is usually available for sale to the utility or other nearby establishments. The groundnut oil industry in the Gambia is able to generate all the 4.5 MW electricity it requires for its screw presses with boilers fuelled by groundnut shells. Other on-site energy generation plants from process wastes are: the sugarcane industry in Mauritius and Kenya which generates all its electrical and heat energy needs from boilers fuelled with bagasse; the rice industry in Malaysia in which rice husk from the rice mills is used to generate the electricity required in the milling and the drying plant at a unit cost of about US $0.03 per kWh.

Typical process of bagasse cogeneration is sketched out in figure 2.6 below.

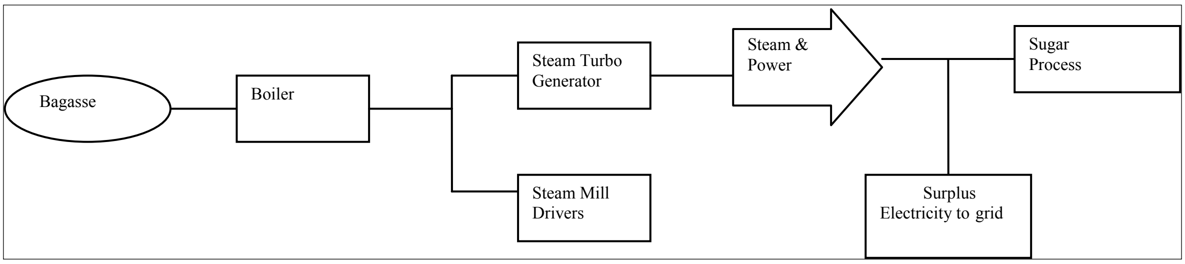


Figure 2.5: Bagasse cogeneration process

Traditionally, the majority of potential investors in cogeneration systems are industrial, commercial and public organizations whose main activity is not the production of energy, and for whom cogeneration represents a significant investment (at about $1500/kW) in a non-core part of their business. Thus, to obtain the best return on such investment, the cogeneration plant is required to run for as many hours as possible in order to recover as much process heat as possible. Hence, correct system sizing and choice of prime mover become critical in cogeneration technology application.

In such traditional applications, the prime mover will generally be fuelled by natural gas or a petroleum-derived fuel such as diesel or aviation kerosene. Such fuels do not give any additional environmental advantage to the technology, by way of carbon savings. However, when the prime mover is fuelled by biomass, biomass-derived fuel or biomass wastes, then potentially greater advantages emerge, particularly for applications in developing countries such as Nigeria where biomass is a ready natural resource. CHP works with all fuels, including renewables; sewage and landfill gas; sawdust, wood shavings and woodchips, straw, sugarcane and other biomass; domestic, commercial, municipal and industrial wastes, etc. It works with new technologies such as fuel cells, micro-turbines, etc.

Benefits and limitations

From a financial point of view, bagasse cogeneration is a win-win investment for the sugar industry. Baggase cogeneration especially in high temperature and pressure configuration could play a leading play role in ensuring widespread access to electricity services. Sugar cogeneration plants have the following economic benefits:

- Increase the viability of sugar mills by diversification their product and income base
- Near-zero fuel costs
- Increased diversity and security of electricity supply
- Location at the point of energy demand, leading to minimal transmission and distribution (T&D) losses; and
- Provides opportunities for additional income through CDM.

Social benefits include the following:

- Improved employment opportunities for the local population
- Increased access to electricity, especially in rural areas
- Improved the security of electricity supply by improving the diversification of sources.

In additional to economic and social benefits, bagasse cogeneration has obvious environmental impacts, and they include the following:

- It has low emission of particulates, SO2, NOx and CO2, compared to conventional sources of electricity
- Compared to composting of bagasse, cogeneration offers reduced emission of greenhouse gases; and
- Improves fuel efficiency.

2.4 Wind power

This section considers the wind energy resources, technology assessment, and market situation of wind technology.

Resource Situation

Nigeria is subject to the seasonal rain-bearing south-westerlies, which blow strongly from April to October and to the dry and dusty north-east trade winds which blow strongly from November to March. Most areas sometimes experience some periods of doldrums in between these periods. Wind energy reserves are measured in terms of wind speeds at 10m above the ground level.

In Nigeria, wind energy reserves at 10m height shows that some sites have wind regime between 1.0 to 5.1 m/s. The wind regimes in Nigeria are classified into following four regimes > 4.0 m/s; 3.1 – 4.0 m/s; 2.1 – 3.0 m/s; and 1.0 – 2.0 m/s. Hence, Nigeria falls into the poor/moderate wind regime. It is also observed that the wind speeds in the country are generally weak in the South except for the coastal regions and offshore, which are windy. In the coastal areas and in the large areas offshore from Lagos State through Ondo, Delta, Rivers and Bayelsa States to Akwa Ibom State, potentials exist for harvesting strong wind energy throughout the year. Except for maritime activities and fishing, there is hardly any obstacle to wind farm development for near-shore wind energy farms. Inland, the wind is strongest in the hilly regions of the North. The mountainous terrains, especially in the middle belt and the northern fringes of the country, where prime wind conditions may exist are to a large extent sparsely populated, and extensive areas for wind energy development exist in these locations.

Estimated Resource Base

Due to the varying topography and roughness of the country, large differences may exist within the same locality. Hence within a few kilometres, the wind speed may vary. The values range from a low 1.4 to 3.0m/s in the Southern areas and 4.0 to 5.12m/s in the extreme North. Peak wind speeds generally occur between April and August for most sites. Initial study has shown that total actual exploitable wind energy reserve at 10m height, may vary from 8 MWh/yr in Yola to 51 MWh/yr in the mountain areas of Jos Plateau and it is as high as 97 MWh/yr in Sokoto.

Status of database, including adequacy and gaps

In this section, the status of the data that are available at the international, national, and site specific levels together with the gaps in available data are discussed.

Types of Data

Wind resource is usually expressed in wind speed (m/s) from which energy units can be obtained. There are usually two levels of data needed for national wind energy development. At the top level is the Meso-scale (National level) data. This type of data is useful for policy and it is usually the first call for developers of wind energy projects. The other is the site specific local level where one obtains more detailed data based on measurements.

Wind Farm Energy Data

When a particular site appears promising for wind farm development, detailed site-specific measurements are carried out through the erection of a meteorology mast, about 30 to 50m in height depending on the terrain, for measuring wind speed and wind direction at different heights. Typical hub heights for wind turbines are now 60m and it is projected to reach about 100m by year 2030

Actual measurements are needed because the power output of a wind farm is sensitive to wind speed, being proportional to the cube of the wind speed. Thus, doubling of the average wind speed leads to an increase of the power in the wind by a factor of eight. Therefore wind speed can determine the viability or otherwise of a wind farm project. Detailed and reliable information about variation in wind speeds and direction over the year is therefore vital for any prospective wind power development. Apart from the wind speed, the wind speed frequency distribution, commonly described by a Weibull distribution is also important

Available National Level Data

The Nigerian Meteorological Agency (NMA), which is the national authority, carries out routine measurements and collection of wind data for the country. The records are for the 42 Synoptic stations mainly based at the airports and urban centres. These records available in its archives (published and unpublished) give the 3-hourly records of wind, the wind speed, the prevailing wind directions, the annual mean of the percentage wind frequencies in different directions and for various speed ranges and the number of days for which the wind force is greater than No. 4 on the Beaufort scale.

The International Institute for Tropical Agriculture (IITA), Ibadan, also has wind data for about four of its stations. IITA only collects wind speed at a height of 2m. Some of the wind instruments at IITA are the Casela and Met014A cup anemometers.

The wind instruments installed in each of the stations of the NMA differ. About 75% of the stations use cup generator anemometers while the remaining stations use the dine pressure tube anemometers. About 90% of the stations have ordinary wind vanes installed alongside the anemometers. The anemometers are installed at different heights due to the presence of tall buildings or trees, but most are installed at 6ft (about 2m) height. Hence, their data need to be harmonized for uniformity for it to be useful for the power sector. Most of the equipment used by the Nigerian Meteorological Agency and IITA are calibrated to WMO standard. There is a WMO Centre for Sub-Saharan Africa in Nigeria.

The data collected at the observing stations are sent to the Data-Returns office at Oshodi, Lagos, which serves as the Data Bank for all meteorological data supervised and collected by the NMA. The data are archived both in their original manuscript form and/or in computer storage devices. The NMA computer centre is equipped with Database Management subsystems for climate computing developed by NMA. Computerization started around 1974 and has about 40 years of computerized wind data.

Wind Atlas

Wind maps/atlases are contour values of wind speed at a specified height for a given geographical area. They represent a first port of call for any wind energy developer, providing an indication of a best estimate of wind resources across a large area. They provide information on areas that merit further investigation when planning a wind farm.

Ideally, wind atlas should be generated through on-site measurement using anemometer. For a large area like a country this is quite expensive and time consuming and impractical. Hence, wind atlases are generally generated by computer models which have been calibrated with wind speed data at local meteorological stations. The models employ parameters such as topography, elevation and ground surface cover.

The World Meteorological Organization (WMO) in 1981 developed a worldwide wind resource map, showing the mean wind speed and mean wind power density of different regions for guidance. This wind resource map described in the Technical Note 175 by WMO is based on the analysis of wind measurements taken by meteorological institutes. Scanty information exists on Nigeria in this document. In order to produce a wind atlas for Nigeria, there is need for data from more than 350 stations - onshore or coastline (China has more than 900 meteorological stations).

Available Site Specific Level Data

A major feasibility study on windmill was undertaken in Nigeria by the UNDP in 1984. This study on the potential for windmill application to various activities concluded that good potential exists in the semi-arid and temperate areas of the North, the middle belt and the shores of Lake Chad for such activities as small scale irrigation, domestic water pumping, livestock water supply and electric power generation. This was a desktop study.

In 2003, the Federal Ministry of Science and Technology engaged a firm of consultants – Lahmeyer International (LI) – for its wind energy mapping programme. This work only covers ten (10) selected sites across the country where detailed site study are to be carried out using about one year (12-month period) continuous data from wind measuring equipment.. Lahmeyer International was also to collect historical wind data, erect wind measurement masts and install wind measurement equipment on the masts for data collection, and produce the zero level wind maps that indicate potential sites. The long-term wind energy potentials of these sites could then be quantified.

Table 2a indicates the wind speed results from the wind mapping in the 10 sites. The study found that there are several areas suitable for large wind energy applications in Nigeria. The table shows data for wind speeds at anemometer heights of 10m, 30m or 40m depending on the particular station. Most of the sites can use small wind turbines and wind mills from the 10m height data.

Further, analysis of the data at 30m or 40m height indicates that all the areas are suitable for wind farms and that the highest wind energy yield is at the coastal area of Lagos, followed by Sokoto area and the Jos Plateau area among the ten sites studied. The gross energy yield data appears in Table 2b where the potential for substantial contribution to rural electrification by wind energy is apparent. A 10 MW wind farm will produce an about 65 GWh/yr at 75% availability, which is enough energy for a number of local government areas that cannot be economically connected to the national grid.

Table 2a: Ranking of Wind Speed Measured in Some Nigerian Sites

Site ID	Site Name	Measured mean wind speed [m/s]	Anemometer height [m]
Sok01	Sokoto/Badaga	5.4 (4.83)	30
Jos01	Jos Airport/Kassa	5.2 (4.67)	30
Gem01	Gembu/Mambila Plateau	5.0 (4.57)	40
Pan01	South Part of Jos Plateau/Pankshin Hotel	5.0 (4.27)	40
Kan01	Kano/Funtua	4.9 (4.07)	30
Mai01	Maiduguri/Mainok	4.7 (3.68)	30
Lag01	Lagos/Lekki Beach	4.7 (2.49)	30
Enu01	Enugu/Ninth Mile Corner	4.6 (4.13)	30
Gum01	Gumel/Garki	4.1 (2.99)	30
Ibi01	Ibi Meteorological Station	3.6 (2.53)	30

Note:
The figures in the ( ) brackets indicate measurements at 10m.

Table 2b: Gross Energy Yield in MWh/yr at the ten stations of the study

Site ID	Gross Energy Yield, MWh/yr		
	Model FL 100, 100/20 Rotor dia. 21.0 m Hub height 34.5 m	Model FL 250, 250/50 Rotor dia. 29.5 m Hub height 42.0 m	Model V52, 850/52 Rotor dia. 52.0 m Hub height 44.0 m
Sok 01	153.5	358.8	1,235.8
Jos01	129.6	299.0	1,025.8
Gem01	112.9	253.9	855.3
Pan01	117.1	272.1	939.6
Kan01	116.3	281.2	963.7
Mai01	102.7	262.2	906.1
Lag01	129.3	386.1	1,402.8
Enu01	92.9	217.9	734.2
Gum01	73.4	197.2	681.4
Ibi01	49.8	141.3	481.2

Note:
Model FL – Fuhrlander make of wind turbines
Model V – Vestas make of wind turbines

Gaps in Available Data

There are no national or local "wind atlases" that have been produced for Nigeria. Only a few wind maps for limited sites are available. Hence there is the need to develop wind maps and atlases for the country that will provide information about the quantity, distribution, quality and utilization possibilities to determine the commercial feasibility of wind energy generation and decision making on investments.

Technical Assessment of Wind Power Technologies

In this section, an overview of the technology used to harness wind for energy use, the technical characteristics, economic competitiveness and benefits and limitations of the technology are presented.

Overview of Wind Power Technologies

A large amount of power is contained in the movement of air in form of wind. Harnessing of wind as a source of energy has a long history starting from the time the Persians built the first known windmills as early as 250 B.C. Much later, wind energy was widely used as a source of power before the industrial revolution. However, the interest in wind technology nose-dived from the industrial revolution period when it was displaced by the more reliable and cheap fossil fuel. In the 1970s there was a renewed interest in wind energy technology because of the increases in oil prices which affected the economies of the industrialized countries. In the last two decades, these interests, reinforced by the need for cleaner energy technologies, have resulted in enormous progress on the development of wind turbine for electricity generation.

(i) Categorization and Applications of Wind Technology

Applications of wind turbines may be categorized as indicated in Table 2.4.1 below, which also shows the unit size of wind turbines that are typically applied in the different categories. Following a decision on extending the electricity production capacity by one or more wind farms, one has to decide where to place the wind farms (siting), the size of the wind farms (sizing) and the optimum layout of the wind farms. The size of a wind farm is often determined with respect to a number of constraints, such as: planning legislation; local and national development plans and policies; land availability, access and transport infrastructure; power system – present and future situation; wind turbine size; financing; electricity market; and environmental impacts.

Table 2.9: Categorization of wind power systems

Installed Power	**Categorization**	**Wind Turbine Capacity Range**
<1kW	Micro systems	<1kW
1-100kW	Wind home systems and hybrid systems	1-50kW
100kW-10MW	Isolated power systems and decentralized generation	100kW-1MW
>10MW	Wind Power Plants – wind farms on-land	>500kW
>100MW	Wind Power Plants – wind farms offshore	>2000kW

Economic and financial optimum choice of wind farm size for society and investors at given conditions may vary for different sites, hence, sizing and siting are integrated activities. Further, sizing involves aspects that may not easily be quantified monetarily. Wind farm site selection most often entails a comparison of selected candidate sites with respect to issues such as: the possibility to obtain planning authorization and approvals; successful outcome of local hearings; potential wind energy production; environmental costs and benefits; sustainability, uncertainties and risks; availability of land and infrastructure; investments and investors; design safety, reliability and lifetime; wind farm and power system operation and maintenance, economic and financial viability.

(ii) Trend in Technology

Although there has always been a wide variety of designs on the margins of commercial technology, in the early days the Danish, three-bladed, single fixed speed, stall regulated turbine dominated the market at rated power levels of generally less than 200kW. Blades were almost invariably manufactured from glass-polyester resin.

In 2003 the focus of attention was on technology around and above 1.5MW rating, and commercial turbines now exist with rotor diameters in excess of 100m. Designs with variable pitch and variable speed predominate while direct drive generators are becoming more prevalent. Epoxy-based resin systems predominate in blade manufacture and carbon fibre reinforcement is increasingly used in big blades. Variable speed may offer a little more energy capture but this is largely offset by the added cost. The design changes have largely been driven by market demands – better acoustic noise reduction and output power quality, reduced gearbox problems etc.

Since the initial commercialization of wind energy in the early 1980s, there have, of course, been huge cost reductions and this is a direct consequence of the dramatic growth in the market. Thus, modern wind turbines are more sophisticated and adaptable than their predecessors on account of technology development and are also much cheaper (discounting inflationary factors) on account of market expansion.

Status of Wind Energy Technology Worldwide

The status of wind energy technology in some countries in the world that are in the forefront in the use of wind energy resources and the state of the technology in the country are discussed in what follows.

(i) *Global Wind Energy Utilization*

World wind energy capacity has been doubling every three years during the last decade and growth rates in the last few years have been even faster. It is doubtful whether any other energy technology is growing, or has grown at such a rate. The attraction of wind as a source of electricity which produces minimal quantities of greenhouse gases has led to ambitious targets for wind energy in many parts of the world. More recently, there have been several developments of offshore wind installations and many more are planned. Although offshore wind generated electricity is generally more expensive than onshore, the resource is very large and there are few environmental impacts. While wind energy is well developed in the industrialized world, it has attractions in the developing world as it can be installed quickly in areas where electricity is urgently needed.

At the end of 2003 there were more than 68,000 wind turbines installed world wide corresponding to about 40,300 MW accumulated capacity distributed as follows:

Table 2.10: Global wind power installed capacity

Region	Installed capacity (MW)	Some specific countries (MW)
Americas	6,905	USA – 6,361
Europe	29,301	Germany, Denmark & Spain – 24,108
Asia	3,790	India – 2, 125
Africa	211	
Rest of the world	95	

Thus more than 80% of the total global capacity was implemented in only five (5) countries: Germany, Spain, USA, Denmark and India.

The largest manufacturing capacity is in Denmark, Germany and Spain. The technological development in wind energy has been extraordinary since 1980, increasing the size of the largest commercially available wind turbines from 50kW to about 4.5MW (with prototypes up to 6 MW or larger planned).

(ii) *Nigeria Wind Energy Utilization*

Wind energy utilization in Nigeria is relatively insignificant. The Tractor & Equipment (T & E) Division of UAC started manufacturing the UNAPOWER wind pumps in Nigeria. Test units were installed in Goronyo, Sokoto State and the UAC Agro Farms in Kedanda, Kaduna State. The project was initially successful and attracted the attention of Katsina State Government who ordered 62 units in 1989. The high cost of each unit (over US$6,000 in 1990) coupled with difficulties encountered in maintenance limited their widespread use. The hundreds of wind pumps scattered all over the country are ill maintained and some have been abandoned. Some state governments, like Jigawa and Kano, are making efforts to install new wind pumps. There are two pilot wind electricity projects in existence. The 5 kWp Sayya Gidan Gada wind electricity project at Sokoto, and a 0.75 kWp wind electricity project near Danjawa village is being run on an experimental basis to prove the viability of wind farm in the area. The Report of the Technical Committee on Quantification of Energy Resources states that as far back as the 1960s, more than 100 wind pumps had been installed in Kano, Jigawa, Sokoto, Yobe, Katsina, Lagos (Badagry) and Plateau (Jos) States to supply water for both human consumption and livestock (European Commission, 2001).

Technical Characteristics of Wind Turbine

The main components of a wind electric generator are the tower, nacelle, rotor, gearbox, generator, braking system, yaw system, controllers and sensors. The life of a wind electric generator is taken as 20 years. When considering the installation of a wind farm, the single most important parameter is the wind speed. As the power output is proportional to the wind speed raised to the third power, a doubling of the average wind speed leads to an increase of the power in the wind by a factor of eight (8), so even small changes in wind speed can produce large changes in the power production.

(i) *The Typical Wind Turbine*

Wind turbines transform kinetic energy in the wind to electricity. Almost all commercial wind turbines are 'horizontal axis' machines with rotors using 2 or 3 airfoil blades, although a few "vertical axis" machines and "Savonius rotor" wind turbines exist. The rotor blades are fixed to a hub attached to a main shaft, which turns a generator normally with transmission through a gearbox. Shaft, generator, gearbox, bearings, mechanical brakes and the associated equipment are located inside the nacelle on top of the tower.

The nacelle also supports and transfers structural loads to the tower, together with which it houses all automatic controls and electric power equipment. The wind turbine automatically yaws the nacelle to the direction facing the wind for optimal energy production. The turbines are stopped at very high wind speeds (typically 25 m/s) to protect them from damage. Rotors may operate at constant or variable speed depending on the design. Modern MW-size machines are all variable speed concepts. Typical rotor speeds at rated power range from 15 revolutions per minute and up – a factor, which influences the visual impact. The larger the rotor the lower the rotational speed in order to keep the blade tip speed in the optimal range – 60-80 m/s. Power output is automatically regulated as wind speed changes to limit loads and to optimize power production.

The present "state of the art" large wind turbines have power control by active stall or pitch control (in both cases pitching blades) combined with some degree of variable speed rotor, and a two-speed asynchronous generator or a gearless transmission to a multiple synchronous generator and power electronics.

Wind turbines range in capacity (or size) from a few kilowatts to several megawatts. The crucial parameter is the rotor diameter – the longer the blades, the larger the area swept by the rotor and thus the volume of air hitting the rotor plane. At the same time, the higher towers of large wind turbines bring rotors higher above the ground where the energy density in the wind is higher. Larger wind turbines have proved to be more cost-effective due to improvements in design and economies of scale, as well as with a higher energy production per swept m^2, due to the higher towers and better aerodynamic design.
Regulation of the output power is obtained through stall and pitch control.

(ii) *Wind Speeds*

Initially, most wind turbines operated at fixed speed when producing power. In a start-up sequence the rotor may be parked (held stopped) and on release of the brakes would be accelerated by the wind until the required fixed speed was reached. Subsequently, variable speed operation was introduced. This allowed the rotor speed and wind speed to match so the rotor could maintain the best flow geometry for maximum efficiency. An important difference between this kind of variable speed operation and conventional fixed speed operation is that moderate speed variations are still permitted.

(iii) *Rotor Size*

The square of the diameter of a wind turbine rotor size determines how much energy it can produce. In recent years the trend is for bigger diameters corresponding to higher power rating of wind turbine. For example there is a remarkable increase from 65m to 69m to almost 74m in average diameter of a 1.5MW turbine for the years 1997, 2000 and 2003 respectively. Both the rotor diameter and the tower heights of present-day commercial wind turbine designs have grown remarkably over the past decade.

Economic Competitiveness

There are many factors affecting the cost of wind generation. These include investment/capital cost, operation and maintenance (O & M) cost, government policy, management capacity and skill, size and capacity factor of the turbine, and site of the project.

(i) *Investment Cost*

The capital cost of a wind energy project is dominated by the cost of wind turbine. This alone takes about 75% of the total cost of a wind energy project. However, over the last 12 years, there has been a reduction in cost by approximately 30%. The cost of a wind energy project is dependent on the size of the turbine. The smaller sizes are more expensive than the larger sizes on a per kW installed capacity basis. Also, capacity factor drives up the relative capital cost. For instance, if there are two wind turbines of the same size but with different capacity factors say 30% and 60%, the relative capital cost of the one with the lower capacity factor will be higher than the one with the higher capacity factor. Table 2.4.2 gives an overview of investment cost for small and large wind turbine sizes for some countries and regions of the world.

(ii) *Energy Cost*

Cost of energy generated is dependent on both turbine size and project site. Generation cost per unit energy is higher for small turbines than for large turbines. At good sites where the wind speed is higher and less intermittent, the cost of energy generation is lower than for bad sites. Table 2.4.2 gives the figures for some regions of the world..

(iii) *Operation and Maintenance (O&M) Cost*

Wind energy projects generally have very low O & M cost. For instance, O & M cost for the first two years in Germany is about 2-3% of total investment cost. It is decreasing for newer and larger wind turbines.

Table 2.11 Cost comparison of wind energy project cost components

Country	Investment Cost $/kW	Generating Cost $/kWh	Operation & Maintenance Cost $/kWh
China	1,000	0.067	-
Europe	1,188-1,518	[1]0.054-0.066	
		[2]0.079-0.106	0.0158-0.0198
USA	3,500	0.5-0.6	-

Note: For Europe, investment cost lower figure is for large turbine while the higher figure is for small turbine. The investment cost for USA is for small turbine.

[1] cost range for good sites, [2] cost range for bad sites

Sources: Liu & Zhang, 2002; Brennand, 2001; EWEA, 2002; Wind Force 12, 2004

(iv) *Cost Comparison of Wind Energy Technology and Other Energy Technologies*
Table 2.11 gives a cost comparison of both investment and generating costs between wind energy technology and other energy technologies in China. This table reveals that these costs for the wind energy technology are becoming competitive even with long standing conventional energy technologies.

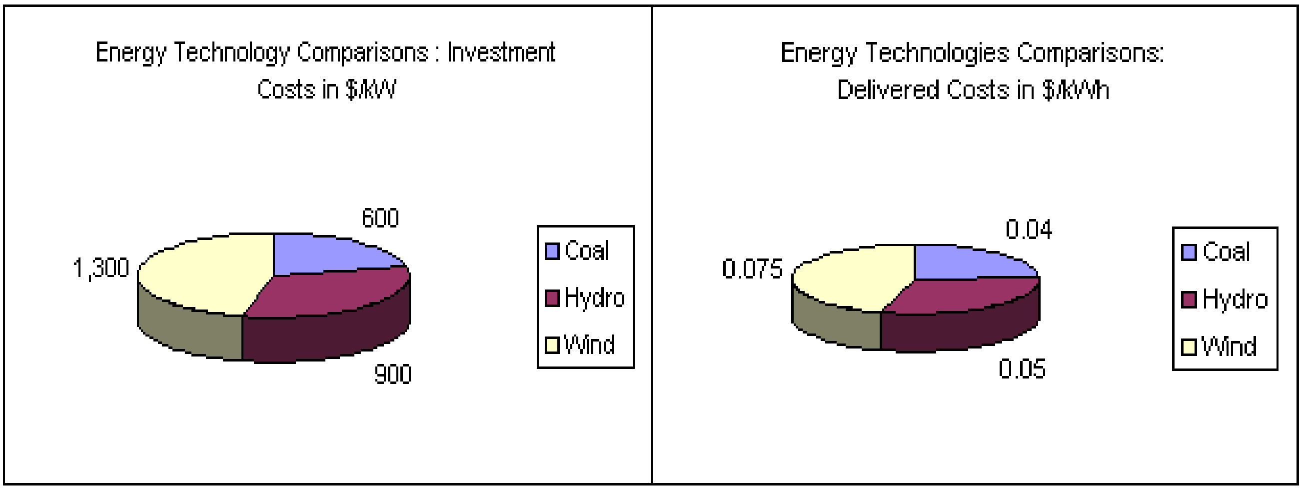


Fig. 2.6: Cost Comparison between Wind Energy and other Energy Technologies in China. Source: Brennand, 2002.

Benefits and Limitations
Wind energy is one of the lowest-priced renewable energy technologies available today, costing between 4-6 cents per kilowatt-hour depending upon the wind resource and project financing of the particular project. The construction time of wind energy technology is less than other energy technologies, it uses cost-free fuel, the operation and maintenance (O & M) cost is very low, and capacity addition can be in modular form, making it adaptable to increasing demand. It enhances diversification of energy carriers for the production of heat, fuel and electricity and also helps in saving fossil fuels for other applications and the future generations. Wind energy is fueled by the wind thereby making it a clean fuel source, non-polluting, and making no demands upon the environment beyond the comparatively modest use of land area. In addition, wind turbines do not produce greenhouse gases which cause acid rain and climate change.

Wind power must compete with conventional electricity generation sources on a cost basis. Depending on how energetic a wind site is, the wind farm may or may not be cost competitive. Even though the cost of wind power has decreased dramatically in the past 10 years, the technology requires a higher initial investment cost than fossil-fueled generators. A major challenge to using wind for electricity generation is that wind is intermittent and not be available when electricity is needed. Furthermore, wind energy cannot be stored unless batteries are used, and not all winds can be harnessed to meet the timing of electricity demands. Wind resource development may compete with other uses for the land and those alternative uses may be more highly valued than electricity generation. Although wind power plants have relatively little impact on the environment

Compared to other conventional power plants, there is some concern over the noise produced by the rotor blades, aesthetic (visual) impacts and sometimes, birds have been killed by flying into the rotors. However, most of these problems have been resolved or greatly reduced through technological development or by properly siting wind plants.

Market Situation of Wind Power Technologies

The main driver for wind power has been the need to reduce greenhouse gases emission especially carbon dioxide. More recently however, other concerns such as energy supply security have also become an important socioeconomic issue in Europe and USA. The main energy strategy of these countries is to diversify the energy supply base away from imported fossil fuels so as to minimize the impact of any disruptions. Energy supply gaps in India have also been a major market driving force for wind energy in that country.

Present demand and supply situation

(i) *Worldwide Wind Energy Capacity*

Wind power capacity has expanded around the world over the past 5 years at a very high rate of about 30%. By 2003, the cumulative installed wind energy electricity was 40,300 MW. Five countries, Germany, USA, Spain, Denmark and India are the main players. They represent over 75% of world capacity. In terms of capacity addition Germany, USA, and Spain accounts for over 50% of the increase in year 2003. See Table 2. 11.

Table 2.11 Worldwide total installed and new capacity of wind power in 2003

Countries	New Capacity in 2003 MW	Total Capacity end of 2003 (MW)
Germany	2,674	14,612
Spain	1,377	6,420
United States of America	1,687	6,361
Denmark	218	3,076
India	423	2,125
Netherlands	233	938
Italy	116	922
Japan	275	761
United Kingdom	195	759
China	--	571
Others	861	3,756
World Total	**8,344**	**40,301**

(ii) *Potential Market for Wind Energy in Nigeria*

There is no established supplier of wind turbines in Nigeria in recent times. About 20 years ago, UAC imported some wind turbines that were sold to states in the North. Given the above, there is no significant market for wind energy in Nigeria. However there are potential markets described below which can be developed if wind energy is to play any significant role in the nation’s energy supply mix.

(iii) *Stand Alone Water Pumping for Agriculture*
Agricultural activities need supply of water. A wind electric pumping system is ideally suited for irrigation and other water pumping activities required in farm settlements that are not connected to the national grid. A wind turbines rating of below 10KW is adequate for water pumping for the small agriculture settlements. This application is especially suitable for the Northern parts of the country.

(iv) Non-grid Hybrid System for Rural Electrification
In many rural areas in Nigeria where there is no access to the national grid or the grid is remote, wind energy could provide a cost effective option for rural electrification. Since the wind energy is intermittent, they can be augmented with either a PV system or diesel generator set. Access to electricity in the rural area of Nigeria has been put to about 20%; hence this hybrid system could be hugely patronized in the country. Depending on the size of village, a wind turbine size of 100KW to 750 KW can be installed.

(v) *Wind Farms*
The cost of large scale wind farm has been steadily declining throughout the last decade. Hence given a favourable wind regime, wind power can be competitive with conventional sources of power production. While 1 to 2.5 MW turbines are increasingly common, 3 to 5 MW turbines are being developed, and may become common in the future. Wind farms in excess of 200 MW range are now common in Europe, USA and India. Wind farms may be grid-connected or may form the backbone of a mini grid for remote areas far away from the main grid.

Barriers to Wind Power Technology Market Development
There are several economic, policies, technical and market barriers that will militate against the rapid adoption of wind power in Nigeria. These barriers must be addressed if the potentials identified earlier and the targets set for the electricity from wind power are to be realized. The barriers are identified below.

(i) *Economic Barriers*
The capital cost of wind turbine energy is still currently above the cost of fossil fuel based base-load electric plant. One factor contributing to this is the lower capacity factor of wind power plants i.e. around 24% compared to over 70% for fossil fuel base-load plants. The lower capacity factor means that to produce a given amount of electricity, it is necessary to install 2-2.5 times more capacity than with fossil fuel plant. This tends to make wind energy more expensive in the initial phase of the life cycle, constituting a barrier to investment and economic decisions on wind energy development.

This barrier is likely to be removed in the future because the capital cost of wind power is expected to decrease in the future. A 2002 EWEA major study predicts that the capital cost of wind power will likely decrease by 30% over the next 15 years. If the cost of environmental damage by fossil fuel electricity is accounted for, it is likely that the capital cost of wind power will become more competitive than it is now.

(ii) *Low Electricity Tariff*

The average electricity tariff in Nigeria is about N6:75 per kWh (approximately 5 cents per kWh). It is estimated that the generating cost of electricity from wind power in Nigeria is between 8-10 cents per kW-h where that of China is about 6.7 cents per kWh. Fig. 2.8 presents electricity tariff in Nigeria which is below the prevailing cost of electricity from wind power, thus discouraging potential wind power investors.

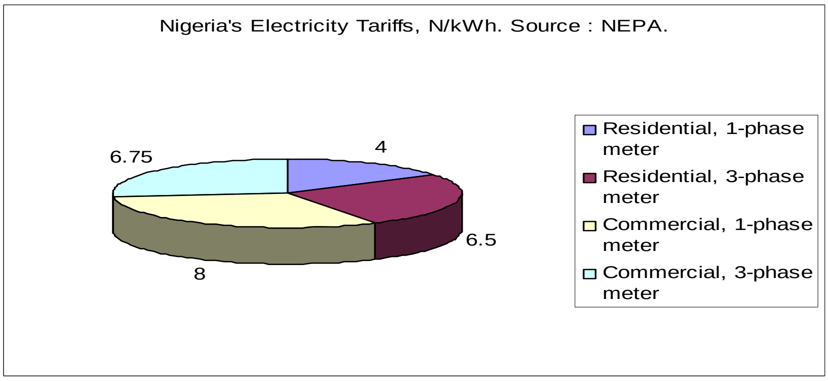


Fig. 2.6 Nigeria's electricity tariffs. Source: NEPA

(iii) Policy and Institutional Framework

Although the national energy policy recognizes the potentials for wind power, there are no specific policies or incentives for promoting wind energy. Key policy on power purchase agreement that will ensure that wind power developers will be able to sell electricity to the national grid is not yet in place. The 2005 Electricity Sector Power Reform Act is yet to become effective structurally.

The coordination between Energy Commission, Ministry of Science and Technology, Ministry of Power and Steel and other Agencies responsible for rural development is weak as it relates to implementing an integrated strategy for renewable energy in general and wind power in particular. None of the two Energy Centres with responsibility for renewable energy research and development has an appreciable wind Research and Development (R & D) programme due to inadequate funding. There is therefore lack of capacity and experience in the country on wind power development.

(iv) Lack of Manufacturing Capability

The lack of such capability in Nigeria as at now will therefore slow down the rapid introduction of wind power into the electricity supply mix. In addition to the lack of manufacturing capability, lack of technical capacity for maintenance of wind turbines is a major barrier to the development of wind power.

(v) Lack of Data on Wind Resource Availability and Technology

Reliable site specific data on wind resources are needed by investors to make investment decisions on wind power. Presently, such data are not readily available in the country. There are only about ten sites where detailed data are currently being collected. This is a big barrier to the development of wind farms.

(vi) *Lack of Awareness about Potentials of Renewable Energy*

Wide understanding of decision makers both in the public and private sector especially in the financial sector is rather low. This lack of information and awareness creates a market distortion which results in higher risk perception for potential wind projects. The general perception is that wind power is not yet a mature technology, hence it is only suited for niche market and even then it will require heavy subsidy to make it viable.

(vii) *Integration with National Grid*

The electricity produced from wind power is intermittent and variable depending on the weather. This poses some technical challenges of reliability when integrating wind power into the national transmission grid. Another barrier is related to the siting of wind turbines which has to be located in areas with good wind resources. More often than not the areas with best wind resources are often far away from load centres (usually urban settlements) where the electricity is needed and served by the national grid. Hence there may be a need for expensive grid extension or the creation of mini grids to transmit and distribute electricity produced from wind energy.

3.0 Targets

The Federal Government of Nigeria sets the following 10-year targets for the contribution of renewable electricity to the economy (2007 – 2016):

- 5% contribution to total electricity generating capacity, excluding large hydropower[2]
- 735 MW cumulative renewable electricity generating capacity
- 5TWh of energy
- 2 Million new connections
- 1 Million Solar Home Systems
- 2000 Rural solar school electrification
- 2000 Rural solar clinics electrification
- 10,000 solar street lights
- 500,000 jobs
- 100 billion Naira renewable electricity industry
- 1.2 MT CO_2 emission reduction

Table: 3.0 Renewable energy targets for Nigeria's electricity sector, MW, based on Peak Demand

	2007	**2010**	**2016**
FMPS Projections	7,000	10,000	15,000
Small Hydro	50	100	400
Solar PV	10	20	130
Wind	0	20	100
Bagasse Cogeneration	0	15	105
Total Renewables, MW	**60**	**155**	**735**
% Total	**1**	**2**	**5**

[2] Together with large hydro, the renewable content of electricity generation will be about 30%.

The Renewable Electricity Action Program targets will be delivered through the following projects by 2016:

1. Small Hydro Project (400 MW), implemented in partnership with relevant stakeholders.

2. Solar Projects
   - 1 Million Solar Home Systems (110 MW)
   - 2000 Rural Solar Schools Project (5 MW) implemented in partnership with the Education Trust Fund
   - 2000 Rural Solar Community Health Centers and Clinics (1 MW) implemented in partnership with National Program on Immunization
   - 10,000 Highway Street Lights implemented in partnership with relevant stakeholders.

3. Bagasse Cogeneration Electricity Project (105 MW) implemented in partnership with relevant stakeholders, especially sugar processing industries.

4. Wind Power Electricity Project (100 MW).

The project targets and budgets are broken down in the following tables:

Table 3.1 Small hydro electricity project

SMALL HYDRO ELECTRICITY PROJECT	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
No of Systems	0	1	2	4	5	5	5	5	5	5
Cumulative No. of systems	0	1	3	7	12	17	22	27	32	37
(Ave. nominal power = 10 MW), MW	0	10	20	40	50	50	50	50	50	50
Cumulative power, MW	0	10	30	70	120	170	220	270	320	370
System cost A @ US$1500/kW, $m	0	15	30	60	75	75	75	75	75	75
System cost B @ US$2000/kW, $m	0	20	40	80	100	100	100	100	100	100
System cost C @ US$2500/kW, $m	0	25	50	100	125	125	125	125	125	125
System cost A @N130/US$, bN	0	1.95	3.9	7.8	9.75	9.75	9.75	9.75	9.75	9.75
System cost B @N130/US$, bN	0	2.6	5.2	10.4	13	13	13	13	13	13
System cost C @N130/US$, bN	0	3.25	6.5	13	16.25	16.25	16.25	16.25	16.25	16.25
1000 Tons CO2 saved, (if natural gas used	0	13.14	26.28	52.56	65.7	65.7	65.7	65.7	65.7	65.7
1000 Tons CO2 saved, (if fuel oil used)	0	19.053	38.106	76.212	95.265	95.265	95.265	95.265	95.265	95.265

Table 3.2: I Million solar home system project

1 M SOLAR HOME SYSTEM PROJECT

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
No. of systems	40,000	60,000	80000	100000	120000	120000	120000	120000	120000	120000
Cumulative No. of systems	40,000	100,000	180,000	280,000	400,000	520,000	640,000	760,000	880,000	1,000,000
(Ave. nominal power = 0.11 kW)	4400	6600	8800	11000	13200	13200	13200	13200	13200	13200
Cumulative power, kW	4400	11000	19800	30800	44000	57200	70400	83600	96800	110000
Cumulative power, MW	4.4	11	19.8	30.8	44	57.2	70.4	83.6	96.8	110
System cost A @ US$8/W, $m	35.2	52.8	70.4	88	105.6	105.6	105.6	105.6	105.6	105.6
System cost B @ US$6/W, $m	26.4	39.6	52.8	66	79.2	79.2	79.2	79.2	79.2	79.2
System cost C @ US$5/W, $m	22	33	44	55	66	66	66	66	66	66
System cost A @N130/US$, bN	4.576	7.92	10.56	13.2	15.84	15.84	15.84	15.84	15.84	15.84
System cost B @N130/US$, bN	3.432	5.94	7.92	9.9	11.88	11.88	11.88	11.88	11.88	11.88
System cost C @N130/US$, bN	2.86	4.95	6.6	8.25	9.9	9.9	9.9	9.9	9.9	9.9
1000 Tons CO2 saved, (nat. gas)	1.32	1.98	2.64	3.3	3.96	3.96	3.96	3.96	3.96	3.96
1000 Tons CO2 saved, (fuel oil)	1.914	2.871	3.828	4.785	5.742	5.742	5.742	5.742	5.742	5.742

Table 3.3: Solar schools project

SOLAR SCHOOLS PROJECT											
		2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
The Solar Schools Project		200	200	200	200	200	200	200	200	200	200
	Cumulative No. of systems	200	400	600	800	1,000	1,200	1,400	1,600	1,800	2,000
	(Ave. nominal power = 2.5 kW)	500	500	500	500	500	500	500	500	500	500
	Cumulative power, kW	500	1000	1500	2000	2500	3000	3500	4000	4500	5000
	Cumulative power, MW	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
	System cost A @ US$8/W, $m	4	4	4	4	4	4	4	4	4	4
	System cost B @ US$6/W, $m	3	3	3	3	3	3	3	3	3	3
	System cost C @ US$5/W, $m	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5	2.5
	System cost A @N130/US$, mN	520	520	520	520	520	520	520	520	520	520
	System cost B @N130/US$, mN	390	390	390	390	390	390	390	390	390	390
	System cost C @N130/US$, mN	325	325	325	325	325	325	325	325	325	325
	Tons CO2 saved (nat. gas)	150	150	150	150	150	150	150	150	150	150
	Tons CO2 saved (fuel oil)	217.5	217.5	217.5	217.5	217.5	217.5	217.5	217.5	217.5	217.5

Table 3.4: Solar community Clinics and health centres project

SOLAR COMMUNITY CLINICS AND HEALTH CENTRES PROJECT

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
No. of systems	200	200	200	200	200	200	200	200	200	200
Cumulative No. of systems	200	400	600	800	1,000	1,200	1,400	1,600	1,800	2,000
(Ave. nominal power = 0.5 kW)	100	100	100	100	100	100	100	100	100	100
Cumulative power, kW	100	200	300	400	500	600	700	800	900	1000
Cumulative power, MW	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1
System cost A @ US$8/W, $m	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.8
System cost B @ US$6/W, $m	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6	0.6
System cost C @ US$5/W, $m	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5
System cost A @N150/US$, mN	104	104	104	104	104	104	104	104	104	104
System cost B @N150/US$, mN	78	78	78	78	78	78	78	78	78	78
System cost C @N150/US$, mN	65	65	65	65	65	65	65	65	65	65
Tons CO2 saved (nat. gas)	30	30	30	30	30	30	30	30	30	30
Tons CO2 saved (fuel oil)	43.5	43.5	43.5	43.5	43.5	43.5	43.5	43.5	43.5	43.5

Table 3.5: Solar street lightening project

SOLAR STREET LIGHTING PROJECT

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
No. of systems	1,000	1,000	1000	1000	1000	1000	1000	1000	1000	1000
Cumulative No. of systems	1000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000
(Ave. nominal power = 0.11 kW)	110	110	110	110	110	110	110	110	110	110
Cumulative power, kW	110	220	330	440	550	660	770	880	990	1100
Cumulative power, MW	0.11	0.22	0.33	0.44	0.55	0.66	0.77	0.88	0.99	1.1
System cost A @ US$8/W, $m	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88	0.88
System cost B @ US$6/W, $m	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66	0.66
System cost C @ US$5/W, $m	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55
System cost A @N130/US$, Nm	114.4	114.4	114.4	114.4	114.4	114.4	114.4	114.4	114.4	114.4
System cost B @N130/US$, Nm	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8	85.8
System cost C @N130/US$, Nm	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5	71.5
Tons CO2 saved (natural gasl)	66	66	66	66	66	66	66	66	66	66
Tons CO2 saved (fuel oil)	95.7	95.7	95.7	95.7	95.7	95.7	95.7	95.7	95.7	95.7

Table 3.6: Wind electricity project

WIND ELECTRICITY PROJECT

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
No. of systems	3	10	20	20	20	20	20	10	10	10
Cumulative No. of systems	10	13	33	53	73	93	113	123	133	143
(Ave. nominal power = 250 kW)	2100	7000	14000	14000	14000	14000	14000	7000	7000	7000
Cumulative power, kW	750	9100	23100	37100	51100	65100	79100	86100	93100	100100
Cumulative power, MW	0.75	9.1	23.1	37.1	51.1	65.1	79.1	86.1	93.1	100.1
System cost A @ US$1000/kW, $m	2.1	7	14	14	14	14	14	7	7	7
System cost B @ US$900/kW, $m	1.89	6.3	12.6	12.6	12.6	12.6	12.6	6.3	6.3	6.3
System cost C @ US$800/kW, $m	1.68	5.6	11.2	11.2	11.2	11.2	11.2	5.6	5.6	5.6
System cost A @N130/US$, Nm	273	910	1820	1820	1820	1820	1820	910	910	910
System cost B @N130/US$, Nm	245.7	819	1638	1638	1638	1638	1638	819	819	819
System cost C @N130/US$, Nm	218.4	728	1456	1456	1456	1456	1456	728	728	728
No. of homes served @ 1.5kW/home	1400	4666.7	9333.3	9333.33	9333.3	9333.33	9333.3	4666.667	4666.67	4666.667
Annual CO2 emission reduction, tonnes at 2.23 tonnes/kW	4683	15610	31220	31220	31220	31220	31220	15610	15610	15610

Cost per rated capacity of wind turbines has decreased steadily in the period 1989-1997 from about €1000/kW to about €800/kW for turbine capacities between 150 kW to 600 kW. For capacities between 600 kW and 1 MW, the cost per kW rose to about €900/kW

Table 3.7: Bagasse cogeneration project

BAGASSE COGENERATION PROJECT

	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016
No. of plants	0	0	1	1	2	2	2	2	2	2
Cumulative No. of systems	0	0	1	2	4	6	8	10	12	14
(Ave. nominal power = 7.5MW)	0	0	7.5	7.5	15	15	15	15	15	15
Cumulative power, MW	0	0	7.5	15	30	45	60	75	90	105
System cost A @ US$1000/kW, $m	0	0	7.5	7.5	15	15	15	15	15	15
System cost B @ US$1200/kW, $m	0	0	9	9	18	18	18	18	18	18
System cost C @ US$1500/kW, $m	0	0	11.25	11.25	22.5	22.5	22.5	22.5	22.5	22.5
System cost A @N130/US$, Nbn	0	0	0.975	0.975	1.95	1.95	1.95	1.95	1.95	1.95
System cost B @N130/US$, Nbn	0	0	1.17	1.17	2.34	2.34	2.34	2.34	2.34	2.34
System cost C @N130/US$, Nbn	0	0	1.4625	1.4625	2.925	2.925	2.925	2.925	2.925	2.925
No. of homes served @ 1.5kW/home	0	0	5000	5000	10000	10000	10000	10000	10000	10000
Annual CO2 emission reduction, tons at 2.23 tons/kW	0.00	0.00	16,725.00	16,725.00	33,450.00	33,450.00	33,450.00	33,450.00	33,450.00	33,450.00

The project uses conventional boiler/steam turbine based on sugar bagasse

4.0 Strategies

The Federal Government of Nigeria is committed to meeting the target of the Renewable Electricity Action Program through the following measures:

4.1 Leveling the playing field for renewable electricity producers

The Federal Government seeks to expand the market for renewable electricity through the consistent removal of subsidies to mature and conventional sources of electricity, tariff regimes that encourage investments, cost-reducing measures for both renewable IPPs and buyers of stand-alone systems.

- **Removal of subsidies to conventional electricity sources** - Consistent with the Federal Government's economic reform program; market distorting subsidies have progressively been removed. Under the EPSR Act 2005, specifically designed and time-bound subsidies are only applicable to rural electrification.
- **Renewable Electricity IPP Pricing Initiatives –** The high costs of renewable electricity will be addressed through long term assured tariffs paid to renewable electricity producers. This subsidy will be financed through the Renewable Electricity Trust Fund.
- **Renewable Electricity IPP Cost Reduction Initiatives –** The Renewable Electricity Trust Fund will provide a source for low-interest loans for renewable IPPs. Already, the Common External Tariff (CET) has reduced duties on imported electrical components significantly. The Federal Government will explore the suitability of time-bound tax exemptions for renewable electricity IPPs.
- **Stand-alone System Subsidies –** The Federal Government will design suitable forms of delivering cost-effective measures to lower the upfront costs of stand-alone systems through system purchase subsidies. In addition, appropriate incentives will be designed to encourage Energy Service Companies (ESCOs) to grow in the renewable energy supply market, thus freeing the customers from the problem of owning and maintaining a renewable energy system.

4.2 Low-hanging fruit public-private-partnership projects

In delivering on the targets of the Renewable Electricity Action Program, the Federal Government will give priority to projects that will provide quick gains in achieving the targets of the program. Priority will be given to mature technologies, cost-effectiveness of projects and possibilities of building partnerships with other sectors in delivering sustainable development. The Federal Ministry of Power and Steel will partner with firms and other agencies in implementing the following public-private-partnership projects:

- **Small Hydro Projects –** About thirty (30) multi-purpose dams built by the Federal Ministry of Water Resources have small hydro power component designs. Several other potential sites have also been identified.

However, none of these dams are currently producing electricity. Some of the dams require minimal or no civil works and the installation of electro-mechanical components. Over the next 10 years, the Federal Ministry of Power and Steel will partner with the Federal Ministry of Water Resources in delivering power from these dams through a public-private partnership that will concession these dams through competitive tenders.

- **Bagasse Cogeneration Projects –** Until recently, the Federal Government owned the following sugar plants: a) Savannah Sugar Company, Numan, Adamawa State, Nigerian Sugar Company, Bacita, Kwara State, Sunti Sugar Company, Sunti, Niger State and Lafiagi Sugar Company located in Lafiagi, Kwara State. These sugar plants have now been privatized. A common challenge faced by all the plants was the lack of access to reliable sources of electricity. With their transfer to private investors, an opportunity has arisen for the use of bagasse, a by-product of sugar processing in the generation of electricity – allowing these firms to sell power as well as sugar.

  Globally, there is a current surge in the market for electricity generation through bagasse cogeneration, including significant growth in Africa. Bagasse is the left-over after the sugar juice has been removed from the cane. A conventional technology employs a bagasse-fired boiler in conjunction with a backpressure steam turbine connected to an electrical generator. [See Chapter 2 for a description of the technology]. By producing and selling electricity many sugar plants, secure their own sources of electricity, generate income from power sales as well as the sale of sugar.

  Over the next 10 years, the Federal Ministry of Power and Steel will collaborate with sugar plants in stimulating the generation and sale of electricity to the grid from their operations.

4.3 Multi-sector partnerships

Priorities will be given to projects that deliver tangible sustainable development benefits through multi-sector partnerships. Examples of these projects include rural water supply, immunization, rural school computerization, highway lighting, etc. Examples of such partnerships include the following:

- **Renewable Electricity Community Health Centers and Clinics –** The Federal Ministry of Power and Steel will partner with the National Program on Immunization to implement projects that provide solar power for refrigeration of vaccines. This enables the NPI to reach more rural communities and allow the FMPS to fulfill its mandate of universal rural electrification.

- **Rural Renewable Electricity School Project –** The Education Trust Fund is currently providing computerization for schools nationwide. The ETF has used solar electrification in some of the school projects. The FMPS would partner with the ETF in expanding this initiative and in finding cost-effective measures of delivering this source of renewable electricity.

- **Renewable Electricity Highway Lighting Project –** The Federal Ministry of Works is currently providing highway lighting through solar PV. The FMPS seeks to expand this initiative in partnership with the FMW.

- **Rural Water Supply –** Several electricity powered rural water schemes implemented by FMWR in some communities have seized to function as a result of broken down diesel generators or lack of access to grid electricity. This project seeks to partner with the FMWR to provide power to water installations through renewable electricity.

- **Community Viewing Centers –** Community viewing centers are social services provided for information dissemination on government programs and activities and community's participation in governance. The viewing centers will have renewable electricity to power radio and TV as well as other information dissemination technologies such as may be available.

4.4 Demonstration projects

The FMPS will embark on pilot projects that demonstrate the technical and commercial viability of particular renewable electricity projects. Such demonstration project will be undertaken in each State or geopolitical zone with the renewable energy source optimal for the area. This will particularly be the case for RE technologies such as small hydro, biomass and wind.

4.5 Supply chain initiatives

The FMPS will address current barriers associated with the importation of renewable electricity technologies by creating an enabling environment for local manufacturing/assembly of components. In implementing the program, emphasis will be on the establishment of solar module assembly plant and the local manufacture of small hydro turbines and small wind turbines and spare parts.

4.6 Public awareness

The Federal Government shall promote public awareness on RE usage through the following measures:

- Implementation of high visibility projects
- Print and electronic media campaigns
- Workshops, conferences, training sessions for journalists and exhibitions
- CBOs, NGOs, organized private sector participation and ownership
- Socio-economic studies and curriculum development for schools.

5.0 Financing the program

Financing is crucial to realizing the Federal Government's policy thrust on renewable electricity. The Government's primary instrument for funding renewable electricity is through the establishment of a fund to stimulate the expansion of the renewable electricity market.

5.1 Renewable Electricity Trust Fund

The purpose of the Renewable Electricity Fund (RETF) shall be to promote, support and provide renewable electricity through private and public sector participation. The RETF seeks to provide support to the following:

- Construction of independent renewable electricity projects, especially in rural and remote areas;
- Establishment of domestic production of technologies for the development and utilization of renewable electricity;
- Provision of resources for micro financing to stand-alone systems under 20kW capacity
- Support to research and development and construction of pilot projects;
- Promote training and capacity building in renewable electricity technology and business development;
- Encourage public awareness initiatives; and
- Provision of surveys and assessments of renewable electricity resources and other relevant information.

With the approximately 15 TWh/a electric energy consumption annually, the fund base would be as follows:

Table 6.0: Renewable energy fund income source scenario

Scenario	Fossil Fuel Levy, N/kWh	TWh/a	Amount generated annually, Nb/a	Amount generated annually, US$m/a
AA	0.1	15	1.5	10.71428571
AB	0.15	15	2.25	16.07142857
AC	0.2	15	3	21.42857143
AD	0.5	15	7.5	53.57142857
AE	1	15	15	107.1428571
AF	5	15	75	535.7142857
AG	10	15	150	1071.428571

Thus, the fund available to fund renewable energy could be between N1.5 b (US$10m) and N150 m (US$1.1b) annually for fossil fuel levy between N0.1/kWh and (N10/kWh). The Fossil Fuel Levy could be graduated according to class of consumers: domestic or residential, commercial, agricultural, institutional, government and industrial.

Support from the RETF shall be guided by the following principles:

- **Support shall be temporary and targeted –** They must have a clear phase-out scheme or timetable and should have an attainable target within that time frame.

- **Support shall be spread out over time –** Facilitating producers and investors to plan. This will create dependability of support and enable short processing procedures.

- **There shall be competition in the financial support system –** This assists in preparing the producers of plants for the market and increases efficiency of the allocation of resources from the fund.

- **Support to projects shall be subject to continuous reviews and evaluations –** Reviews and evaluations of support should be an on-going process to determine their impact and eliminate either waste.

5.1.1 Source of funds – The Renewable Electricity Trust Fund is a proportion of the Rural Electrification Fund and shall consist of the following capital and assets:

- Monies appropriated by the National Assembly
- Revenue from surcharge on eligible consumer of electric power as may be determined by the NERC
- Donations, gifts and loans from international donors

5.1.2 The Rural Electrification Trust Fund and the Renewable Electricity Fund

The sources of funds for the Renewable Electricity Trust Fund is a proportion of the Rural Electrification Fund as may be determined by the Honorable Minister of Power and Steel in addition to other donations, gifts and loans dedicated to renewable electricity from local and international sources.

5.1.3 Management of the Renewable Electricity Trust Fund

The Renewable Electricity Trust Fund shall be managed under the Rural Electrification Fund according to the 2005 EPSR Act.

5.1.4 Funding guidelines – Priorities shall be given to the following projects:

- "Low hanging fruits" projects requiring minimal subsidies to accomplish;
- Economic and financial viability of projects beyond the initial support;
- The demonstration effect of projects, especially in terms of rapid scale up;
- Investor commitment in terms of equity and independent loan financing.

Consistent with the EPSR Act and the Draft Rural Electrification Policy, eligible projects must be demand-driven with proven investor or community support.

5.2 Other sources of financing

The Federal Government shall continuously improve the climate for enhanced funding of renewable electricity through equity, debt financing, grants and micro finance.

5.2.1 Equity Investments – The Federal Government shall continuously review the conditions for effective private sector participation in renewable electricity investments with a view to improving the attractiveness of the sub-sector.

5.2.2 Debt Financing – A key component of the Federal Government's policy is the improvement of the overall macro-economic and financial framework that ensures the availability and affordability of long-term funding for investors in renewable electricity. The Renewable Electricity Trust Fund and other measures shall assist in lowering the cost and improving access to funding for these projects.

5.2.3 Grants – The Federal Government is committed to mobilizing resources through international cooperation towards the development of renewable electricity for sustainable development in Nigeria. Grant financing from agencies of government and independent foundations shall also be promoted.

5.2.4: Micro credit for solar PV systems – As a result of the high upfront cost of solar PV components, the Federal Government shall provide resources through the Renewable Electricity Trust Fund for micro credit to buyers of solar PV systems, especially in rural areas.

6.0 Program coordinating bodies

The program will be implemented by the Rural Electrification Agency of the FMPS under a Renewable Electrification Advisory Committee (REAC) to be appointed by the Honorable Minister of Power and Steel.

The key institutions for the implementation of the policy and program will be the following:

6.1 Federal Ministry of Power and Steel

The Federal Ministry of Power and Steel will have the overall responsibility for formulating electric power policy, including the policy on renewable electricity.

The specific functions of the Ministry will include:

- proposing policy options and recommendations to the Federal Government concerning legislation, policy and investment on renewable electricity;
- Monitoring and evaluation of implementation and performance of the policy within governmental agencies and in the electricity market;
- Establishing, monitoring and evaluating the performance of renewable electricity policy on increasing the access to electricity in rural areas;
- Facilitating the close coordination of renewable electricity activities among agencies of the Federal Government;
- Ensuring that Nigeria’s renewable electricity policy is consistent with national obligations in regional and international organizations; and Liaising with the National Assembly on matters relating to renewable electricity production and use.

6.2 Nigerian Electricity Regulatory Commission

The promotion of a growing market for renewable electricity requires an effective and independent regulatory agency. The Nigerian Electricity Regulatory Commission (NERC) is established by law to carry out the following functions:

- To create, promote, and preserve efficient industry and market structures, and to ensure the optimal utilization of resource for the provision of electricity services;
- To maximize access to electricity services, by promoting and facilitating consumer connections to distribution systems in both rural and urban areas;
- To ensure that an adequate supply of electricity is available to consumers;
- To ensure that the prices charged by licensees are fair to consumers and are sufficient to allow the licensees to finance their activities and to allow for reasonable earnings for efficient operation;
- To ensure the safety, security, reliability, and quality of service in the production and delivery of electricity to consumers;

- To ensure that regulation is fair and balanced for licensees, consumers, investors, and other stakeholders; and
- To present quarterly report to the President and National Assembly on its activities.

In discharging its regulatory functions, NERC shall in respect of renewable electricity seek to perform the following functions:

- Develop simplified licensing procedures for renewable energy investments;
- Develop a framework for power purchase agreement that ensures access to grid-based renewable electricity;
- Ensure preferential prices for renewable electricity to cover additional costs due to size, technology, location and the intermittent nature of the particular renewable electricity resource base;
- Lower licensing charges for renewable electricity licensees
- Develop and maintain quality standards for renewable electricity equipments and installations;
- Lessen the regulatory compliance and reporting burden;
- Ensure that appropriate Environmental Impact Assessments are conducted prior to award of licenses; and
- Report specifically on the status of the renewable electricity industry in its quarterly report to the President and the National Assembly

6.3 Rural Electrification Agency

The Rural Electrification Agency was established by the EPSR Act 2005. The primary function of the REA includes the following:

- Extension of the main grid
- Development of isolated and mini-grid systems; and
- Renewable energy power generation.

In promoting renewable electric power supply, the REA shall carry out the following functions:

- Serve as an implementation agency for the REAP;
- Provide a coordinating point for renewable electricity activities among state and federal agencies; and
- Carry out such duties as may be assigned by the Honorable Minister.

6.4 Other Partners

Other partners in the implementation of the REAP include the following:

- Energy Commission of Nigeria
- Federal Ministry of Water Resources
- Other agencies of the Federal, State and Local Governments
- Private sector, NGOs and CBOs

7.0 Risk assessment

S/N	Risk	Risk Rating	Risk Mitigation Measure
1	Political/policy risk of an incoming administration not committed to pursuing current electricity sector reforms, including RE market development.	M	The EPSR Act provides a legal and regulatory backing for pursuing renewable electricity expansion. Federal Executive Council approval of the Renewable Electricity Action Program and the Establishment of the Renewable Electricity Trust Fund will further strengthen the institutionalization of the policy guideline and program.
2	Regulatory risks associated with inadequate capacity/interest to deliver clear and supportive rules for renewable electricity industry.	M	Increased capacity building within NERC will enhance its ability to provide a clear and supportive regulatory environment to the growth of the renewable electricity industry.
3	Limited capacity and/or interest by implementing agencies to executive non-conventional electricity projects.	M	Enhanced capacity-building, including training and excursion will assist in increasing capacity and commitment within REA and the FMPS.
4	Inadequate private sector capacity to respond to government incentives in expanding renewable electricity generation and distribution.	M	A program to support electricity service industry in business development and access to finance services will improve the capacity of the private sector to invest in renewable electricity.
5	Economic and financial risks, including exchange rate instability and higher than expected interest rates.	M	The provision of soft loans through the RETF and additional fiscal incentives by government will dampen potential instability in the financial market.
6	Supply chain risks due to lack of domestic production and efficient importation processes for RETs – resulting in construction delays and cost overrun.	M	Current port reforms and emphasis on local production will reduce supply chain risks.
7	Adverse climate conditions can affect the availability of all key sources of renewable electricity.	M	The commitment to pursue a balanced energy system with comparative developments in conventional electricity will check possible climatic risks.
8	Credit risk of energy supply companies (ESCO's) operating in rural areas.	S	The provision of micro credit and investment incentives by Government will assist in addressing these issues.

Key: M – Moderate, S – Severe

8. 0 Monitoring and evaluation

The program will be executed by the Rural Electrification Agency under the supervision of the Federal Ministry of Power and Steel. Monitoring and Evaluation will be implemented through the following measures:

- Establishment of the Renewable Electricity Advisory Committee (REAC) to monitor progress, provide advice and ensure key stakeholder participation in the program; REAC will comprise representatives of stakeholders as may be determined by the Honorable Minister of Power and Steel.
- A stand-alone annual report by the REA on the status of the REAP. This report will be made available to a wide range of stakeholders; and
- Annual stakeholder meeting on the REAP to provide a broad based participation and input on the program.

Appendices

Glossary

Average Electricity tariff: The average price paid by consumers over the course of one year. It is significant in that it will often be the base for the setting of tariffs paid under Tariff Mechanisms.

Capital subsidies or consumer grants: One-time payments by the government or utility to cover a percentage of the capital cost of an investment, such as a solar hot water system or a rooftop solar PV system.

Co- generation: A method of using the heat that is produced as a by- product of electrical generation and that would otherwise be wasted be wasted. The heat can be used for space heating of buildings (usually in district or community heating schemes) or for industrial purposes. Utilizing the heat in this way means that 70-85% of the energy converted from fuel stuffs can be use, rather than the 30-50 % that is typical for electrical generation alone. Co-generation schemes can be relatively small scale, for use at the level of a factory or hospital, or can be major power stations. The term CHP is employed at the level of a factory or hospital, or can be major power stations. The term CHP is employed in the UK and some other parts of Europe, while the term co-generation is employed elsewhere in Europe, the US and other countries.

Contestable Markets: A contestable market is one where the barriers to entry are low. Thus a perfectly contestable market would have no barriers. Barriers can include anything which acts to protect the industry incumbent from new entrants and can stem from institutional or regulatory arrangement relating to pricing, licensing, marketing or a number of other sources.

Demand Side Management: The planning, implementation, and monitoring of utility activities designed to encourage consumers to modify patterns of electricity usage, including the time and level of electricity demand. It refers only to energy and load-shape modifying activities that are undertaken in response to utility-administered programs. It does not refer to energy and load –shape changes arising from the normal operation of the market place or from government – mandated energy efficiency standards. Demand-side Management (DSM) covers the complete range of load –shape objectives, including strategic conservation and load management, as well as strategic load growth.

Distribution Network Operator: The owner of the physical network providing electricity at low voltages. Generally connects the transmission grid to the majority of consumers, though some lager consumers may connect directly to the transmission grid. The DNO may have some involvement in balancing the supply of electricity.

Energy Conservation: Using less energy (kWh) irrespective of whether the benefit increase, decrease or stay the same. Energy Conservation is thus the goal if environmental targets are to be met.

Energy Efficiency: This can be defined in slightly different ways, and includes using less energy (kWh) to achieve the same benefits (e.g. internal temperature, industrial output etc), or using the same or a lesser amount of energy (kWh) but achieving more benefits (e.g. a warmer home, higher output). The focus tends to be on improving the welfare of the end-user.

Feed-in tariff: A policy that set a fixed price at which power producers can sell renewable power can sell renewable power into the electric power network. Some policies provide a fixed tariff while others provide a fixed tariff while others provide fixed premiums added to market –or cost- related tariffs. Some provide both.

Gigawatt (GW)/Gigawatt-hour (GWh)/Gig watt-thermal (GWth): See megawatt,kilowatt-hour, megawatt-thermal.

Investment tax credit: Allows investments in renewable energy to be fully or partially deducted from tax obligations or income.

Kilowatt-hour (kWh): A unit of produced or consumed electricity. Also the most common unit for the retail price of electricity is in cents/kWh.

Large hydropower: Electricity from water flowing downhill, typically from behind a dam. No international consensus exists on the threshold that separates large from small hydropower, but the upper limit varies from 2.5 - 50 MW with 10MW becoming more standard.

Megawatt (MW): A unit of power-generating capacity. Represents an instantaneous power flow and should not be confused with units of produced energy (i.e., MWh, or megawatt-hours).

Megawatt-thermal (MWth): A unit of heat-supply capacity used to measure the potential output from a heating plant, such as might supply a building or a neighbourhood. More recently used to measure the capacity of solar hot water/heating installations. Represents an instantaneous heat flow and should not be confused with units of produced heat (i.e..MWh(th), or megawatt-hours-thermal).

Micro-generation: Micro-generation systems typically range in size from a few kilowatts (kW) to 500kW. They are small generators installed close to the point of use, either in smaller businesses or for household use.

Modern biomass: Biomass- utilization technologies other than those defined for traditional biomass, such as biomass co-generation for power and heat, biomass gasification, biogas anaerobic digesters, and production of liquid bio-fuels for use in vehicles.

Net metering: Allows a two-way flow of electricity between the electricity distribution grid and customers with their own generation. When instantaneous consumption exceeds self –generation, the meter runs forward. When instantaneous self generation exceeds consumption, the meter runs backward and power flows to the grid. The customer pays for the net electricity used in each billing period and may be allowed to carry over net generation from month to month.

Performance Based Regulation (PBR): Regulatory approaches rely on the application of financial incentives and disincentives related to specific outputs to induce desired behaviours on the part of regulated companies. PBR links company outputs to revenue and can be applied to achieve benefits such as increased innovation, increased standards for quality of supply, reduced losses and a range of other things which are perhaps otherwise not addressed by regularly approaches by regulatory approaches such as rate of return.

Production Tax Credit: Generally provides a per kilowatt- hour tax credit for electricity generated by qualifying energy resources. The mechanism tends to be used exclusively in the US to stimulate renewable energy exploitation. Usually available for a fixed period, tax credits provide a fixed credit per kWh adjusted annually for inflation. The use of credits can penalize smaller generators if they do not pay sufficient tax to use the credits against other investments.

Regulatory Risk: A risk to businesses that changes in regulation will have a negative impact on their operation. Where government and regulatory risk, they are likely to come under pressure to allot some form of compensation to companies who suffer as a result of regulation in order to ensure that future investment is not discouraged.

Renewable Energy: The use of energy from a source that does not result in the depletion of the earth's resources whether this is from a central or local source.

Renewable Energy Certificates (RECs): A certificate that represents a unit of renewable electricity generated that can be used to verify the fulfillment of an obligation to source a certain percentage of renewable generation as required in Renewable Portfolio standard schemes. Trading may be allowed so that companies that under-achieve their obligation can buy certificates from those who have over-achieved.

Renewable energy target: A commitment, plan or goal by a country to achieve a certain level of renewable energy by a future date. Some targets are legislated while others are set by regulatory agencies or ministries. Can take many forms with varying degrees of enforcement leverage. Also called "planning targets", "development plans," and "obligations."

Renewable portfolio standard (RPS): A standard requiring that a minimum percentage of generation sold or capacity installed is provided by renewable energy. Obligated utilities are required to ensure that the target is met, either through their generation, power purchase from other producers or direct sales from third parties to the utility's customers.

Small/mini/micro/pico hydropower: Small hydropower is commonly is commonly defined as below 10 MW, mini below 1MW, micro below 100kW and pico below 1kW. Pico hydro will typically not involve a dam but just captures the power of flowing water.

Soft loans: A loan made available (usually by a government) at a preferred rate of interest, or with interest deferred for some time (or both). Such a loan can be made available to encourage investment in particular technologies or industrial sectors.

Solar home system: A rooftop solar panel, battery and charge controller that can provide modest amounts of power to rural homes not connected to the electric grid. Typically provides an evening's lighting (using efficient lights) and TV viewing from one day's battery charging.

Solar photovoltaic (PV) panel/module/cell: Converts sunlight into electricity. Cells are basic building block, which is then manufactured into modules and panels.

"Sustainable Development:" That which meets all the needs of the present generation without compromising the ability of future generations to meet their own needs."(U.N. Brundtland Commission).

Tradable renewable energy certificates: Each certificate represents the certified generation of one unit of renewable energy (typically one MWh). These certificates allow trading of renewable energy obligations among consumers and /or producers, and in some markets like the United States allow anyone to purchase separately the green attributes of renewable energy.

Tariff mechanism: A mechanism to encourage the growth of renewable energy generating capacity. Notable examples are Denmark and Germany. A tariff mechanism generally provides a particular rate per kWh of electricity generated and guarantees that payments will continue for a fixed or minimum period. The tariff can be fixed beforehand, can be fixed to reduce in specific gradations over time or can be linked to the Average Electricity Tariff.

Transmission System Operator (TSO) (also Transmission Network Operator-TNO): The Company which owns and maintains the transmission (high voltage) network, and which is responsible for balancing supply and demand in the electricity system.

Utility green pricing: A utility offers its customers a choice of power products, usually at differing prices, offering varying degrees of renewable energy content. The utility guarantees to generate or purchase enough renewable energy to meet the needs of all green power customers.

The consultation process

In the process leading to the development of this draft policy guidelines, the following stakeholders were consulted:

- Federal Ministry of Power & Steel
- Federal Ministry of Water Resources
- UNIDO Regional Centre on Small Hydro
- Energy Commission of Nigeria
- Federal Ministry of Agriculture and Rural Development
- Federal Ministry of Environment
- Power Holding Company of Nigeria (Abeokuta, Calabar & Enugu)
- First Bank Plc
- Bank of Industry
- Energy Commission of Nigeria
- NESCO
- Canadian International Development Agency
- World Bank
- United States Agency for International Development
- Presidential Implementation Committee on Climate Change

Table 9.1: Current status and potential future costs of renewable energy technologies

Technology	Turnkey Investment Costs (US$/kW)	Current Energy Cost	Potential Future Energy Cost
Biomass Energy			
Electricity	900 - 3000	5 - 15 c/kWh	4 - 10 c/kWh
Heat	250 - 750	1 - 5 c/kWh	1 - 5 c/kWh
Ethanol		8 - 25 $/GJ	6 - 10 $/GJ
Wind Energy			
Wind Electricity	1100 - 1700	5 - 13 c/kWh	3 - 10 c/kWh
Solar Energy			
Solar PV Electricity	5000 - 10,000	25 - 125 c/kWh	5 - 25 c/kWh
Solar Thermal Electricity	3000 - 4000	12 - 18 c/kWh	4 - 10 c/kWh
Low temp. solar heat	500 - 1700	3 - 20 c/kWh	2 - 10 c/kWh
Hydroelectrricty			
Large	1000 - 3500	2 - 8 c/kWh	2 - 8 c/kWh
Small	1200 - 3000	4 - 10 c/kWh	3 - 10 c/kWh
Geothermal			
Electricity	800 - 3000	2 - 10 c/kWh	1 - 8 c/kWh
Heat	200 - 2000	0.5 - 5 c/kWh	0.5 - 5 c/kWh
Marine Energy			
Tidal	1700 - 2500	8 - 15 c/kWh	8 - 15 c/kWh
Wave	1500 - 3000	8 - 20 c/kWh	Unclear
Current	2000 - 3000	8 -15 c/kWh	5 - 7 c/kWh
OTEC	Unclear	Unclear	Unclear

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Source: World Energy Assessment Report, UNDP, UNDESA, World Energy Council, 2000.