RENEWABLE ENERGY MASTER PLAN

FINAL DRAFT REPORT

ECN **UNDP**

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LIST OF CONSULTANTS WHO DRAFTED THE REMP

S/N	Name	Status	Affiliation
1	Mr. Ewah Eleri (Executive Director)	Lead Consultant (Hydrogen, Ocean, & Geothermal,)	ICEED, Abuja
2	**Prof. R. 'Layi Fagbenle (Professor of Mechanical Engineering)	Consultant (Solar Thermal)	University of Ibadan, Ibadan
3	*Prof. A. O. Adegbulugbe+ (Professor of Energy Management)	Consultant (Wind Energy)	CERD, Obafemi Awolowo University, Ile-Ife
4	Prof. B. Garba (Professor of Renewable Energy)	Consultant (Biomass & Biofuel)	SERC, Usmanu Danfodiyo University, Sokoto
5	Dr. O. U. Oparaku (Director)	Consultant (Solar PV)	NCERD, University of Nigeria, Nsukka
6	Dr. J. K.Okoye (Managing Director)	Consultant (Small Hydropower)	WADSCO, Abuja
7	Dr. B.G. Danshehu (Mechanical Engineer)	Consultant (Woodstoves & Briquetting)	SERC, Usmanu Danfodiyo University, Sokoto

*Now Special Adviser on Energy Matters to the President, Federal Republic of Nigeria
**Currently serving as Provost, College of Engineering & Technology, Olabisi Onabanjo University, Ibogun Campus, Ogun State.

+The Consultants wish to acknowledge the significant contribution of Dr J-F.K. Akinbami, Senior Research Fellow of the CERD, OAU, Ile-Ife to the work of the Wind Energy Consultant who was appointed Special Adviser on Energy Matters to the President of the Federal Republic of Nigeria midstream in the course of the Project.

TABLE OF CONTENTS

Acronyms

AC	Alternating Current
ADP	Agricultural Development Programme
ADB	African Development Bank
APPA	African Petroleum Producers Association
ARCEDEM	African Regional Centre for Engineering Design and Manufacture
ASDB	Asian Development Bank
ASL	Above Sea Level
AU	African Union
CASHPP	Capital Alliance for Small Hydro Power
CDA	Caribbean Development Authority
CO_2	Carbon dioxide
DC	Direct Current
DTCD	Department of Technical Cooperation for Development
ECN	Energy Commission of Nigeria
ECOWAS	Economic Community of West African States
EIA	Environmental Impact Assessment
EIA	Energy Information Administration (of the US Department of Energy)
EMV	Expected Monetary Value
FAO	Food and Agricultural Organization
FCT	Federal Capital Territory, Abuja
FEPA	Federal Environmental Protection Agency
FMA	Federal Ministry of Agriculture
FORMECU	Forestry Monitoring and Evaluation Coordinating Unit
GEF	Global Environmental Facility
GJ	Giga Joule (Giga = 10^9)
GW	Gigawatt
GWh	Gigawatt-hour
Ha	Hectares
HGS	High growth scenario
IAEA	International Atomic Energy Agency
IC – SHP	International Centre for Small Hydro
IDB	Inter-American Development Bank
IMF	International Monetary Fund
IPP	Independent Power Producer
ITF	Inter-Tropical Front
Kg	Kilogramme
kJ	Kilojoule
Km/h	Kilometre/hour
kW	Kilowatt
KWh/m^2	Kilowatt hour per square meter
kWh	Kilowatt-hour
LGS	Low growth scenario

M	Metre
M^3	Cubic Metre
M^3/s	Cubic Meter Per Second
MCM	Million Cubic Meters
MFO	Market Facilitation Organization
MJ	Megajoule
MOU	Memorandum of Understanding
MToe	Million Tons of oil equivalent
MW	Megawatt
MWh	Megawatt-hour
NBRRI	National Building and Roads Research Institute
NCERD	National Centre for Energy Research and Development
NEEDS	National Economic Empowerment and Development Strategy
NEP	National Energy Policy
NEPA	National Electric Power Authority
NEPAD	New Partnership for African Development
NERC	Nigerian Electricity Regulatory Commission
NERDP	New Energy Research and Development Programme
NGO	Non Governmental Organization
NIMOR	Nigerian Institute of Marine and Oceanographic Research
NIREDA	Nigerian Renewable Energy Development Agency
NNPC	Nigeria National Petroleum Corporation
NRSE	New and Renewable Sources of Energy
NYSC	National Youth Service Corps
O & M	Operation and Maintenance
OPEC	Organization of Petroleum Exporting Countries
OTEC	Ocean Thermal Energy Conversions
PJ	Picojoule
PSP	Private Sector Participation
PV	Photo Voltaic
R&D	Research and Development
REMP	Renewable Energy Master Plan
RET	Renewable Energy Technology
RMRDC	Raw Materials Research and Development Council
RS	Reference scenario
SERC	Sokoto Energy Research Centre
SHESTCO	Sheda Science & Technology Complex
SHP	Small Hydro Power
SHS	Solar Home Systems
TJ	Terajoule
Toe	Tons of oil equivalent
TPES	Total primary energy supply (demand)
TW	Trillion Watt
TWh	Trillion Watt Hour (Tera -10^{12})
UEMOA	Economic and Monetary Union of West Africa

UN	United Nations
UNCDF	United Nations Capital Development Fund
UNDP	United Nations Development Program
UNESCO	United Nation Educational Scientific and Cultural Organisation
UNIDO	United Nations Industrial Development Organization
USA	United States of America
VITA	Volunteers in Technical Assistance
WB	World Bank
WEC	World Energy Council

Section One: Executive Summary

Introduction

The Renewable Energy Master Plan (REMP) articulates Nigeria's vision and sets out a road map for increasing the role of renewable energy in achieving sustainable development. The REMP is anchored on the mounting convergence of values, principles and targets as embedded in the National Economic Empowerment and Development Strategy (NEEDS), National Energy Policy, National Policy on Integrated Rural Development, the Millennium Development Goals (MDGs) and international conventions to reduce poverty and reverse global environmental change.

Towards the coming decades, Nigeria envisions a peaceful and prosperous nation driven increasingly by renewable energy. The country will exploit renewable energy in quantities and at prices that will promote the achievement of equitable and sustainable growth.

In the short term, crude oil will continue to play a dominant role in the economic development of the country. However, Nigeria's fossil-led economy is under severe pressure. In decades to come, the sun will slowly but certainly set on crude oil production. Today, large hydropower plants are increasingly threatened by a shrinking River Niger, shaking the security of electricity supplies. Human activities upstream, and possibly climate change constitute critical challenges in our nation's strive to meet its electricity needs. A silent crisis is also unfolding, as fuel wood remains scarce – increasing the vulnerability of the poor and endangering efforts to reduce poverty.

In the medium term, Nigeria envisions an energy transition from crude oil to a less carbon intensive economy increasingly powered by gas. Gas will represent a new growth pole and provide a bridge to a low carbon economy that secures increased prosperity and preserves our environment. In the next ten years, gas is expected to overtake crude oil as a source of revenue; provide a basis for reliable power supply and a cleaner environment. In the medium term, the effect of renewable energy in national energy supply should begin to be felt.

In the long term, Nigeria envisions a country that will significantly be less dependent on hydrocarbons. Energy from the Sun, modern and more efficient conversion of biomass energy, small hydro plants and wind – along with conventional technologies, will provide opportunities to empower people and communities in meeting their energy and development needs. Far into the future, Nigeria will join the rest of the world in developing a hydrogen economy and in accessing the vast energy entrapped in the oceans and in the Earth's crust.

Barriers and opportunities

This bold new vision is achievable as Nigeria addresses present barriers. These barriers include the reform of the policy, regulatory and institutional framework that will enable a rapid scale up of the market for renewable energy. Secondly, prices and financing constraints will be addressed to create a level playing field, and increase incentives for renewable energy. Thirdly, poor product quality and standards must be regulated to ensure consumer confidence and sustainability of the market. Fourthly, public awareness and promotion will be critical elements of the drive to expand the market for renewable energy. Lastly, addressing gaps in key R&D areas and building human and manufacturing capacities are key issues that must also be addressed.

As Nigeria tackles these barriers, renewable energy will open vast opportunities for meeting the development challenges facing the country. Reform will unleash the potentials of diversified and abundant sources of energy, including solar photovoltaic and solar thermal energy, efficient and modern applications of biomass technologies, investments in small-scale hydro plants and wind power. Secondly, creating an enabling environment will assist in lowering renewable energy prices and expanding access to energy services particularly for the poor. Finally, renewable energy reforms will help in achieving NEEDS and MDG targets by providing opportunities to reach rural areas, industries and improving energy services to the poor.

Drivers for change

Certain factors will drive the process towards the successful implementation of necessary reforms and the realization of targets. These drivers include: the demand for energy services by a huge proportion of the population that remain inadequately served. Secondly, the commitment and completion of far reaching power sector reforms will also create a basis to expand the role of renewables in meeting electricity targets, especially in rural power supply. Thirdly, international development in the market for renewable energy technologies and the actions of government – bilaterally and within multilateral bodies will help shape successes in delivering more energy from renewable sources. Other drivers include technological change, global and local environmental concerns as well as Nigeria's challenges in meeting the security of future energy supplies.

Several factors underscore the imperative to develop the REMP. Current management of the sector with its focus on centralized conventional energy supply has been inadequate in meeting the yearnings of Nigerians for development. Second, expanding the scope for renewable energy use will require specific actions to bring some renewables from the laboratory to the energy marketplace. Third, the decentralized nature and scale of renewable energy schemes make them available to remote and under-served communities. Fourth, the Master Plan will encourage a balanced development of all available energy resources within the framework of the power sector and energy sector-wide reforms. Fifth, certain renewable energy sources such as hydrogen, ocean and geothermal energy will play a role in several decades to come. The Master Plan provides a tool to secure Nigeria's R&D interests in these energies of the future. Sixth, the challenge of managing local and international environmental challenges has become crucial. Renewable energy provides a vehicle to meet the twin objectives of development and environmental protection. Finally, as many players become involved in renewable energy development and implementation activities, there is need for an overall guide that will channel all activities, in a complementary manner, towards the same goals.

Key objectives

The overall objective of the REMP is to articulate a national vision, targets and a road map for addressing key development challenges facing Nigeria through the accelerated development and exploitation of renewable energy. It will put in place a comprehensive framework for developing renewable energy policies, legal instruments, technologies, manpower, infrastructure and market to ensure that the visions and targets are realized. Among other things, the master plan has the following specific objectives:

- Expanding access to energy services and raising the standard of living, especially in the rural areas;
- Stimulating economic growth, employment and empowerment;
- Increasing the scope and quality of rural services, including schools, health services, water supply, information, entertainment and stemming the migration to urban areas;
- Reducing environmental degradation and health risks, particularly to vulnerable groups such as women and children;
- Improving learning, capacity-building, research and development on various renewable energy technologies in the country; and
- Providing a road map for achieving a substantial share of the national energy supply mix through renewable energy.

Renewable Energy Resources, Technologies and Markets

Nigeria is endowed with significant renewable energy resources including large and small hydroelectric power resources, solar energy, biomass, wind and potentials for hydrogen utilization; and development of geothermal and ocean energy. Table 1 presents estimated renewable energy resources in Nigeria, excluding potential hydrogen, ocean and geothermal energy.

Table 1: Nigeria's Renewable Resources

Energy Source	Capacity
Hydropower, large scale	10,000MW
Hydropower, small scale	734 MW
Fuelwood	13,071,464 hectares (forest land 1981)
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)

The level of resource endowment, capacities to utilize certain technologies, government policies and the economics of the energy section are all issues that challenge the optimal utilization of the various sources of renewable energy in the country. In many cases, costs are critical to the overall success in developing a particular resource base. Table 2 presents an overview of the initial costs of electricity generating systems while table 3 presents a comparative assessment of operation and maintenance costs.

Table 2: Initial Capital Costs of Electricity Generating Systems

Technology	Size (KW)	Initial Capital Cost ($/KW)
Engine Generator		
Gasoline	4	760
Diesel	20	500
Micro hydro	10 – 20	1,000 – 2,400
Photovoltaic (PV)	0.07	11,200
Photovoltaic (PV)	0.19	8,400
Wind Turbine	0.25	5,500
Wind Turbine	4	3,900
Wind Turbine	10	2,800

Table 3: Operation, Maintenance, and Fuel Costs for Different Technologies

Technology	O & M Costs (cents/KWh)	Fuel Costs* (cents/KWh)
Engine Generator	2	20
Micro Hydro	2	0
Photovoltaic	0.5	0
Wind Turbines	1	0

* Assuming Diesel Fuel Price of 5 US$/L

The following is an overview of specific renewable energy resources, technologies and markets relevant to the pursuit of Nigeria's renewable energy vision.

Small Hydropower

From NEPA's most recent estimate, the gross hydro potential for the country is 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. From a 1980 survey of 12 of the old states of the federation, it was established that some 734 MW of small hydropower (SHP) could be harnessed from 277 sites.

Unfortunately the database on SHP in Nigeria is limited, incomplete and substantially obsolete. No new surveys have been conducted since those undertaken in only three northern states 20 years ago, 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.

The lifetime of small hydro facilities is 20 – 30 years, compared with 8 – 10 years for diesel engine generators. Long service life is an important attraction of the small hydro system. In Nigeria, some NESCO SHP projects, which were completed between 1923 and 1964, have continued to provide virtually uninterrupted power to not only supply the Jos metropolis and meet local consumption, but have also continued to feed surplus energy into the national power grid.

Although, small hydropower may require a moderately high capital cost, its low operation and maintenance (O & M) requirements coupled with long life span are its major advantage over other prospective sources of power to small and medium sized rural communities and industries. Among the limitations of SHP are its being drought-sensitive, weather- and seasonal dependence, and its site-specificity.

Solar Energy

Nigeria lies within a high sunshine belt and, within the country solar radiation is fairly well distributed. The annual average of total solar radiation 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. This gives an average annual solar energy intensity of 1934.5 kWh/m^2-yr; 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 annual average electrical energy generated by the NEPA. With a 10% conservative conversion efficiency, the available solar energy resource is about 23 times the Energy Commission of Nigeria's (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 High Growth Scenario. For the Low-Growth Scenario, the available resource is about 12 times the year 2030 demand and just under 100 times the year 2010 demand.

The solar radiation measuring stations of the Nigerian Meteorological Agency (NIMET) are mostly airport and aerodrome weather stations that were originally set up to aid civil aircraft navigation. To obtain a good solar radiation database there is need to create more purpose-built radiation measurement stations all over the country.

Solar Thermal

Solar thermal technologies that are available in the international market today are efficient and highly reliable, delivering solar energy in a wide range of applications, among which are: domestic hot water and space heating in residential and commercial buildings, swimming pool heating, solar-assisted cooling, solar-assisted district heating, industrial process heat, desalination, agricultural products drying, hatcheries, chick brooders and seed germinators, solar cooking, and electric power generation. In Nigeria, the ECN, with its two renewable energy centres, has developed or adapted a variety of renewable energy technologies and capacities, including solar dryers, solar water heaters, solar cookers and solar chick brooders. Many tertiary institutions have also developed or adapted several solar thermal technologies for local use. These local developments need to get from the present largely demonstration or dissemination stage to the next stage of commercialization, with private sector driven but high profile public sector led initiatives.

Most solar thermal technologies are economically competitive even in developed countries of the world where the market is fully developed and private-sector driven. The competitiveness of solar water heating for commercial and institutional water heating has been demonstrated for Nigeria in previous studies. However, the solar thermal power (STP) generation technologies are at present economically uncompetitive. A study of the electricity cost for market introduction of STP technologies has shown that competitive markets can emerge between 2010 and 2015 at about 4-6 US cents/kWh. Sustained global markets for STP is expected between 2015 and 2020, during which period the total installed capacity would have increased from the present level of just 354 MW to over 5000 MW.

Solar Photovoltaic

Solar photovoltaic technologies are gaining an increasing acceptance in Nigeria. However, despite improvements in local R&D efforts, the body of knowledge on these technologies and their market potentials is considerably inadequate. Launching major national initiatives on these technologies require a robust knowledge base and capacity.

The three most common solar PV technologies are the crystalline, amorphous and the thin film technologies. In the crystalline technology, Silicon is the most widely used and best characterized semiconductor material. Amorphous Silicon (a-Si) is the most extensively researched thin film material with the largest manufacturing experience mainly based on low power devices (watches, calculator etc). The thin film technologies that have achieved some level of market penetration are Copper Indium Diselenide (CuInSe2 or CIS), Cadmium Telluride (CdTe), and Thin Film Silicon (a-Si) Technologies.

In all, PV technologies are showing increasing promise in terms of efficiency improvements and costs. The estimated lifetime of PV modules of 25 and 30 years make them exceptionally attractive for investors. Today, all the PV modules in the Nigerian market are imported. Solar PV systems are being extensively used for a wide range of electrical energy requirements, including; solar home systems, water pumping, refrigeration and telecommunications. These applications have positive social and economic impact on the lives of individual users, businesses and communities.

Biomass

Some of the methods for biomass conversion to biogas include physical, biological, pyrolysis, gasification, burning, anaerobic digestion or biodegradation processes. Nigeria's biomass resources include wood, forage grasses and shrubs, animal waste, and other wastes from forestry, agriculture, municipal and industrial activities as well as aquatic biomass. Biomass is similar to fossil fuels as it is made up of hydrocarbons that readily burn to release heat. Its ubiquitous availability and simple conversion technologies make biomass resources the most widely used source of energy in the country. However, no clear overview exists on the size of this important resource base and the sustainability of its resource management. Efforts by government to improve the resource management of biomass energy have essentially focused on enhancing the adoption of improved wood stoves, briquetting and biogas technologies.

Improved Wood Stoves and Biomass Briquettes

Traditional three-stone wood stoves are the dominant heating technologies in the country. They have very low efficiency, endanger the national wood stock as well as increase the burden of wood gathering. The Sokoto Energy Research Centre (SERC) has developed improved clay stoves for an average rural family. These improved double-hole wood stoves were constructed with wire mesh and ½" flat bar reinforcement incorporated in the clay structure to take care of the twisting and stirring forces experienced in the traditional cooking. Fuelwood and time savings of 37% and 24%, respectively, have been recorded in some of the investigations carried out. The National Energy Research and Development Centre (NERDC) at the University of Nigeria, Nsukka has developed steel-based wood stoves that have proved effective, particularly for institutional uses. However, in all these R&D efforts, improved wood stoves have not gained any significant foothold in any part of the country.

Several machines have been developed in Nigeria for briquettes production, including a single cylinder extrusion machine that transforms rice, millet and sawdust husk to briquettes that produce 13kg of briquettes/hour. There are, however, only two small-scale companies in Nigeria situated in Ogun and Kaduna states which produce and market sawdust briquettes. The locally produced briquette has 6 to 7 times more energy content per kg than un-briquetted biomass. In addition, the heating flame and temperature obtained in cooking process are better when compared with other renewable energy fuels. Today, most work on biomass briquetting is confined to University R&D centers.

Biogas

There are three biogas designs presently available. These include the fixed dome, the floating cover and the bag digester. The fixed dome consists of an airtight container normally constructed of brick, stone or concrete with the top and bottom being hemispherical. The floating cover consists of a cylindrical container constructed with some specific height and diameter ratio and made of brick or concrete reinforced with chicken wire. The bag digester, on the other hand, comprise of a long cylinder made of either polyvinyl chloride (PVC) or similar material. The bag will usually have inlet and outlet pipes for feedstock and slurry as well as a gas outlet pipe. While biodigesters have experienced significant breakthroughs in countries similar to Nigeria, only a handful of biodigesters presently exist in Nigeria. So far, less than 20 pilot projects on biogas have been established across the country, including a UNDP pilot project in Kano State.

Wind Energy

Wind speeds in Nigeria 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. Wind speeds in Nigeria are generally weak in the South except for the coastal regions and offshore locations. In Nigeria, 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. Hence, Nigeria falls into the poor/moderate wind regime.

The Nigerian Meteorological Agency (NMA) carries out routine measurements and collection of wind data for the country. These records are available in its archives. There is also a wind mapping programme initiated by the Federal Ministry of Science and Technology. This work only covers ten selected sites across the country where detailed site study is to be carried out using about one year continuous data from wind measuring equipment. Only a few wind maps for limited sites are available. Hence there is the need to develop wind maps and update existing atlas.

Wind energy utilization in Nigeria is practically minimal. 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 is a pilot wind electricity project in existence which is the 5 kWp Sayya Gidan Gada wind electricity project at Sokoto. In addition, a 0.75 kWp wind electricity project in the center of the town is being run on an experimental basis to prove the viability of wind farming in the area.

Wind energy is one of the lowest-priced renewable energy technologies available today, costing between 4-6 cents per kilowatt-hour, depending on the wind resource base and 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. However, several economic, policy, technical and market barriers militate against the rapid adoption of wind power in Nigeria. These barriers must be addressed if the potentials identified and the targets set for electricity from wind power are to be realized.

Hydrogen, Ocean and Geothermal Energy

Hydrogen, ocean and geothermal energy are important in the long-term vision of providing secure, abundant, cost effective and clean sources of energy for Nigeria. Their impacts might not be felt in the next few decades, but these emerging energy sources will be key to meeting future energy challenges when the country is weaned of its dependence on hydrocarbons.

Hydrogen Energy

Hydrogen can be produced from water using various forms of energy. It can also be extracted from anything that contains hydrocarbons, including gasoline, natural gas, biomass, landfill gas, methanol, etc. The resources base is therefore limitless.

Hydrogen energy technologies are maturing and are increasingly meeting energy needs particularly in industrialised countries. The US hydrogen industry alone produces about 9 million tonnes of hydrogen annually for use in chemical production, petroleum refining, metal treatment and electrical applications. As an energy carrier, this quantity of hydrogen can power about 20-30 million cars or an equivalent of 5-6 million homes. The emerging hydrogen energy technology has the following segments: production, delivery, storage, conversion and end-use technologies.

High prices and low R&D capacity are still some of the most formidable obstacles for using hydrogen in Nigeria. Moreover, the availability of low-cost fossil fuels may constitute a major disincentive to innovative technologies making an inroad into the energy market. A primary benefit of hydrogen energy to Nigeria is its potential for being the energy of last resort in the future. The resource is abundant and inexhaustible. When developed, it will contribute to the nation’s energy security in a post-fossil economy. It is also clean and will assist in addressing local and global environmental challenges such as global warming. Fuel cell, for instance, has the potential for meeting remote power needs.

Hydrogen as an energy form is not produced in Nigeria, and no known importation of fuel cell technologies and other hydrogen conversion technologies are known. There is therefore no existing market for hydrogen energy in Nigeria.

Ocean Energy

With Nigeria’s geographical location, power from the ocean ought to be part of the long-term energy vision for the country. Oceans cover more than two-thirds of the earth’s surface. They are therefore the world’s largest solar collectors. Oceans can produce thermal energy from the sun's heat, and mechanical energy from tides and waves. While the gravitational pull of the moon drives the tides, the wind powers the ocean waves.

The West African coast has a poor wave energy regime of 10kW/m. Good wave energy sites in Africa include the coast of South Africa with 40-50kW/m; while the coast of the United Kingdom presents some of the world’s best potentials of about 70kW/m.
The entire southern boundary of Nigeria is covered by the Atlantic Ocean. This provides a potentially significant ocean energy resource base. However, there is no known systematic energy resource assessment conducted on the country’s coastline resources.

Nigeria has a good number of institutions with the capacity to carry out research and development activities on ocean energy. These institutions include the Nigerian Institute for Oceanographic and Marine Research in Lagos and Departments of Oceanography at the universities. However, there is currently no known systematic body of R&D on ocean energy in existence in Nigeria.

Tidal Energy
For tidal differences to be harnessed into electricity, the difference between high and low tides must be at least five meters. Evidence shows that there are perhaps only about 40 such sites on the planet with tidal ranges of this magnitude. Tidal barrage, tidal fence and tidal turbine are the three main technologies under investigation worldwide.

The technical life of a tidal scheme could be about 120 years or upward for the civil structure. The electrical generating plant may have a technical life of about 40 years. Since the tidal resource is site specific, the plant availability will necessarily vary. Technical efficiency of the plants will also vary from the technology used.

Tidal energy projects require high initial capital expenditure. It has very long construction periods and low load factors, leading to long payback periods. This leads to very high overall cost and major challenges in funding a commercial tidal project. The best sites in the UK are estimated to produce power at about 20cents/kWh.

Tidal energy is clean and renewable. However, Nigeria does not seem to have a significant tidal energy resource.

Wave Energy
Wave energy can be converted into electricity through both offshore and onshore systems. Offshore systems are situated in deep water, typically more than 40 meters. Onshore wave systems are usually built along shorelines to extract the energy in breaking waves. Worldwide, wave energy technologies are still at various stages of commercialization. In Nigeria, the wave energy regime along the Atlantic coast does not permit the efficient deployment of today's technologies.

Ocean Thermal Energy Conversion (OTEC)
Ocean Thermal Energy Conversion uses the heat energy stored in the oceans to generate electricity. OTEC works best when the temperature difference between the warmer, top layer of the ocean and the colder, deep ocean water is at $20^{o}C$. These conditions exist in tropical coastal areas, roughly between the Tropic of Capricon and the Tropic of Cancer.

Geothermal Energy
Geothermal energy is currently meeting an increasing proportion of the world's energy requirements. In 2004 over 9,000 megawatts of electricity were produced from some 250 geothermal power plants in 22 countries around the world. These plants provide reliable base-load power for well over 60 million people, mostly in developing countries. In Africa, Kenya, Algeria, Tunisia and Zambia have significant installed capacities. Geothermal direct use applications provide about 10,000 thermal megawatts (MW-th) of energy in about 35 countries. Two known geothermal resources exist in Nigeria, and they are: the Ikogosi Warm Springs in Ondo State and the Wikki Warm Springs in Bauchi.

Three power plant technologies are being used to convert geothermal fluids to electricity: Dry steam plants, which directly use geothermal steam to turn turbines; Flash steam plants, which pull deep, high-pressure hot water into lower-pressure tanks and use the resulting flashed steam to drive turbines; and Binary-cycle plants, which pass moderately hot geothermal water in thermal contact with a secondary fluid with a much lower boiling point than water. This causes the secondary fluid to flash to vapor, which then drives the turbines. Direct thermal applications of geothermal energy include: hot spring bathing, agriculture, aquaculture, industrial hot water uses, heating of individual and residential districts. Heat pumps have also become widely used in temperate regions.

The economics of geothermal energy is highly variable depending on applications and site-specific conditions. The cost of geothermal power production vary from USc/kWh 5 -7 for plants less than 5 MW and USc/kWh 2.5–5 for large plants of more than 30 MW for high quality reservoirs. Direct capital costs vary significantly. Large plants in high quality sites can be as low as US$750/kW and as high as US$2300/kW for small plants.

Geothermal energy is not likely to play a major role in Nigeria's future energy market. However, certain future economic factors will influence the use of existing geothermal resources and the capacity to utilize future resource discoveries.

Targets

Available resource base, technologies and the market situation of the various energy sources form the basis for establishing realisable targets for the growth of the renewable energy industry in the country. The Energy Commission's High Growth Scenario projection for energy demand and NEEDS projections form the basis to compare progress on renewable energy with the overall sector growth. The projected electricity supply, from all sources (conventional and renewable) in the short (2007), medium (2015) and long term (2025) is estimated to be 7000MW, 14000MW and 29,000MW, respectively.

The Master Plan sets out broad targets for electricity and non-electric sub-sectors. Table 4 presents a breakdown of targets for each of the five renewable energy sub-sectors as a proportion of projected energy demand according to the ECN High Growth Scenario.

Table 4: Targets for Installed Electricity Capacity (MW)

Sources		2007	2015	2025
Wind		1	20	40
Solar PV		5	75	500
Solar thermal		-	1	5
Small hydro		50	600	2000
Biomass			50	400
Total		**56**	**746**	**2945**
ECN High Growth Scenario Projections		7000	14000	29000
Percentage share of projected energy demand		0.8	5	10

The target contributions to the electricity supply mix from RE sources (solar, wind, small hydro, biomass) are 56MW, 701 MW and 3060 MW in the short, medium and long term respectively. This represents an achievement of 0.8%, 5% and 10.5% of total electricity demand in 2007, 2015 and 2025, respectively.

Expected percentage contribution of non-electricity renewable energy sources to the overall projected energy demand will actually decline in the period of the plan. These figures will decline from 41% in 2007 to 16% and 9% for 2015 and 2025 respectively. The expected decline of the contribution of biomass to the overall energy demand will account for this trend.

Table 5: Targets for Non-Electrical Renewable Energy Production

	2007.0	2015.0	2025.0
All energy forms (GWh)	193789.0	202128.0	248869.0
Fuelwood & charcoal, (GWh)	144,544	121,352	95,869
Fuelwood & charcoal [Biomass energy]++, (% of total)	74.6	60.0	38.5
Solar thermal share of total thermal energy, (%)	10.0	20.0	40.0
Ren. Energy share of total thermal energy, (%)	84.6	80.0	78.5
Other non-Ren. energy share of total thermal energy, (%)	15.4	20.0	21.5
Ren. Energy share of total thermal energy, (GWh)	163922.9	161777.6	195416.6
Solar thermal share of total thermal energy, (GWh)	19378.9	40425.6	99547.6

Note: Biomass energy has 0, 4.3 and 6 GWh in the short, medium and long terms respectively

Distribution of Solar Thermal Share	Share, (%)			Share, (GWh)		
	2007.0	2015.0	2025.0	2007.0	2015.0	2025.0
All Solar Thermal	100.0	100.0	100.0	19378.9	40425.6	99547.6
Solar Water & Air Heating	75.0	70.0	60.0	14534.2	28297.9	59728.6
Solar Drying & Brooding	18.0	15.0	18.0	3488.2	6063.8	17918.6
Solar Desalination, solar stills, etc.	0.0	1.0	2.0	0.0	404.3	1991.0
Solar Cooking	1.0	2.0	2.0	193.8	808.5	1991.0
Solar refrigeration & A/C & passive architecture	2.0	4.0	5.0	387.6	1617.0	4977.4
Solar pasteurization, sterilization	4.0	3.0	3.0	775.2	1212.8	2986.4
Solar Thermal Electricity	0.0	5.0	10.0	0.0	2021.3	9954.8

The implication of these targets is a rapid scale up of most of the renewable energy technology applications. Some of the highlights include a combined increase in wind power generation to 1MW, 19MW and 38MW in 2007, 2015 and 2025 respectively. Small-scale hydro plants will contribute 56MW, 600MW and 2,000MW in 2007, 2015 and 2025 respectively. A significant expansion of improved woodstoves dissemination will occur with 300,000, 500,000 and 1,000,000 units in the short, medium and long-term periods respectively. An estimated 40,000, 400,000 and 4,000,000 solar home systems will be achieved within the same periods. Solar cookers will increase from 1,500 in 2007, 50,000 in 2015 and 150,000 in 2025. Solar water heaters and chick brooders are expected to experience significant increases within the period.

Planned Activities and Milestones

The REMP sets out six distinct activities with concrete milestones to be reached within the plan period. These activities are organized around the following programmes:

Framework Programme for Renewable Energy Promotion;
Nigerian Solar Programme;
Nigerian Small Hydro Programme;
Nigerian Wind Programme;
Nigerian Biomass Programme; and
New Energy Research and Development Programme.

The Framework Program for Renewable Energy Promotion addresses a range of cross-cutting issues, including policy, regulatory and institutional framework; pricing and financing issues; product standards and quality control; capacity-building, research and development as well as public awareness. It is designed to provide the enabling environment for the attainment of the targets set for each of the technology areas. The various programs reflect a twenty-year commitment to realize the targets of the Master Plan for all the renewable energy sub-sectors. The programs will address R&D, database, market as well as capacity issues in realizing the targets of the REMP.

Strategies and Implementation Issues

The Federal Government is committed to addressing key implementing issues as well as developing adequate strategies to enable the realization of the vision of the Renewable Energy Master Plan. This will involve the review of policy, legal, institutional, fiscal and regulatory instruments that would attract domestic and international investment to develop renewable energy resources in the country. A primary strategy is to evolve a participatory process in identifying necessary interventions that must be put in place. This involves the mobilization of key stakeholders in realizing a sustainable future in which renewable energy plays an important role.

Key among strategies to be adopted includes the ‘leveling of the playing field’ in the energy market. This will involve the removal of hidden subsidies, or at least making them more transparent and internalizing external cost. In addition, another key element of the overall framework is the adoption of a renewable portfolio standard. This is a policy that requires that firm and realistic targets and effective strategies for renewable energies be set in consultation with other stakeholders.

Another element of the policy framework is the creation of innovative fiscal and market incentives to encourage the renewable energy technology supply industry. Fiscal incentives will include preferential customs duty exemption for imported renewable energy technology components, tax credits, capital incentives and opportunities for long term preferential loans. In the short-term, the Renewable Energy Master Plan proposes a moratorium on import duties for renewable energy technologies. A zero-import duty regime will give the needed impetus to the industry. Some potential market incentives include dedicated markets, fixed price or fixed payment approach, fixed capacity or fixed quantity target approach, and of course competitive bidding for license areas or concessions, as has long been practiced in the petroleum industry, and market franchise. The REMP further recommends the establishment of a Renewable Energy Fund, to be managed by a new National Renewable Energy Agency (NREA).The funds will provide resources for incentives, micro-credit schemes, training and R&D. The Government will put in place a framework for building capacity to attract international finance for RE in Nigeria.

One pressing concern in the development of renewable electricity in the country is absence of a framework for power sales from small-scale renewable energy producers to the grid. While the Electric Power Reform Law allows for increased grid-tie opportunities, there is a need to draw up Power Purchase Agreements (PPA) between market actors.

Nigeria lacks a strong institutional leadership for renewable energy. A redesign of the institutional framework leading to an actor, or set of actors that will champion the development of renewable energy is required. It will encourage efficiency in the provision and use of all types of energy; raise the quality of management and training in energy provision and use; heighten public awareness of energy-related issues; encourage local institutional reforms to help meet policy goals; and reduce environmental risks. The Renewable Energy Master Plan calls for the establishment of NREA, as an interim measure – pending when a full Ministry of Renewable Energy could be put in place. Other institutional innovations include Renewable Energy Testing Centres and the establishment of professional bodies. A new institutional design will also assist in putting in place an inter-agency collaboration to enhance the synergy between the various levels of government.

Human and institutional capacity building at all levels is required to achieve the scientific, engineering and technical skills and infrastructure relevant for the design, development, fabrication, installation and maintenance of RE Systems. Capacity building in four critical areas is most essential, and these include: training of manpower to install, operate and maintain RE systems; development of manufacturing capabilities; development of critical mass of scientists, engineers, economists etc for R&D; and design and effective functioning of institutional framework.

Lack of information and awareness creates market distortions that results in higher risk perception for potential renewable energy projects, as well as generate uncertainties among potential users of RE. The Federal Government will put in place a framework to systematically generate public awareness of the potentials of RE.

A strong and credible national research and development policy is essential for the growth of the renewable energy industry in Nigeria. Designing and ensuring the success of RETs R&D programmes will require the articulation of near-term as well as long-term goals and targets.

Financial Implications

Meeting the targets of the Renewable Energy Master Plan will demand significant investments in renewable energy systems. Tables 6.1 – 6.6 present an overview of estimated costs for these investments for all activities outlined in Chapter Four of the Master Plan. All cost estimates are in 2005 Naira.

Table 6.1 Framework Programme for Renewable Energy Promotion

S/No.	Programmes and Activities	ST (Nm)	MT (Nm)	LT (Nm)	Total (Nm)
1	Policy, legal and regulatory framework	0	90	32	122
2	Institutional framework	0	0	0	0
3	Economics and Financing	0	70	20	90
4	Capacity Building	100	100	100	300
5	Public Awareness	10	100	100	210
6	Inter-Agency Collaboration	10	10	10	30
7	Research and Development	50	50	50	150
8	Monitoring and Evaluation	0	10	10	20
	Sub-Total	**170**	**430**	**322**	**922**

Table 6.2 Biomass Energy

S/NO	ST	ST	MT	LT	TOTAL
1	Data Acquisition	200	100	100	400
2	Capacity Building: Manpower	1082	2246	6,978	10,306
3	Market Development and Promotion	271	315	290	876
4	Site Identification	30	90	90	210
5	Technology Assessment & Review	10	10	15	35
6	Biogas Technology/Diffussion Programme	60	120	180	360
7	Intensive Plantation of fast growing trees	100	300	600	1000
8	Capacity Building	40	50	3100	3190
	Sub-Total	**1,793**	**3,231**	**11,353**	**16,377**

Table 6.3 Solar Energy

S/NO	Activities	ST	MT	LT	TOTAL
1	Data Acquisition	40	80	100	220
2	Capacity Building :Manpower	60	240	260	560
3	Capacity Building : Manufacturing and Production	10	100	100	210
4	Capacity Building; Support Infrastructure	100	500	800	1400
5	Market Development and Promotion	650	1100	1100	2850
6	Research and Development Framework	50	100	200	350
7	International, Regional and Inter-Agency Cooperation	10	50	100	160
8	Public Awareness	10	10	50	70
9	Policy, legal, & regulatory framework	310	345	500	1155
	Sub-Total	**1240**	**2525**	**3210**	**6975**

Table 6.4 Small Hydropower

S/No.	Activity	ST (Nm)	MT (Nm)	LT (Nm)	TOTAL (Nm)
1	National Survey	18	0	0	18
2	Assessment of Agricultural & Industrial Demand	6	0	0	6
3	Implementation of Fiscal measures	0	0	0	0
4	Codes and Standards	5	0	0	5
5	Institutional Structure	0	200	0	200
6	Power Purchase Agreement	3	0	0	3
7	Information System	4	0	0	4
8	Public Awareness	10	0	0	10
9	Domestic, Private Sector Participation	4	0	0	4
10	Water Resource Management	4	0	0	4
11	Pilot Schemes	14	840	1,500	2,354
12	Capacity Building	30	120	120	270
13	Research and Development	36	80	100	216
14	Private Sector Participation	0	4	6	10
	Sub-Total	**134**	**1244**	**1,726**	**3,104**

Table 6.5 Wind Energy

S/NO	Activities	ST	MT	LT	TOTAL
1	Data Acquisition	150	100	140	390
2	Data Analysis	0	0	200	200
3	Establishment of a wind test facility	500	0	100	600
4	Capacity Building: Manpower	60	100	0	160
5	Establishment of a Hybrid Demonstration Plant	200	0	0	200
6	Policy Framework	10	0	0	10
7	Capacity Addition	0	170,000	380,200	550,200
8	Capacity Building; Support Infrastructure	0	0	30,000	30,000
	Sub-Total	**920**	**170,200**	**410,640**	**581,760**

Table 6.6 New Energy Research And Development Programme

Table 6.6.A Hydrogen Energy

S/NO	Activities	ST	MT	LT	TOTAL
1	Research and Development Centres	5	5	50	60
2	Proposal Development	2	10	50	62
3	Appropriation	0	0	30	30
4	Budget Line	0	0	0	0
5	Commencement of Research	10	25	0	35
	Sub-Total	**17**	**40**	**130**	**187**

Table 6.6.B Ocean Energy

S/NO	Activities	ST	MT	LT	TOTAL
1	Research and Development Centres	5	5	50	60
2	Proposal Development	2	10	50	62
3	Appropriation	0	0	30	30
4	Budget Line	0	0	0	0
5	Commencement of Research	10	25	0	35
	Sub-Total	**17**	**40**	**130**	**187**

Table 6.6.C Geothermal Energy

S/NO	Activities	ST	MT	LT	TOTAL
1	Research and Development Centres	5	5	50	60
2	Proposal Development	2	10	50	62
3	Appropriation	0	0	30	30
4	Budget Line	0	0	0	0
5	Commencement of Research	10	25	0	35
	Sub-Total	**17**	**40**	**130**	**187**
	GRAND TOTAL	**4,308**	**177,750**	**427,641**	**609,699**

Implementing the REMP will demand an estimated investment portfolio of 4 billion, 178 billion and 610 billion Naira, in the short (2005 – 2007), medium (2008 – 2015) and long term (2016 – 2025), respectively.

Financing these investments will depend on the mobilization of resources from Governments at all levels, the domestic private sector and international sources. International investments will include foreign direct investments (FDI), grants and projected revenues from carbon credits.

Risk Analysis

Certain risks to the realization of the objectives and targets of the REMP are prevalent. These include policy and political risks, market volatility, energy pricing, changes in financing parameters, environmental as well as risks associated with standards and quality control.

As is the case with any new programme, some degree of uncertainty exists over the initial adoption of the Master Plan, and when adopted, if stakeholders will generate enough commitment to fully implement the various outlined activities. Policy inconsistency, frequent personnel changes and contending interests within government often consign government plans like the REMP to the shelf. Likewise, possible regime change tends to throw away plans with the administration that created them. Furthermore, support for the plan by the international community depends on their priorities. This has been known to suffer sudden changes in the past.

As energy reforms increasingly adopt market-based instruments, risks such as macro economic instability, international demand and supply capacities of producers of renewable energy technologies as well as developments in the market for alternative fuels become salient issues. With the weakness of Nigeria's emerging renewable energy industry, managing these risks can be daunting. In many cases, market volatility influences prices for various renewable energy systems and create a disincentive for widening their uses. However, given Nigeria's large population and undeveloped markets, the potential demand, and hence the domestic market, is high. This will assist in mitigating market risks.

The financial markets also present crucial risks. Increases in interest rates, volatility of exchange rates, poor or non-implementation of agreed financial incentives, inadequate access to credit and capital as well as instability in the ongoing financial reforms – all constitute significant risks. Added to these are the uncertainties with regards to funding support from donor agencies and the inflow of foreign direct investments. Managing these risks requires partnerships between market actors, the government and the international community.

Environmental risks are also prevalent in several renewable energy projects. These might affect land use, result to resettlements or cause aesthetic damages. Environmental impact assessments, environmental audits and strategic planning are some of the instruments that assist in managing these risks.

Standards and quality control are also issues that inhibit the development of renewable energy. As relatively newer technologies, there is always a perception that these are untested technologies. Poorly developed standards and testing procedures assist in allowing market entry by sub-standard products and unprofessional people, resulting in damaging public perception of the technologies.

Section Two

Chapter 1: Rationale for, Vision and Objectives of REMP

1.0 Introduction

1.1 Energy situation in Nigeria

Nigeria is endowed with a rich energy resource base. Table 1.0 gives an overview of the energy resources available in the country. The country possesses the sixth largest reserves of crude oil and the ninth largest natural gas reserve in the world. Associated and non-associated natural gas reserves are in the ratio of 53.5:46.5. The Federal Government has intensified efforts to exploit tar sands. Coal is widely available in 13 of the 36 states of the Federation. In energy terms, crude oil, tar sands and natural gas are of comparable levels of reserve at 31.1%, 29.2% and 26.7% of total fossil fuels, respectively.

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 tonnes	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)		

The Rivers Benue and Niger provide Nigeria with a formidable potential for hydropower. Currently only about 20% of this potential is tapped. Small hydro development around the country's seven river basins is minimal. Woodlands occupy 15.4% of the total land and marine mass of the country. This vegetative cover is being denuded due to the incursion of agriculture, energy use and other natural and man-made factors. The average solar radiation in Nigeria is about 5.5kWh/m^2-day. The wind regime is moderate with the best conditions along the coast and in the mountainous areas of the North.

The demand for energy in Nigeria has previously been dominated by fuelwood. Today, its share of the total demand is 37%. Households consume about 95% of fuelwood. The share of natural gas has risen to 34%, and is set to rise even further with growth in gas-based power production. Hydropower comes third at about 24%, while other non-gas petroleum products represent 5%. Despite significant coal deposits, the consumption of coal is almost insignificant.

The energy supply infrastructure has remained inadequate in meeting the growing demand of the economy. With the exception of urban supplies that are catered for by commercial dealers, fuelwood is freely collected by rural dwellers. There is a significant mismatch between the rate of consumption for wood and the rate of reforestation. To meet the demand for petroleum products, the country has four refineries with a nominal capacity of 445,000 barrels per day. Presently, average capacity is less than half of the total installed capacity. Much of the country's current consumption is imported. Natural gas is used for power production, LPG for heating and exports as liquefied natural gas. The West African Gas Pipeline opens an additional opportunity for gas exports. Presently the nominal electricity generating capacity is less than 6,000MW. Actual output represents about half of the installed capacity. Government plans to boost power production through new gas plants and Independent Power Producers (IPPs)

1.2 Development and Energy Challenges

Nigeria is facing formidable economic, social and human development challenges (see Table 1.1). Of all the challenges confronting the country, none is as critical and daunting as the deepening level of poverty. Incidence of poverty increased from 28.1 percent in 1980 to 65.6 percent in 1996. While 18.26 million Nigerians were poor in 1980, the population living in poverty in 1996 swelled to 76.1 million. The NEEDS estimates that about 70 percent of the population is currently living under poverty. Given an estimated current population of about 130 million, the number of poor Nigerians is over 93 million. The UNDP Human Development Report paints even a bleaker picture with the assessment that nine in ten Nigerians live on less than two dollars/day – nearly 120 million people.

With 2002 GDP of about $45 billion and per capita income of only about $290, Nigeria is one of the poorest countries in the world. Despite huge incomes from crude oil exports,

Table 1.1: Nigeria Development Profile

Population	133 million
GDP (2002)	$45 billion
GDP (1980)	$93 billion
GDP per capita (2002)	$290
GDP per capita (1980)	$890 (1980)
Life expectancy at birth	47 years
Under-5 mortality per 1000 births	153
Under-5 malnutrition	36%
Adult illiteracy rate	36%
Population below $1/day	70%
Population below $2/day	91%

the standard of living has progressively fallen in the past twenty years. External debts represent about 70 percent of GDP; while domestic debts owed contractors, pensioners and local banks continue to put pressure on government finances. Since the 1980s the economy has not grown at rates that increase productivity, generate jobs and reduce poverty.

Economic decline in Nigeria has been driven by several forces, among which include, poor economic management, macroeconomic volatility, unattractive investment climate, poor infrastructure, weak private sector, high cost of funds and a debilitating level of access to energy services.

The relationship between energy and economic development represents a tremendous paradox in Nigeria. Large incomes from oil and abundance of energy resources – including, oil, gas, coal, hydro, biomass and solar radiation, have not necessarily led to growth and development. Indeed, domestic production of energy has remained nearly static over the years of phenomenal export of oil and gas; and in some years, it has actually decreased from erstwhile levels. The GDP (without the exported oil component) has commensurably remained static or decreased over the same years of oil and gas export growths. Most manufacturers have had to resort to self-generated electricity to keep from going under. There is now, however, a growing consensus that renewable energy resources could play an increasing role in meeting the development challenges facing Nigeria today. These challenges include accelerating economic growth, reducing poverty, promoting human development and addressing environmental concerns. The Federal Government is committed to reaching the MDG targets of reducing by half the number of people living under extreme poverty by the year 2015. This commitment is strongly embedded in the NEEDS.

Access to cost-effective and sustainable energy services is critical to re-launching the Nigerian economy and meeting MDG and NEEDS targets. However, barely 40 percent of all Nigerians have access to electricity services. This leaves about one hundred million Nigerians literarily in the dark, while generation shortages and poor transmission and distribution infrastructure consigns the industrial and services sectors to under-performance. The power sector is so inadequate that it constitutes a major roadblock to economic progress and social well-being. The economy suffers from petroleum product supply constraints as well as poor gas infrastructure and utilization. Beyond the formal sector, denudation of forest resources and wood scarcity remain a crisis unfolding in slow motion. Biomass energy accounts for 37% of the aggregate national energy demand, and ninety-five percent of rural energy use.[i] The diminishing stock of fuelwood will compound the problem of poverty reduction and challenge efforts to empower women, children and fuelwood merchants.

In many ways therefore, the energy sector in Nigeria is ripe for reforms. Among the key elements of the Federal Government's energy policy reform is the accelerated promotion of renewable energy resources and technologies. The National Energy Policy (NEP) sets the framework for the development of the nation's renewable energy resources. Among other things, the policy seeks to ensure the development of the nation's energy resources for the achievement of national energy security and an efficient delivery system with optimal energy resource mix. It further aims at guaranteeing adequate, reliable and sustainable supply of energy at appropriate costs and in an environmentally friendly manner. The NEP moreover, seeks to ensure a comprehensive, integrated and well-informed energy sector plans and programmes for effective development. The policy articulates in details, the Federal Government's aims, objectives and strategies on all renewable energy resources.

1.3 Drivers for Change

Building a post-fossil economy is possible. Despite the obstacles to growth for renewable energy – high prices, unsupportive policies, poorly regulated product quality, weak supply chain and inadequate public awareness – Nigeria's vision of an economy increasingly driven by renewable energy is achievable in the next two decades. Several factors will drive this transformation.

Abundant renewable resources. The Nigerian renewable energy resource base is enormous. The country lies within the sunshine belt – creating opportunities for everybody everywhere to meet their energy needs. Annual average daily solar radiation varies from about 3.5 kWh/m^2/day in the South to 7 kWh/m^2/day in the northern arid region. Annual average sunshine hours vary from 4 to 9 hours/day, while the 10m height annual average wind speed varies from 2- 4 m/s – all with the same increasing trend from the South to the North. There are seven river basins in the country, namely Sokoto River, Niger, Hadejia-Jama're, Chad, Upper Benue, Lower Benue and Cross River. Each of these has small-scale hydropower potentials estimated to be about 734.2 MW. There are of course the major rivers, namely, the Niger, Benue and Cross Rivers which have large scale hydropower potentials estimated at over 10,000MW. FORMECU estimates of forest and wood land area is approximately 13 million ha., while the production of animal wastes and crop residue have been estimated at 61 and 83 million tons/year, respectively. As hydrogen and ocean energy technologies mature, the renewable energy opportunities will expand.

Energy Demand. In twenty years, Nigeria's population will almost double. Aggregate energy demand will more than triple. The rapidly growing demand for energy will create opportunities for renewable energy. Conventional energy sources alone will not meet the challenges of an increasing population at affordable costs and in a flexible manner. Expanding economic opportunities to rural areas will particularly demand an aggressive deployment of renewable energy options. Increasing demand for rural water supply, lighting, health services and the needs of micro enterprises are already driving the market for PVs. This trend will continue to drive small hydro and wind power plants, while dwindling fuelwood reserves will drive improved utilization of biomass, and demand for alternatives to fuelwood.

Power sector reforms. NEPA's unbundling generation, transmission and distribution components will eliminate the present monopoly and enable the emergence of IPPs. The development of a competitive wholesale power market; self-generation by end-users, privatization and commercialization as well as competitive retail power markets will all provide greater incentives for the development of renewable energy. As grid extension may not expand rapidly to rural areas under market forces, renewable alternatives for off-grid power supply provide alternative solutions. Presently, likely renewable candidates for power generation will be small hydropower, solar PVs and cogeneration technologies, with wind and biomass providing additional opportunities. The proposed Rural Electrification Agency and the Rural Electrification Fund have clear mandates to provide technical and financial support to renewable energy projects.

International development. The initial impetus for intensive development and increased dissemination of renewable energy worldwide was the oil shock of the 1970s. This led to accelerated spending on RE research and development. Innovations that followed have resulted in dramatic price reductions for PVs and wind power, while small hydro and biomass have witnessed significant positive technological and price changes. Beyond the security of energy supplies, concerns over global warming have driven an unprecedented attention to renewable energy development. Donor support has been important in accelerating policy reforms, planning and programming on renewable energy in Nigeria. The convergence of international interest, technology and investment finance will continue to propel the sector. Presently, international instruments such as the Clean Development Mechanism (CDM) and Global Environmental Facility (GEF) as well as several bilateral initiatives provide technical and financial support to the sector. However, not all international developments will be supportive of a rapid scale up of renewable energy systems. The capacity of major producers of renewable energy systems to meet a stretched world demand is in doubt. For instance, the imbalance between current demand and supply of solar photovoltaic modules are already slowing down price reduction targets for these particular technologies.

Technological change and prices. Cost reduction through technological innovation has driven the renewable energy market worldwide. According to the International Energy Agency (2003), high cost reduction is expected from technologies that are expensive and are recent in development. For instance, solar technologies are expected to reduce their costs by some 30-50% in the next two decades as a result of learning and market growth. Medium cost reduction potential is expected among technologies that have both low to medium cost range and are relatively recent in development. Wind is expected to reduce its cost by some 25% in the next two decades on this basis, and geothermal by some 10 – 25% in the same period. Small cost reduction potential is likely among mature technologies, for instance, small hydropower and biomass. Only about 5-10% reduction in cost is expected in the next two decades for these more mature technologies.

Environment. A convergence of environmental challenges will continue to focus public spending on renewable energy. First and foremost is desertification in Northern Nigeria as well as hydro-geological changes in the region. The loss of biomass cover will expand the scope for improved efficiency in biomass conversion; while the lowering of the water table in the North will continue to make PVs, wind and perhaps small hydro relevant choices in water supply. Global warming and activities to mitigate the greenhouse effect are already directing public funding towards renewable energy initiatives.

Energy security. While the security of energy supplies is at the center of policies in several developed and emerging economies of the world, Nigeria is currently richly endowed with energy resources, particularly petroleum. In a few decades, the availability of fossil fuel will however become an issue. Declining reserve-to- production ratio is already affecting North Sea petroleum producers. Weaning the country of its dependence on petroleum will require adjustment in policies that enables the mainstreaming of RE in energy policymaking. Securing the energy foundations of future development will require going beyond today's mature technologies. In the long-term, energy security for future generations will underscore national attention to ocean, geothermal energy, and particularly hydrogen energy.

Meeting NEEDS and MDG targets. The new economic development programme sets several targets for overall growth of the economy as well as improvements in the social sectors, including education, health services, water supply and employment. It outlines key sectoral targets and strategies for meeting them. Renewable energy resources, technologies and emerging energy markets create new opportunities for developing growth poles in the economy, expanding access to social services and reducing poverty. While energy alone does not guarantee progress in meeting MDGs, the diffusion of non-conventional energy is supportive of efforts to fast-track poverty reduction, decline in the burden of diseases, provision of safe water supply and sanitation, school enrolment, quality education and gender equality.

1.4 Rationale for the Renewable Energy Master Plan

There are several compelling reasons to embark on the REMP. First and foremost, Nigeria's petroleum age will likely expire in a few decades. There is a need for a post-fossil national energy vision. While increased exploitation of gas provides a bridge to a low carbon energy future, renewables loom large in the long-term energy vision for the country. Since renewable energy technologies and markets are at various stages of maturity, actions are needed today in preparing tomorrow's Nigerians to meet their own energy needs. The REMP provides a roadmap to meeting Nigeria's renewable energy vision.

Second, despite remarkable progress made in the development of several renewable energy technologies, most of them are still at a junction between scientific research and the energy marketplace. What is needed is a properly coordinated policy and implementation framework that supports an accelerated market development for these technologies. Creating a level playing field will support such ready-for-the-market technologies such as solar PV, solar thermal, small hydro, wind, cogeneration, biomass briquetting and improved woodstoves.

Third, two-thirds of the population of Nigeria resides in rural area. Integrated rural development will require increased access to energy services. Centralized energy forms, primarily grid electricity may either be too costly or may take a long time to reach most rural areas, especially as the sub-sector becomes market-driven. Decentralized renewable energy sources and technologies often will provide modern, convenient and cost-effective alternatives to centralized sources.

Fourth, the restructuring of the electricity supply industry will among other things lead to a competitive wholesale power markets, increased self-generation by end-users, accelerated privatization and commercialization, unbundling of generation, transmission and distribution and a competitive retail power market. These reforms have profound impacts on the development of renewable energy in the country. More competition may lead to the reduction of subsidies and eventually costs, increase access to information and reduce transaction costs. The setting up of the Rural Electrification Agency and the Rural Electrification Fund provide important opportunities to focus on and finance renewable energy.

Fifth, for specific technological and market conditions, some renewable energy resources, including wave, tide, geothermal, hydrogen and liquid biomass require special attention. It is therefore in the national interest to plan research and development activities that keeps Nigeria at an advantage in the development of these technologies.

Sixth, renewable energy is benign to the environment. Reducing indoor air pollution, promoting urban air quality and the global climate are issues that are high on the national development agenda. A master plan that promotes renewable energy use is supportive of a cleaner and sustainable development.

Finally, as many players become involved in renewable energy development and implementation activities, there is need for overall guide that will ensure that all the activities are complimentarily integrated and channeled towards the same national goals.

1.5 Nigeria's Renewable Energy Vision

The National Economic Empowerment and Development Strategy (NEEDS) sets out a bold new vision to return Nigeria to the path of growth, stability and sustainable development. The Renewable Energy Master Plan (REMP)'s vision is based on the core values, principles and targets of the NEEDS. It is further anchored on the commitment of Nigeria to achieve the Millennium Development Goals (MDGs). The vision is inspired by the objectives and strategies of the National Energy Policy (NEP) on renewable energy. It takes full recognition of various national initiatives including the Power Sector Reform Act, the Rural Electrification Strategy and the Integrated Rural Development Policy. It is further inspired by the 2004 international commitment of world leaders in Bonn to accelerate the utilization of renewable energy, and the opportunities to build a sustainable future for Nigeria and the world.

Towards the coming decades, Nigeria envisions a peaceful and prosperous nation driven increasingly by renewable energy. By the middle of the century, sustainable and affordable energy will provide half of the country's energy demand.
Fossil fuels, especially crude oil, have transformed modern Nigeria. Crude oil has created opportunities for prosperity by injecting over 300 billion USD to the economy. Crude oil, natural gas, large hydro and previously coal provided the foundation for building the current energy economy. Meanwhile, woody biomass has remained the cornerstone of rural energy supply. However, this fossil-led energy economy is under severe threat.

"Nigeria envisions a peaceful and prosperous nation driven increasingly by renewable energy. By the middle of the century, sustainable and affordable renewable energy will provide half of the country's total energy demand".

An exact prediction of the end of history for petroleum is not yet possible. Crude oil reserves will however slowly but certainly run out in decades to come. Low seasonal water levels are already putting large-scale hydroelectric plants under pressure. The River Niger has shrunk to only a fraction of its normal size. Human activities, including climate change will in the near future exert even more pressure on hydro resources. Strikingly, the energy of last resort for the poor – biomass, is fast being depleted. An increasingly encroaching Sahara Desert, expanding agricultural activities, logging and the daily scramble for wood in villages are pointers to a silent crisis. In many ways, the energy foundation of modern Nigeria is flagging.

In the coming years, crude oil will continue to fuel the development of the country. However, in the medium term, Nigeria envisions an energy transition from crude oil to a less carbon intensive economy powered by gas. Gas will provide a bridge to a future that is more secure, prosperous and sustainable. Within the next ten years, gas will overtake crude oil as a source of revenue; provide a basis for reliable power supply and a cleaner environment. More so, effective management of gas resources will assist Nigeria in meeting the MDGs in 2015.

By 2025, gas will increasingly provide a bridge to a renewable energy driven economy.
The transition to a post-fossil economy will not be complete over the two decades of the REMP. However, renewable energy will increasingly offer alternative solutions to key development challenges facing Nigeria.

1.6 Objectives of the Renewable Energy Master Plan

The overall objective of the REMP is to articulate a national vision, targets and a road map for addressing key development challenges facing Nigeria through the accelerated development and exploitation of renewable energy. It will put in place a comprehensive framework for developing renewable energy policies, legal instruments, technologies, manpower, infrastructure and market to ensure that the visions and targets are realized. Among other things, the master plan has the following specific objectives:

- Expanding access to energy services and reducing poverty, especially in the rural areas;
- Stimulating economic growth, employment and empowerment;
- Increasing the scope and quality of rural services, including, schools, health services, water supply, information, entertainment and stemming the migration to urban areas;
- Reducing environmental degradation and health risks, particularly to vulnerable groups such as women and children;
- Improving learning, capacity-building, research and development on various renewable energy technologies in the country; and
- Providing a road map for achieving a substantial share of the national energy supply mix through renewable energy, thereby facilitating the achievement of an optimal energy mix.

1.7 Expected Outputs

The master plan sets clear and verifiable national targets in the short, medium and long term. Short-term targets are to be achieved by the year 2007 when the term of the present administration will end. Medium-term targets will be achieved by the year 2015 coinciding with the target year of the MDGs. Long-term targets are set for 2025, – two decades after the launching of the REMP.

By 2007, the REMP envisages an aggregate electricity demand of about 7000MW with new renewable energy (excluding large scale hydro) playing a marginal role. In 2015, the country will likely achieve a doubling of electricity demand to about 14000MW of which new renewables will constitute about 5% (701MW). In 2025, aggregate electricity demand will increase to 29000MW with new renewable energy making up 10% of the total energy demand of the country. Small hydro plants will represent over 66% of the entire new renewable energy contribution; solar PV 17%, biomass 14%, wind 1.3% and solar thermal 0.7%.

Expected contribution of non-electricity renewable energy sources to the overall projected energy demand will actually decline in the period of the plan. These figures will decline from 41% in 2007 to 16% and 9% for 2015 and 2025 respectively. The expected decline of the contribution of fuelwood to the overall energy demand will account for this trend.

The implication of these targets is a rapid scale up of most of the renewable energy technology applications. Some of the highlights include a combined increase in wind power generation to 1MW, 19MW and 38MW in 2007, 2015 and 2025 respectively. Small-scale hydro plants will contribute 56MW, 600MW and 2,000MW in 2007, 2015 and 2025 respectively. A significant expansion of improved woodstoves dissemination will occur with 300,000, 500,000 and 1,000,000 in the short, medium and long-term periods respectively. An estimated 40,000, 400,000 and 4,000,000 solar home systems will be achieved within the same periods. Solar cookers will increase to 1,500 in 2007, 50,000 in 2015 and 150,000 in 2025.

To reach the set targets, REMP outlines concrete activities and milestones, reviews key make or break implementation issues and identifies risks and how they can be managed.

The REMP has developed a number of concept notes for potential projects. These concept notes are found in the annex.

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, Wind Energy, and Hydrogen, Marine, Ocean and Geothermal Energy.

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.

2.1.1 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.

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. 2.1.1 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.

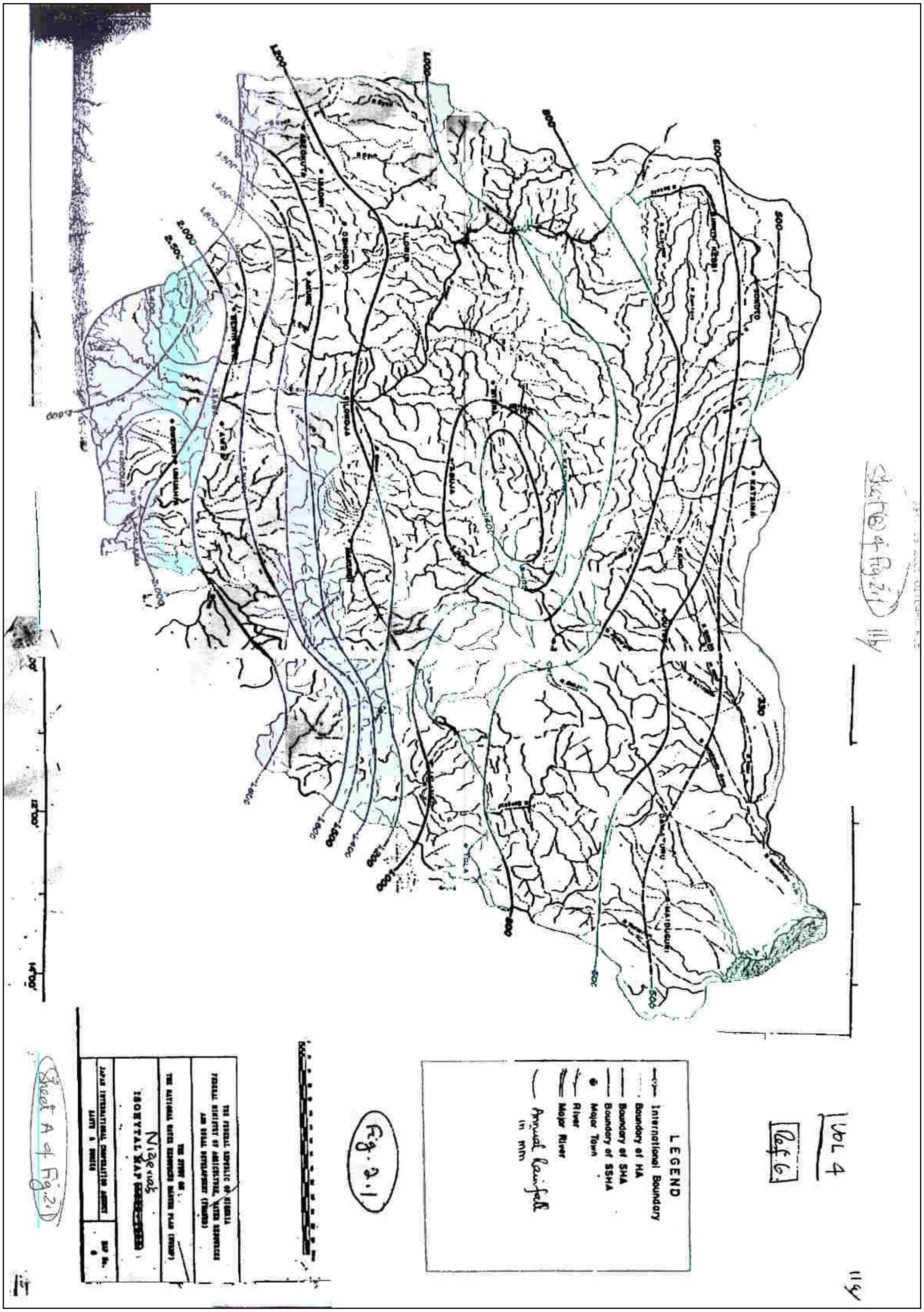


Fig. 2.1.1: Nigeria's Isohyetal Map

2.1.1.1 *Estimated Resource Base*

From NEPA's most recent estimate, the country's outstanding total exploitable hydro potential, listed in Table 2.1.1 currently stands at 12,220 MW. Added to the 1930 MW (Kainji, Jebba and Shiroro), already developed, the gross hydro potential for the country would be approximately 14,750 MW. Current hydropower generation is about 14% of the nation's hydropower potential and represents some 30% of total installed grid-connected electricity generation capacity of the country.

Table 2.1.1: NEPA Estimate of Current Exploitable Hydro Power Sites in Nigeria

Location	River	~~Installed~~ 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
Afokpo	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 2.1.2), that some 734 MW of SHP can be harnessed from 277 sites. The potential would of course increase when the rest of the country is surveyed. It is presently estimated by the Inter-Ministerial Committee on Available Energy Resources (2004) that the total SHP potential could reach 3,500 MW, representing 23% of the country's total hydropower potential.

Table 2.1.2: 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-Jamaare	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**	**734.2**

Listed in Table 2.1.3 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 2.1.3: 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 2.1.4: 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
~~Table 2.1.4 Cont'd.~~							
		Kwali	**Ankwil I**	**Ankwil II**	**Kurra**	**Jekko I**	**Jekko II**
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 2.1.4, NESCO projects were completed between 1923 and 1964 and have continued to provide virtually uninterrupted power to not only supply the Jos metropolis and meet local consumption, but also feed into the national grid. NESCO operations are a clear example of a very successful independent power production (IPP) that should be replicated in other parts of the country.

2.1.1.2 Status of Database

As noted in *Section 2.1.1.1*, 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.

2.1.2 Technical Assessment

2.1.2.1 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 ro~~a~~tational energy, an alternator which converts ro~~a~~tational 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 2.1.3, 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.

2.1.2.2 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 2.1.5, several types of turbines are available for the small hydro. The impulse turbines, which have the least complex design and rely on flow velocity to move the wheel or runner, are the most commonly used for the high head SHP systems. The most common types of impulse turbines are the Pelton and Turgo wheels.

Table 2.1.5: 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 existing from a nozzle and striking double buckets attached to the wheel. The resulting impact creates a force that rotates the wheel at a high efficiency rate of 70 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. 2.1.2, 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.

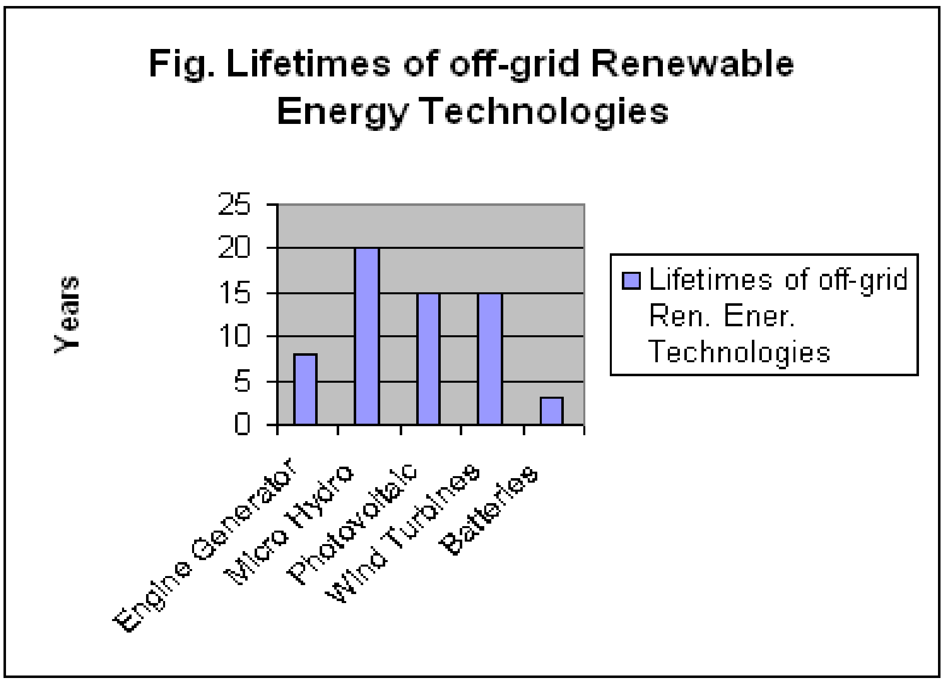


Fig. 2.1.2 Lifetimes of off-grid Renewable Energy Technologies

Table 2.1.6: **Lifetimes of Off-Grid Renewable Energy Technologies**

Technology	**Lifetime (Years)**
Engine Generator	8 – 10 (diesel)
Micro Hydro	20 – 30
Photovoltaic	20 – 30
Wind Turbines	15 – 25
Batteries	3 – 5

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.

2.1.2.3 Economic Competitiveness

Although, the small hydro may require a moderately high capital cost (Fig. 2.1.3), its low operation and maintenance (O & M) requirements (Fig. 2.1.4) 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 gensets 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.

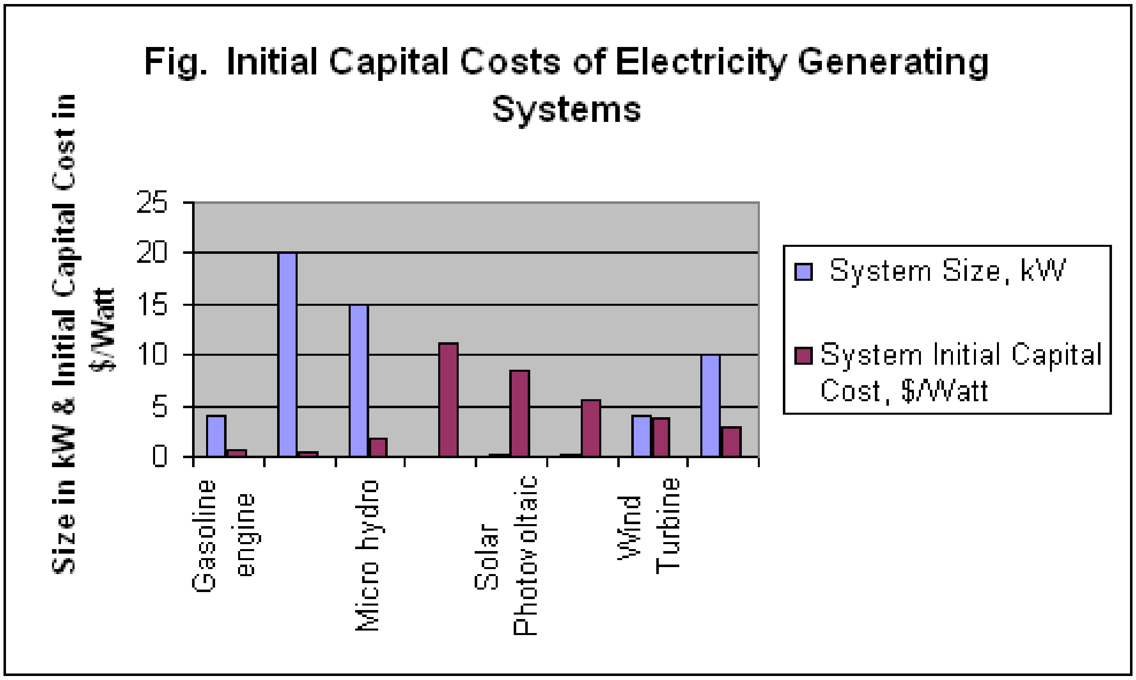


Fig. 2.1.3 Initial capital costs of electricity generating systems

~~Table 2.1.7: **Initial Capital Costs of Electricity Generating Systems**~~

~~Technology~~	~~Size (KW)~~	~~Initial Capital Cost ($/KW)~~
~~**Engine Generator**~~	~~-~~	~~-~~
~~Gasoline~~	~~4~~	~~760~~
~~Diesel~~	~~20~~	~~500~~
~~Micro hydro~~	~~10 – 20~~	~~1,000 – 2,400~~
~~Photovoltaic (PV)~~	~~0.07~~	~~11,200~~
~~Photovoltaic (PV)~~	~~0.19~~	~~8,400~~
~~Wind Turbine~~	~~0.25~~	~~5,500~~
~~Wind Turbine~~	~~4~~	~~3,900~~
~~Wind Turbine~~	~~10~~	~~2,800~~

Costs are as of 1990

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

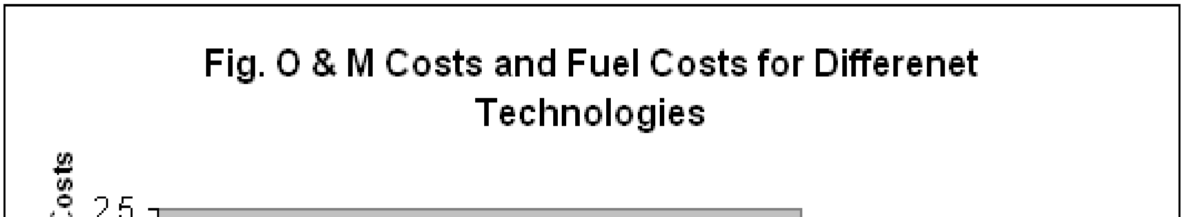


Fig. 2.1.4 Operating & Maintenance (O & M) and Fuel Costs for different technologies
Source: National Energy Plan Vision 2010 Small Hydropower Technology (March, 2004)

~~Table 2.1.8: Operating, Maintenance, and Fuel Costs for Different Technologies~~

~~Technology~~	~~O & M Costs (cents/KWh)~~	~~Fuel Costs* (cents/KWh)~~
~~Engine Generator~~	~~2~~	~~20~~
~~Micro Hydro~~	~~2~~	~~0~~
~~Photovoltaic~~	~~0.5~~	~~0~~
~~Wind Turbines~~	~~1~~	~~0~~

~~* Assuming Diesel Fuel Price of 5 US$/L~~

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.

2.1.2.4 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 upliftment 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 2.1.6: 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 spearsely populated regions In Nigeria. µ

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.

2.1.3 Market Situation

2.1.3.1 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.

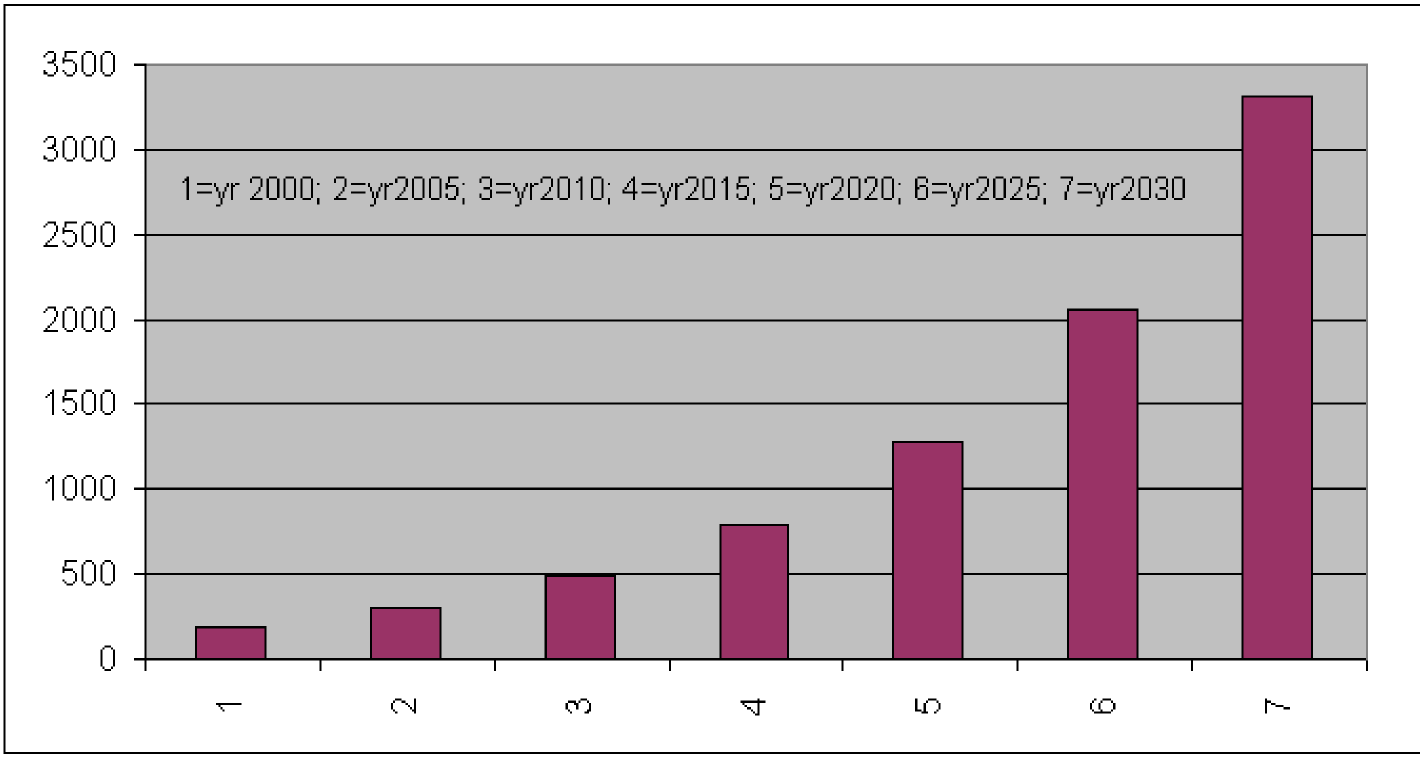


Fig. 2.1.5. Projected Nigerian Small Hydro Power Demand

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.

2.1.3.2 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.

2.1.3.3 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

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.

2.2.1 Resource Situation

The Solar Thermal Energy Resource of Nigeria is the totality of the solar radiation falling on its 923,768 km^2 land area. This total solar radiation includes the direct radiation as felt on clear sunny days, diffuse radiation scattered by clouds and atmospheric gases and vapors and felt on cloudy days even when the sun is not visible. For some applications, the albedo or solar radiation reflected by the ground and surroundings of the location or solar device of interest may be included in the total solar radiation. Application of solar radiation in most solar thermal technologies is based on the totality of the shortwave, visible spectrum, and long-wave radiation within the wavelength range of 0.1 to 100 micron-meter. A few specialized technologies however do discriminate within certain wavelength bands such as the ultra-violet or the near infrared ranges.

Undoubtedly, 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 of20 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.

2.2.1.1 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 1 km^2 if a conversion device having an efficiency of only 10% were used.

The total final energy demand for the high growth scenario in Nigeria is estimated by the Energy Commission of Nigeria, ECN to be 131.13 mtoe (million tonnes of oil equivalent, ≈ 5507 PJ or 1530 TWh) by 2030 and 55.74 mtoe (≈ 2341 PJ or 650 TWh) in 2010. This ECN projection of Nigeria's total final energy demand for 2010 and 2030 can be provided by the average annual solar energy intensity falling on 339 km^2 and 798 km^2 of Nigeria's total land area respectively.

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.

2.2.1.1a 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 solar radiation measuring instruments used at the stations are generally the old, first generation Gun- Bellanni instruments which have long been overtaken by generations of technological changes. Standard pyranometers and pyhreliometers need to replace the old instrumentation. Calibration and standardization issues also need to be high on the Department's priorities. The effect of the Information and Communication Technology era needs to be felt in the instrumentation of the Department's weather stations. Stations should be equipped with telemetry and remote sensing dataloggers equipped with electronic chips which can produce both instantaneous and integrated solar radiation data at each station and transmit same to the base station at the Meteorological Agency headquarters. There are, however, encouraging developments in the Meteorological Department that are taking cognizance of some of the above issues and gaps, although quite more substantial financial resources would be required to effect a comprehensive instrumentation update or replacement.

2.2.1.2 Technical Assessment of Solar Energy Technologies

The two broad classifications of Solar Energy Technologies are Solar Thermal Energy technologies and Solar Photovoltaic (PV) technologies. Each of these two broad classifications contains many sub-classifications of technologies which will be technically assessed in this section.

2.2.1.2a Overview of Solar Thermal Technologies

Following the broad overview presented below, solar thermal technologies are considered in greater detail under the following three broad categories as Table 2.2.1 shows: (i) proven, mature and commercial stage, (ii) proven, mature but largely demonstration-stage, and (iii) proven but immature development-stage. For each of these categories, the technical characteristics, economic competitiveness, and the benefits and limitations of each technology are examined.

Table 2.2.1 Classification of Solar Thermal Technologies by stage of development

Proven, mature & Commercial	*Proven, mature but largely Demonstration*	*Proven but largely Developmental*
Solar water and air heating	Solar stills	Solar furnace & very high temp. heating
Swimming pool solar heating	Solar desalination	Photovoltaic/Thermal (PV/T)
Heat pump solar heating	Solar drying	Solar ejector cooling
Solar cooking	Solar brooding	Solar ponds

	Incubation, etc.	
Solar passive architecture	Solar pasteurization &	
	Sterilization	
	Solar refrigeration &	
	cooling - AB & AD	
	Solar desiccant cooling	
	Solar Thermal Electricity	
	PT; PD; CR-PT	

Legend: AB - absorption systems; AD - adsorption systems; PT - parabolic trough systems; PD - parabolic dish systems; CR-PT - central receiver power tower systems; PV/T - photovoltaic-thermal composite systems

Solar thermal technologies available in the international market today are efficient and highly reliable, delivering solar energy in a wide range of applications, among which are: domestic hot water and space heating in residential and commercial buildings, swimming pool heating, solar-assisted cooling, solar-assisted district heating, industrial process heat, desalination, agricultural products drying, hatcheries, chick brooders and seed germinators, solar cooking, and electric power generation. In Nigeria, the Energy Commission of Nigeria, with its two renewable energy centres, namely, the National Center for Energy Research and Development, NCERD, at the University of Nigeria, Nsukka and the Sokoto Energy Research Center, SERC, at Usmanu Danfodiyo University, Sokoto, has developed or adapted a variety of renewable energy technologies and capacities, including solar dyers, solar water heaters, solar cookers and solar chick brooders. Many tertiary institutions have also developed or adapted several solar thermal technologies for local use. These local developments need to get from the present largely demonstration or dissemination stage to the next stage of commercialization, with private sector driven but high profile public sector led initiatives.

I. Proven, mature and commercial-stage solar thermal technologies

(i~~a~~) Solar Water Heater (Collector) technology (SWHs)

There are basically two major types of commercial solar water collectors: the Flat Plate Collectors (FPCs) and the Evacuated Tube Collectors (ETCs)~~, *shown in Appendix A-1.2*~~. The FPCs consist of an insulated outer metallic box covered on the top with one or two glass sheets. Inside there are blackened metallic absorber sheets (selectively coated for maximum absorption of solar radiation transmitted through the glass covers) with built in channels or riser tubes to carry water to the headers. The ETC is made of double layer borosilicate glass tubes evacuated to provide insulation, much like the thermos flask glass. The outer wall of the inner glass tube is again coated with a selective absorber paint material. This helps to maximize absorption of solar radiation and its transfer to the fluid flowing inside the inner glass tube. ETCs can attain considerably higher temperatures (> 100°C) than FPCs which generally operate below 80°C. Both FPCs and ET~~P~~Cs are very mature, reliable technologies.

Solar water heating has been a proven, mature and reliable technology for about two decades (five decades in Japan!). It has been able to reduce a significant portion of the conventional energy being used for heating water in homes, commercial and institutional establishments as well as in industrial applications. An IEA study estimated that over 100 million m^2 of collector area has so far been installed worldwide for heating water, and about a tenth of this is in the EU countries. Solar water heater capacities of 100-300 litres producing hot water at 60-80°C are suitable for domestic purposes while larger systems find ready application in hotels, hospitals, restaurants, dairies, and industries worldwide.

The benefits to the user include either total elimination of, or substantial reduction in, grid electricity for heating water in geysers; to the utility and the economy, positive contribution to peak shaving of electrical capacity and avoided or delayed utility generation cost; and to the society, a better cleaner environment from the adoption and cumulative use of solar water heaters, avoidance of millions of tonnes of CO_2. For example, according to Renewable Energy World journal, the annual collector yield of all solar water collectors installed by the end of 2001 in 26 countries studied is 41,795 GWh (150,463 TJ), corresponding to an oil equivalent of 6.7 billion litres, and an annual avoidance of 18.2 million tonnes of CO_2. Further, establishment of a local solar water industry creates a significant number of local jobs with the proper enabling and regulatory environment in place, particularly if the industry is based on intermediate technology rather than high technology concepts.

Commercial solar water collectors have an average of 15 to 25 years lifetime. The efficiency of the commercial solar collectors is generally over 60% at average solar radiation for the FPC and over 70% for the ETC. The average cost per m^2 of FPC glass surface area is US$300 - 800, while ETCs could cost as much as 3 to 4 times higher. Data from India indicate payback periods of 2-3 years when electricity is replaced, 4-5 years when furnace oil is replaced, and 6-7 years when coal is replaced.
For warm climates, the thermosyphon circulation systems which do not require pumps are the most common packaged commercial solar domestic FPC product configuration. They are comparatively low-cost and more affordable than forced flow types or evacuated tube types.

Solar water heaters developed in Nigeria by the NCERD, Nsukka and at the SERC, Sokoto are mounted on stands as opposed to the typical roof-mounted solar water heaters available on the international market. The SERC, Sokoto has also designed, built and installed a 1000-litre capacity solar water heating system at the Usmanu Danfodiyo University Teaching Hospital in Sokoto. Installed in 1998, the system is still operational and supplies the hot water needs of the maternity ward of the hospital. Local capacity exists for the manufacture of solar water collectors on a commercial basis, and the market exists initially in the following sectors: institutional (hospitals, hostels, etc.), commercial (hotels, restaurants, etc.), industrial (bottling plants, dairies, juice extraction factories, malt preparation, etc.). There is limited opportunity for solar water heaters in the Nigerian domestic sector in the high elevation areas of Plateau and Mambilla which experience near-temperate climates during the harmattan season.

(iib) Swimming pool heating and (c) heat pump solar water heating applications:
Swimming pool applications are similar to the domestic SWHs and differ only in the piping (and storage tank, if used at all) requirements. Solar-boosted heat pump water heaters with direct solar heating of the heat pump evaporator have also been developed and are available on the market, and they have domestic, commercial and industrial applications. The large hotels and the upper strata of society constitute the potential market for this technology, and it is a substantial and growing market in Nigeria.

(iiid) Solar Cookers
Solar cooking technology is also a mature, proven simple technology. It has received varying degrees of acceptance worldwide, particularly in many tropical developing countries of Africa, Asia and South and Central America, and among strong environmental promoters in the developed countries of Europe and North America. The main types are: (i) the box-type, (ii) the parabolic deep-focus concentrator (SK14) type, (iii) the flat-plate oil working fluid type suitable for domestic indoor cooking, and (iv) the Scheffler type for commercial/industrial cooking applications. Solar cookers in India have been found to generate savings of about 900kg/year on fuelwood per household; and a reduction in CO_2 emissions of about 1,000 kg/year. The approximate manufacturing cost of the fabricated "Sunstove" box solar cooker is about US$10-20 and could be a good employment generating cottage industry. The "SK-14" parabolic concentrator collector costs approximately *~~465,00 DM~~US200*. Box-type and the concentrator type solar cookers have been developed by the SERC, Sokoto. Several higher institutions in Nigeria have similar research and development stage solar cookers. As with solar water heaters, it is the "commercialization barrier" that needs to be overcome in Nigeria through the active involvement of all stakeholders but with private sector driven initiatives.

There are social and institutional barriers to overcome in introduction of the technology in Nigeria, such as changing habits and social cooking mores to accommodate solar cooking. Environmental benefits of adopting solar cooking technology include reduced rate of depletion of forest cover and hence desert encroachment.

(ive) Solar Passive (Low Energy) Architecture
There are many projects in temperate climates that are specifically executed as passive solar design demonstration projects. Notable among these are the Milton Keynes projects of the late 1980s in the United Kingdom, where it was found that the overall space heating load could be reduced to 1500 kWh/yr for a fairly standard three bedroom house, yielding a total gas bill of around US10~~£6~~/year.

For the tropical climates, passive solar design is aimed at reducing the influx of solar radiation into the building living and working area but rather capturing it on the its outer fabric and using it positively to reduce the cooling energy requirement of the building itself. Coupled with unpleasantly high temperatures, many tropical climates also have very high humidity. Solar energy captured on the outer fabric of the building could similarly be used to reduce the indoor humidity to comfortable levels through solar cooling and desiccant technologies. This dual goal should be the role of solar passive design for tropical climates such as we have in Nigeria. The involvement of the building -related professional bodies, the Standards Organization of Nigeria, SON, and the Nigerian Building and Roads Research Institute, NBRRI, and regulatory acts will be necessary to introduce passive solar design concepts in the building industry through high visibility demonstration projects.

II. Proven, mature but still largely demonstration-stage technologies
(i~~a~~) Solar Stills
The first conventional solar still is acknowledged to have been designed by Carolos Wilson, a Swedish engineer in 1872, in northern Chile and it is reported to have operated for about 40 years. Other types of stills are the multi-wick solar still and the single and double slope multi-wick fibre re-inforced plastic (FRP) solar stills. The inverted absorber solar still was developed to suppress the convective thermal losses of the conventional still, thereby maximally utilizing the solar radiation. In this type of still, the solar radiation is absorbed at the bottom of the solar still. An inverted absorber asymmetric line-axis compound parabolic concentrator (CPC) solar still with concentration ratio between 1.5 and 2 has vast improved performance over the previous solar stills. The condensing surface is cooled with air from a blower to greatly improve the yield.
Although solar still technology is mature, it is hardly commercial in the sense of packaged units that are available for solar water heaters. It is still largely a made to order technology or designed to suit specific needs. In the tropical climates, economic factors make it unaffordable to devote scarce resources to solar stills to provide potable water, especially when they may have to trek several kilometres to fetch the water in the first place. Where wells are sunk, the water table is usually sufficient to provide safe potable water in most tropical communities. Hence the need for this technology is not greatly felt except in areas with brackish water or high salinity creeks and deltas such as we do have in the riverine areas of Nigeria. The SERC as well as many tertiary institutions in the country have had many demonstration solar stills for over two decades, but as already noted, it is progress to the commercialization stage that is now urgently required.

(ii~~b~~) Solar Desalination
Industrial-size solar desalination demonstration plants have been built at La Paz, Mexico in 1979 and at Aqaba, Jordan in 1977. The Mexico plant is a multi-stage flash desalination plant in which the thermal energy required at a temperature of 90 - 120°C is provided by two collector fields. The collector field comprises 530m^2 of selectively coated heat pipe collectors and 160 m^2 of concentrating collectors. A vacuum of about 60 mbar is attained in the last stage requiring a 40 m^3/h, 40 mbar vacuum pump to extract the non-condensable gases. The Jordan desalination plant is rather like the conventional solar still except that heat pipes collectors are used to trap the solar energy and the heat is fed to a separate brine basin to evaporate the sea water. The yield of the one- and two-stage operation is respectively 80-90 litres/day and 120-140 litres/day from 200-300 litres/day sea (brackish) water feed.

Laboratory-scale and smaller solar desalination demonstration plants similar to the solar stills described in the previous section have been available in our national research centers as well as in our tertiary institutions for decades. The enabling environment and the push to get them to the commercialization stage is what is now required.

(iiic) Solar Dryers for agricultural products and timber drying/seasoning kilns
Like solar stills, there are no packaged commercial solar dryers although the technology is proven, mature and generally reliable. Unlike the case of solar stills, there is a great need and market for solar dryers in agriculture all over the world. Small cabinet solar dryers have been well-researched and proven dryer for fruits, vegetables, herbs, tomatoes, peppers, etc. The large scale applications however appears to be where the agricultural and industrial market lies. Such large-scale dryers are in-situ dryers. The market however will be larger if these large-scale dryers are built to be easily towed from one location to another as communities or storage barns demand. Demonstration stage dryers of the NCERD, Nsukka ~~have been in operation since~~was commissioned in 1991. There is a need to get through to the diffusion and large-scale dissemination stage towards the commercialization stage of such agricultural dryers.

(ivd) Solar Brooders, Incubators, and Seed-Germinators.
The NCERD at Nsukka has also developed the solar chick brooders. Other researchers have also developed solar incubators and solar energy operated seed germinators.

(e) Solar liquid and solid absorption and adsorption refrigeration
Absorption refrigeration has been commercially available for over three decades, and it is well known for its advantage of requiring very little pump power as opposed to the large power requirement of compression refrigeration systems. The thermal energy required in the standard absorption refrigeration cycle is usually provided by steam generated from a boiler. Incorporation of a solar collector into the absorption plant to produce the required thermal energy removes the need for a fossil fuelled boiler. For air conditioning applications, absorption chillers using water-lithium(H_2O-$LiBr_2$) bromide as the sorption pair are often employed, with water as the refrigerant and $LiBr_2$ as the sorbent. In a single-effect machine, thermal energy at 80°C - 100°C is required to drive the refrigerant into the vapour phase from the refrigerant-sorbent liquid solution in the generator in equal mass to that evaporated in the evaporator. The coefficient of performance (COP) of about 0.7 is achieved, where the COP is the ratio of cooling effect produced to the thermal energy required to produce it. Higher COPs in the range of 1.1 to 1.2 are achievable with double effect machines; however driving temperatures of 140 °C-160°C are typically required in such chillers which are of capacities greater than 100 k W. The NCERD at Nsukka is internationally recognized for the quality research and development work it has carried out on solar absorption refrigeration. This seminal work needs to progress to the demonstration stage.

Machines using solid adsorption materials are also available. Systems available
on the international market use water as a refrigerant and silica gel as a sorbent and basically consist of two sorbent compartments, the evaporator and the condenser. At present, only two Japanese manufacturers produce solid adsorption chillers. Under typical operating conditions, with about 80°C driving temperatures, the solid adsorption systems achieve a COP of about 0.6.

The coupling of solar thermal collectors and thermally driven chillers requires sophisticated controls, since both components exhibit an inverse relation to operation temperature. For refrigeration systems, common liquid a<u>b</u>~~d~~sorption pair in commercial systems is ammonia-water, (NH_3 - H_2O), where NH_3 is the refrigerant and H_2O is the sorbent. A common solid adsorption pair in refrigeration is activated carbon-methanol.

(<u>v</u>~~f~~) Desiccant cooling systems

Desiccant cooling systems employ a combination of evaporative cooling with air dehumidification by a desiccant or hygroscopic material that is capable of absorbing moisture from the air. Again, either liquid or solid materials can be used as a desiccant.
The standard cycle most commonly used today utilizes rotating desiccant wheels, equipped with either silica gel or lithium chloride as the sorption material. Liquid sorption desiccant systems are now close to market introduction, with advantages of higher air dehumidification at the same driving temperature and the possibility of high levels of energy storage by means of concentrated hygroscopic solutions.

(<u>vi</u>~~g~~) Solar furnace for high temperature metallurgical or foundry processes

Very high temperature solar ovens are based on the compound parabolic collector (CPC) principle with the addition of a sun tracking mechanism. Temperatures exceeding 1200°C have been attained by several solar ovens in demonstration projects. The CPC itself continues to be developed to attain higher efficiencies and concentration ratios. Some student solar furnace projects which have recorded temperatures close to 800°C exist in some Nigerian tertiary institutions.

(<u>vii</u>~~h~~) Solar Thermal Plants (STP) for Power and Process Heat

Solar thermal technology using concentrating systems has been used to generate solar electricity or process heat. The three main concentrating systems are the dish, tower and parabolic trough. They are applicable for both central and distributed electricity generation, and possess the highest potential for competing with conventional power plants after wind power plants. All concentrating systems possess four key elements: concentrator, receiver, transport-storage unit, and power conversion unit. The power conversion unit has successfully employed Rankine, Brayton, Combined or Stirling cycles. In spite of this, the high investments costs and the high cost of electricity generated by these technologies continue to be barriers to their widespread replication. The 354 MW solar electric generating systems (SEGS) parabolic trough power plants have been connected to the Southern California grid since the mid-1980s and parabolic troughs represent the most mature STP technology of the three systems.

(<u>vii a</u>~~i~~) The parabolic trough system or solar farm

Over 100 plant years of accumulated operating experience from nine STPs of the parabolic trough type, ranging in size from 14 to 80 MW, have been feeding over 9 billion kWh of electricity into the Southern California grid, generating over US$ 1 billion.

It is generally agreed in industry circles that the parabolic trough system is ready for more widespread replication which will then lead to further innovation and cost reduction.

This system consists of long parallel rows of identical concentrator modules, typically using trough-shaped glass mirrors. The trough concentrates the direct solar radiation onto an absorber pipe located along its focal axis as it tracks the sun from east to west. The heat transfer medium, typically oil, at temperatures up to 400°C, is circulated through the pipes. The hot oil then converts water to steam through a heat exchanger, to drive a steam turbine in a typical Rankine cycle conversion system.

(vii bii) The solar central receiver or power tower

In this system, the solar central receiver or power tower is surrounded by a large array of dual-axis tracking mirrors (heliostats), reflecting direct solar radiation onto a fixed receiver located at the top of the tower. Within the receiver, a fluid - water, liquid metal, and molten salt have been used - transfers the absorbed solar heat to the power conversion system where it is used to produce steam in a steam generator. Advanced high-temperature power tower concepts are cmrent1y being investigated, in which air is heated above 1000°C in order to feed it into the conventional gas turbine of modem combined cycles.

Power tower plants have had more than 15 years of experiments worldwide in which they have proved to be technically feasible in projects using different heat transfer media - steam, air, sodium, and molten salts in the thermal cycle and with different heliostat designs. Unlike the trough system, the power tower system has not been used commercially as yet. Multinational companies like Boeing and Bechtel have however expressed an interest in commercializing second-generation power tower technology and have recently constructed and operated demonstration power tower plants. At Barstow, California, a 10 MW pilot plant (Solar One) operated with steam from 1982 to 1988. The complete plant was then modified in 1996 and recently started operation as Solar Two, using molten salt as the fluid heat transfer and storage medium. Solar Two had a few thousand hours of experience before shutting down in April 1999 after having delivered power to the electricity grid on a regular basis.

Convinced of the environmental promises and the economic aspects of STP technologies, the World Bank's Global Environmental Facility (GEF) in year 2000 approved grants for the first solar thermal projects in Egypt, India, Mexico and Morocco of approximately US$200 million in total. GEF study had earlier predicted electricity generating costs for large solar parabolic trough power plants as well as for large central receiver power tower plants below 6 US cents/kWh after the year 2010. As of 2000, there were twelve international solar thermal power plant project developments worldwide, with two in Africa in Egypt (35 MWe solar capacity) and Morocco (30-50 MWe solar capacity).

(vii c(iii) Solar SunDish Technology of STM Corporation, Ann Arbor, Michigan, USA.

The parabolic dish solar power plant technology consists of a number of parabolic dishes which focus the solar radiation onto the STM engine to heat and expand an enclosed amount of gas (hydrogen). The engine operates on the Stirling cycle thermodynamics principle. It is claimed by the manufacturer (STM) to be well suited to supply peaking power to a grid, it is capable of running at night on any common fuel natural gas, landfill gas, propane, diesel, fuel oil, and gasoline); it generates electricity at about 3.2 cents/kWh (year 2000); and total system cost is approximately 5.4 cents/kWh (year 2000 advert assuming 15-year depreciation).

III. Proven, immature or development-stage solar thermal technologies
Three promising technologies, among several others, to be considered in this section are the Hybrid Photovoltaic/Thermal (PV/T) Systems, the Solar Ejector Cooling Systems, and the Solar Pond.

(i~~a~~) Photovoltaic/Thermal (PV/T) Systems
While solar thermal collectors are designed to generate thermal energy, solar photovoltaic (PV) cells produce electricity directly from solar energy. However, during the photovoltaic energy conversion process, thermal energy is also generated which goes to increase the PV cell temperature. Unfortunately, the efficiency of conversion of solar to electric energy in the cell drops as the cell temperature increases. The traditional method is to try to dissipate this heat to the surrounding air in a PV cell installation by mounting the PV cell with an air gap between the module and the building surface. The hybrid PV/T approach however is to harness this heat, rather than just dissipating it, and to combine it with the electricity generated as a composite useful output. Hybrid PV/T is a new but promising technology for the simultaneous production of thermal and electrical energy from a solar PV cell. Among several experimental and demonstration PV/T projects worldwide is the hybrid PV/T system developed in Kandenko, Japan for use on a domestic building in 1994. The 3.3 kW (electric) and 24 kW (thermal) PV was made from polycrystalline silicon wafers, and overall efficiencies of 70% have been recorded.

(ii~~b~~) Solar Ejector Cooling Systems (SECS)
A solar ejector cooling system consists of a typical ejector cooling system (ECS) with a solar collector incorporated to provide the required heat energy. The refrigerant R-141 b has been found to be the best for ECS and has appeal in refrigeration systems because of its low power requirements and modest efficiencies.

(iii~~c~~) Solar Ponds
Salt-gradient solar ponds are ponds containing layers of salt solutions of differing densities arranged so that the lower layers are the heavier layers thus arresting convection tendencies. The bottom of the pond has a selective black absorber material lining which makes the heavier layers at the bottom to store more of the solar radiation transmitted through the upper lighter layers, thereby creating a temperature gradient in the same direction with the density gradient. This thermal energy gradient can be used to drive an organic fluid in a Rankine cycle to produce electrical power. Solar ponds ~~have been~~ have been investigated by local researchers while demonstration solar ponds exist in Israel.

2.2.1.3 Economic competitiveness of solar thermal technologies

Most of the solar thermal technologies are economically competitive even in developed countries of the world where the market is fully developed and private-sector driven. The competitiveness of solar water heating for commercial and institutional water heating has been demonstrated for Nigeria in previous studies. However, the solar thermal power (STP) generation technologies are at present economically uncompetitive. The market success of STP plants has been found to depend heavily on the choices made between environmental protection and the lowest possible electricity cost. The final outcome will undoubtedly depend on both energy policy decisions and international support for responsible environmental actions in a climate of scarce resources. A study of the electricity cost for market introduction of STP technologies with initial subsidies has shown that competitive markets are achievable as from 2010 at about 4-6 US¢/kWh for intermediate load power. Sustained global markets for STP is expected between 2015 and 2020, during which period the total installed capacity would have increased from the present level of just 354 MW to over 5000 MW. A Greenpeace-European Solar Thermal Power Industry Association (ESTIA) study has projected 21,540 MW installed solar thermal power capacity by 2020 with a total investment of about US$42 billion.

2.2.1.4 Benefits and limitations of solar thermal energy

Solar thermal energy is all benefits as far as environmental pollution is concerned. Its limitations include lack of enabling environment for the various solar thermal technologies to become competitive with the fossil energy technologies which have long enjoyed entrenched subsidies and huge technology and market investments. The initial cost of some solar thermal technologies such as solar water collectors is unaffordable to large segments of the many developing economies without public sector intervention.

2.2.2 Solar Photovoltaic (PV) Technologies~~Overview of Solar 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

2.2.2.1 Overview of Solar PV 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 MoO/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^{o}C, 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 developing 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.

2.2.2.2 Technical Assessment of solar PV technologies~~Characteristics~~

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. The energy conversion efficiency – the ratio of electrical power out to solar power in – is quite in a modest range for most commercial modules. Second generation thin films based on amorphous silicon, copper indium diselenide have shown some improvement, with present efficiencies in the 6%-10% range.

Whilst the efficiency values have risen in the laboratory, the average efficiency for single crystal silicon cells in production have advanced much more slowly. A simple arithmetic average of the efficiency for commercial modules available today shows the singly crystal silicon modules to be only slightly ahead of the polycrystalline silicon module, (12.8 as opposed to 12.6%). PV modules based on crystalline Si technology claimed 89% of PV market production in 2003.

Copper-indium-diselenide has a very high optical absorption, promising efficiency and performance stability. PV module lifetimes are estimated to lie between 25 and 30 years.

2.2.2.3 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 ~~and~~ 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.

2.2.2.4 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 benigin. 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.

2.2.3 Market Situation for Solar Energy Technologies

This section will consider the situational analysis of the market for both solar thermal energy technologies and solar PV technologies in Nigeria.

2.2.3a.1 Market situation for solar thermal energy technologies

Thermal energy is used daily in most sectors of the economy: in the domestic/residential sector for cooking, heating bath water, and washing; in the commercial/institutional sectors for cooking, heating bath water, and washing in cafeterias, hotels, schools, hospitals, clinics, government buildings, etc.; in the agricultural sector for drying agricultural crops and grains, spices, fish, etc; in the industrial sector for heat energy in industrial processes, e.g. in the following industries: tobacco, textiles, vegetable oils, beverages, pharmaceuticals, leather, cement, breweries, etc.

2.2.3a.2 Present thermal energy demand and supply situation

There is very little public awareness of the tremendous solar thermal energy resource available for utilization in many sectors of the economy: domestic/residential, commercial, industrial, government/institutional, and agriculture. Consequently, there is a corresponding lack of demand for, and supply of, solar thermal technologies in the large thermal energy market. Solar thermal energy market share in the overall thermal energy market is therefore nil in all areas/segments of the market. The market is yet to be created from the present largely demonstration stage of solar thermal technologies in the country.

Solar thermal energy can easily play a significant role within the national thermal energy equation. Table 2.2.1~~1~~ below gives a sectoral thermal energy demand, in PJ, based on several sources. ~~The projection in Table 1 is based largely on the work of Ibitoye et al. (1998) which is derived from the computer simulation model MADE II (Model for Analysis of Demand for Energy) and the MARKAL (Market Allocation) model, a large-scale linear optimization model.~~ The estimates under Agriculture/Rural Development were based on information from several sources among which are the Biomass chapter of this report and ECN study reports. The thermal energy demand totals for the target years 2007, 2015 and 20~~9~~25 are 392 PJ, 605 PJ and 810 PJ respectively, as Tables 2.2.2 and 2.2.3~~2~~ show~~s~~. In the business as usual scenario, these will be met mainly by fossil fuels including electricity from fossil fuels and biomass (fuelwood mainly).

Table 2.2.2. Sectoral thermal energy demand estimate, in PJ.

Sector	1990	*2007**	2010	*2015**	*2025**	2030
Domestic/Residential	120.4		220.9			384.5
Cooking	71.7		121.5			190.9
Non-substitutable electricity, (NSE)	8.6		20.5			45.6
Thermal component of NSE, 20%	1.72		4.1			9.12
Thermal Sub-total, Domestic	73.42	117.773	125.6	144.21	181.42	200.02
Commercial	16		50.6			160.9
Cooking	0.6		1			1.9
NSE	12.3		39.4			126.6
Thermal component of NSE, 20%	2.46		7.88			25.32
Thermal Sub-total, Commercial	3.06	7.134	8.88	13.465	22.635	27.22
Agricultural/Rural Development	5.51		9			16
Drying	2		4			6
Dairy, pasteurization, etc.	0.1		1.5			4
Chick brooding, egg incubation	0.01		0.5			2
Thermal Sub-total, Agriculture/R.D.	2.11	4.833	6	7.5	10.5	12
Government/Instituional/Hospitals, hotels, clinics, schools, health centres, etc.						
Cooking, water heating, etc.	90		150			300
Distillation, sterilization, desalination	2		10			20
NSE	8		40			80
Thermal Sub-total, Govt./Instituional	100	170	200	250	350	400
Industrial	86		215.9			372.9
Process heat	59.6		156			252.1
NSE	2.1		6.7			21.3
Thermal Sub-total, Industrial	61.7	92	162.7	190.38	245.73	273.4
THERMAL ENERGY GRAND TOTAL	240.29	**391.74**	503.18	**605.55**	**810.28**	912.64
Thermal Energy Grand Total in TWh	66.747	108.817	139.77	168.21	225.08	253.51
Thermal Energy Grand Total in GWh	66747	108817	139772	168207	225076	253511
Total Thermal Energy Demand in GWh by ECN		193789		202128	248869	

* Target years

The ECN has made projections of the total final energy demand in Nigeria by sectors till the year 2030, for each of the three scenarios: the Reference Scenarios (RS), the High Growth Scenario (HGS), and the Low Growth Scenario (LGS). Table 2.2.4 gives the thermal energy demand as a percentage of the ECN total final energy demand for each of the three scenarios, from which it is seen that the thermal energy demand is about 20% of the total final energy demand regardless of the scenario within the plan horizon.

Table 2.2.33 Total Thermal Energy Demand as a percentage of Total Final Energy Demandby scenario, in PJ.

	2000	2007*	2010	2015*	2020	2025*	2030
Total thermal energy demand, PJ	329.38	391.74	503.18	605.55	707.91	810.28	912.64
Total final energy demand by scenario, in PJ							
High Growth	1517	2093.8	2341	3183	4025	4766	5507
Reference	1517	2039.9	2264	2975	3686	4124	4562
Low Growth	1517	2001.4	2209	2832.5	3456	3754.5	4053

* Target years

Table 2.2.4 Total Thermal Energy Demand as percentage of Total Final Energy Demand

	2000	2007*	2010	2015*	2020	2025*	2030
Total thermal energy as % of Total final demand by scenario							
High Growth	21.71	21.56	21.49	19.54	17.59	17.08	16.57
Reference	21.71	22.07	22.23	20.72	19.21	19.61	20.01
Low Growth	21.71	22.46	22.78	21.63	20.48	21.50	22.52

* Target years

A significant proportion of this thermal demand projection could be met by solar thermal energy, thus reducing the fossil fuel required with consequent environmental, ecological, social and health benefits. Quantification of the environmental benefit appears in later tables. An estimate of how much of the thermal energy in each sector that could be met by solar thermal collectors appears in Table 2.2.5. It is seen that solar thermal energy could contribute as much as about 7% and 9% of the HGS and the LGS total final energy demand respectively within the target period.

Table 2.2.5 Thermal energy demand that could be met by solar thermal systems, PJ

Sector	1990	2007*	2010	2015*	2025*	2030
Domestic	36	56	60	69	86	95
Commercial	0.8	2	2.2	3.4	5.7	6.8
Agriculture	1.6	4.1	4.5	6	7.5	9
Govt./Instituion/Hotel/ Clinics/Schools/etc.	50	92.5	100	133	167	200
Industry	12	29.5	32.5	40	47	55
Total, PJ	100.4	184.1	199.2	251.4	313.2	365.8
Total, TWh	27.89	51.14	55.33	69.83	87.00	101.61

* Target years

Thermal energy is required in the domestic sector for boiling water for bathing and cooking as well as for cooking food. Most homes, particularly rural homes meet this requirement from biomass and paraffin cookers, while the upper middle to the upper class use LPG and electric cookers and geysers. In the commercial sector, thermal energy is similarly used for boiling water and cooking; in the informal commercial sector, biomass is the main cooking and water boiling fuel while in the formal commercial sector, both LPG and electricity are the main fuels used to meet the thermal energy needs. In the conglomerate of sectors termed Govt./Institutions/Hospitals/Hotels/Clinics/Schools/etc., the thermal energy requirement is met by all the main types of fuel, namely, electricity, biomass, paraffin, and LPG. In the industrial sector, the thermal energy requirement is met mainly by boilers and heaters using heavy fuel oil, diesel oil, or natural gas.

2.2.3a.3 Key drivers for solar thermal energy technology market

Solar energy can be successfully applied for heating purposes at all latitudes. Some of the strongest markets for solar thermal energy in the world are in Europe (Germany and Austria) where the average solar radiation received annually is less than that received in most sunny tropical regions. Indeed, even in Europe, Germany and Austria receive considerably less sunshine than southern European countries such as Spain, Italy and Greece and Mediterranean Cyprus and Malta, yet the market in these countries lag far behind those of Germany and Austria. The lessons learned from the successful thermal energy stories of Germany,~~ Barcelona,~~ Spain, India and Botswana~~ in Southern Africa~~ provide an insight into the important key drivers for the solar market from the decades of these national experiences as follows.

Policy formulation, particularly regulations that make installation of solar thermal systems mandatory in some sectors are important. Market competitiveness of solar thermal technologies need to be improved through stable and well-designed financial market incentives and financing mechanisms for investors and users by the Government. Such incentives include capital subsidies which are investment assistance in the form of grants and allowances, operational cost grants; preferential loans and guarantees, and tax privileges. Duties, VAT, levies, etc. on solar thermal energy systems should be removed, until the market forces can take control. Similarly subsidies, both direct and indirect, for non-renewable energy technologies and competing fossil-energy equipment and systems need to be removed.

Regulatory, administrative, and institutional conditions which make private sector investment difficult would need to be relaxed or scrapped. Conscious effort must be made to Improve information dissemination strategies to stakeholders in order to win wide public acceptance for solar thermal technologies. Education and training and international cooperation strategies must be strengthened.

General awareness of solar thermal, especially among the relevant decision-makers, the political class and bodies, and awareness of energy savings and environmental issues must be increased. There should be organized public campaigns promoting solar thermal technology by the government with the involvement of the private sector and NGOs. Highly visible demonstration projects, with public authorities serving as a model will increase public confidence in the new technologies. A high level of trust would be achieved through quality products, recognized labels and availability of standard products and systems and development reputable local manufacturers and suppliers and availability of specifically skilled installers. There must be unqualified support for research, development, demonstration, dissemination and diffusion of solar thermal energy technologies.

2.2.3a.4 Gaps and barriers to solar thermal technology market development

Flaws in the ways markets operate, such as entrenched subsidized energy prices of fossil fuels, energy prices that do not internalize the full social, health and environmental costs, and poorly informed consumers. These barriers also relate to human behaviour, among which are the low priority given to saving energy by many consumers, both domestic and business corporate consumers, and the tendency of consumers to purchase products based on least initial cost rather than the least life-cycle cost.

Further barriers relate to public policies and institutions, and include the lack of attractive financing for renewable energy measures, and regulations that directly or unwittingly discourage renewable energy uptake. Specific barriers include: Lack of competitiveness as a result of high upfront costs and relatively long payback periods; High investment costs (due to low energy density) and frequently excessive profit anticipation of investors make financing of renewable technologies difficult; Lack of financing sources and/or of access to appropriate financing mechanisms; High discount rates which disadvantage projects with high capital costs but low running costs, such as solar thermal and other renewable energy technologies; Higher transaction costs (information, procurement, installation works, etc.) than conventional thermal energy systems, e.g. an electric geyser vs. solar water heater. Further, solar thermal energy is not yet perceived as an option, not to talk of standard option, thus decision makers must be informed and especially motivated. Need for solar thermal bodies and institutions – NGOs, Associations, Institutes, etc. to be formed to influence and educate decision makers, professional bodies and industry.

Other barriers are the lack of availability of motivated and specially-skilled installers and technicians; Little or no awareness of solar thermal, especially among decision-makers and the public at large; also low awareness of its energy savings and associated environmental benefits; and lack of Codes of Practice, Standards, Testing and

Certification bodies and quality labels and infiltration of substandard equipment, service, and products, thereby eroding investor and customer confidence in solar thermal energy technologies. These barriers can be overcome only through well-designed and effectively implemented public policies, programmes and projects.

2.2.3b.1 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.~~ APPENDIX 4.3 shows the demand scenario of world PV market by application area between 1993 and 2003.~~
~~It is to be noted that the available literature did not specify the global supply and demand pattern for other PV system components - batteries, charge controller etc.~~

2.2.3b.2 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 2.2.6.

Table 2.2.6. 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. ~~*APPENDIX 4.6* shows the cumulative installed capacities of the three major components in a PV system from 1990 to the middle of 1999.~~

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.

2.2.3b.3 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 **s**ome 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.

2.2.3b.4 Gaps and barriers to solar PV technology market development

The gaps and barriers to market penetration of photovoltaics include: High cost of PV system components; high import duties; psychological inertia; low public awareness; inadequate commercial activities and financial options; lack of regulatory standards; inadequate local technical expertise; political instability and security issues.

Other gaps and barriers include lack of local manufacture of PV components, low level of government patronage, low sensitivity to environmental protection, port delays, no tax rebates and the cost-effective power limitation ~~inability~~ of PV systems~~ to carry air conditioners~~. ~~(at prices affordable to those who want to use them)~~

2.3 Biomass Energy

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.

2.3.1 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.

2.3.1.1 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 2.3.1 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 Table 2.3.1 below.

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 2.3.1: 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

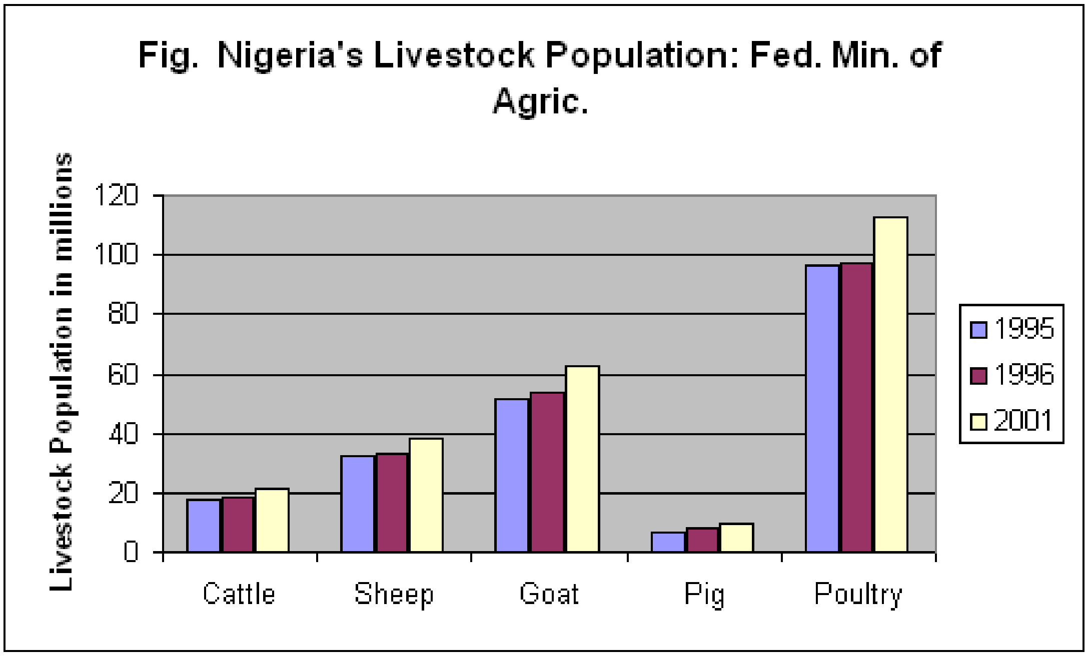


Fig. 2.3.1 Nigeria's livestock population. Source: Federal Ministry of Agriculture.

~~**Table 2.3.2: Nigeria's Livestock Population (in millions)**~~

~~Livestock~~	~~1995~~	~~1996~~	~~2001~~
~~Cattle~~	~~17.6~~	~~18.1~~	~~21~~
~~Sheep~~	~~32.4~~	~~33.2~~	~~38.5~~
~~Goat~~	~~51.5~~	~~53.8~~	~~62.4~~
~~Pig~~	~~6.7~~	~~8.3~~	~~9.6~~
~~Poultry~~	~~96.1~~	~~97.3~~	~~112.9~~

~~Federal Ministry of Agriculture reported Nigeria's livestock population as shown in Table 2.3.2 above. The figures for 2001 were calculated based on an annual grown rate in Nigeria's livestock population of 3.2%.~~

Considering cattle for instance, reported values of daily manure production range from 10kg to 60kg per animal. This indicates that Nigeria's 2001 cattle population of 21 million should be expected to produce from 210 million kg to 1,260 million kilogramme (i.e. 0.21 to 1.26 million tones) of manure daily. These values result in an annual manure production from cattle alone ranging from 76.7 to 450 million tones of for Nigeria.

Table 2.3.2: Calculated manure production of Nigeria's livestock

S/No		**England**		**Nigeria**			**Manure Produced**
	Livestock	**Population (millions)**	**Manure produced (million tones)**	**FMA (1997) population (million)**	Manure produced (calculated figures) (million tones)	**Population based on FMA (1997) figures (millions)**	**2001 (Calculated figures) (million tones)**
1	Cattle	85	80	18.1	170.4	21	197.6
2	Sheep	28	11	33.2	13	38.5	15.1
3	Goat			53.8	21.1	62.4	24.5

4	Pig	69	11	8.3	13.2	9.6	15.3
5	Poultry	104	30	97.3	28.1	112.9	32.6
	Total		**132**		**245.9**		**285.1**

From the foregoing it is seen that Nigeria's livestock manure aggregated production of 285.1 million tones shown in Table 2.3.2 is potentially able to produce far more than 3 billion cubic meters of biogas yearly, and this is more than 1.25 million tones of fuel oil per annum.

From Fig. 2.3.2, 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. 2.3.2. From all the above, it is seen that Nigeria's annual production of agricultural biomass is enormous.

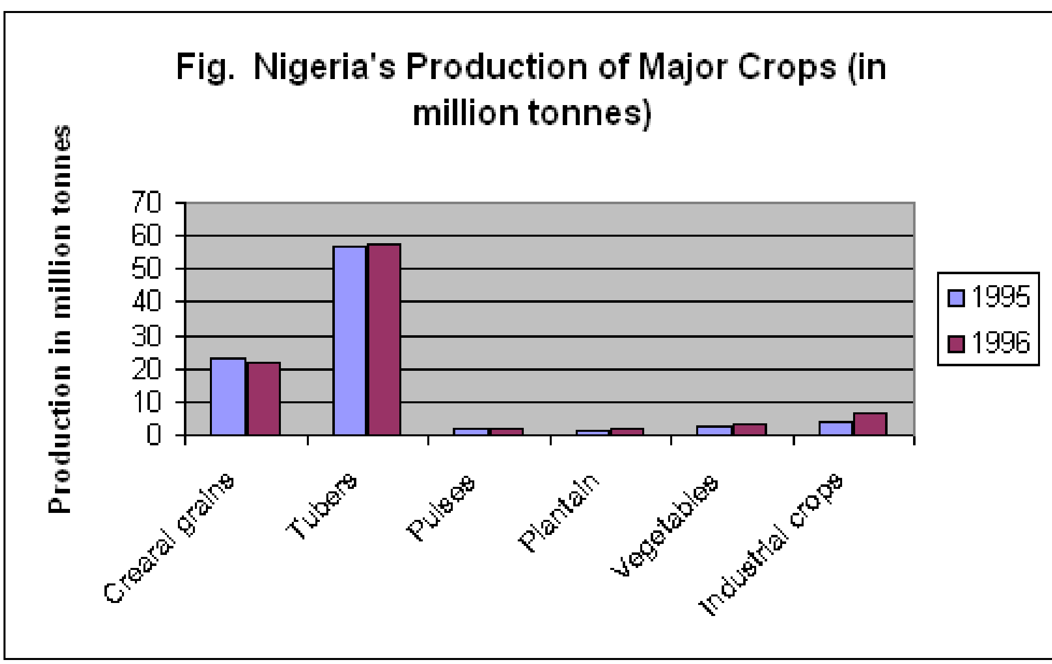


Fig. 2.3.2 Nigeria's production of major crops (in million tones)

Table 2.3.4: Nigeria's Production of Major Crops (Million Tones)

S/N	Crop	1995	1996
1	Cereal grains	22.9	21.7
2	Tubers	56.7	57.4
3	Pulses	2	2.2
4	Plantain	1.6	1.7
5	Vegetables	2.6	3.5
6	Industrial crops	3.7	6.8
-	Total	89.5	93.3

Source Federal Ministry of Agriculture

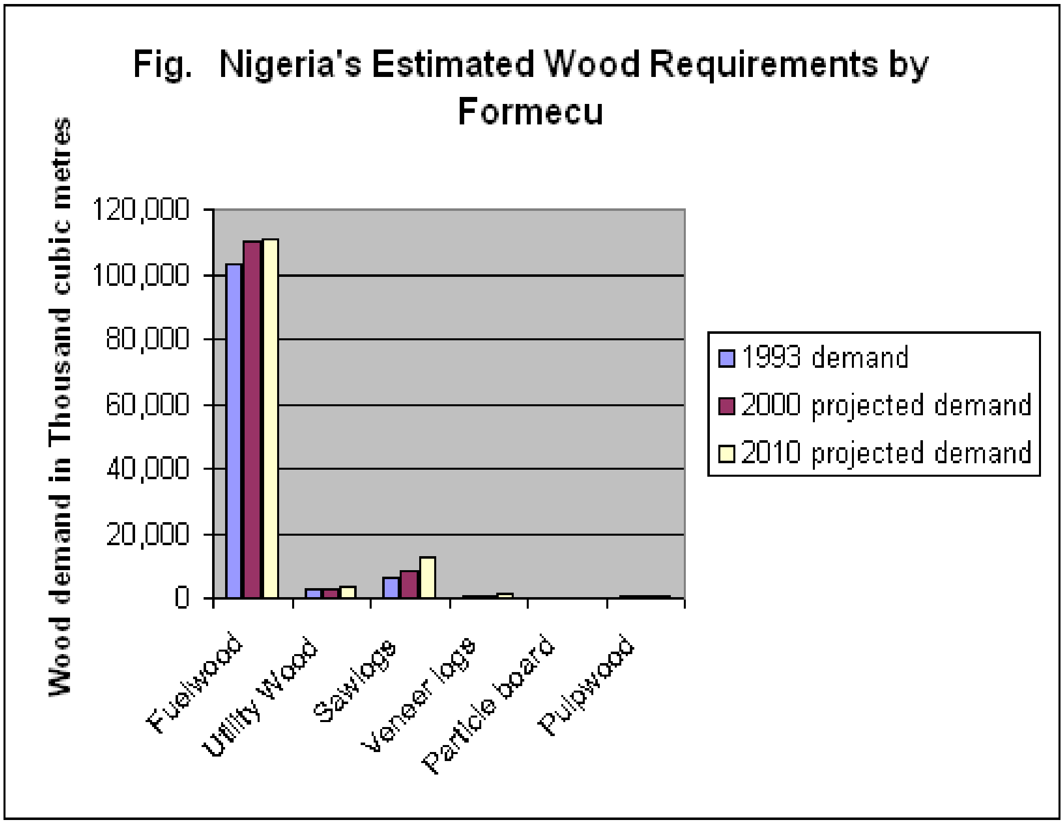


Fig. Nigeria's Estimated Wood Requirements by Formecu

Table 2.3.5: Estimated Nigeria's Wood Requirements (in '000 m^3)

-	1993	2000	2010
Fuelwood	103,474	109,966	111,102
Utility Wood	2,514	2,874	3,441
Sawlogs	6,182	8,398	12,864
Veneer logs	618	857	1,359

~~Particleboard~~	~~69~~	~~111~~	~~230~~
~~Pulpwood~~	~~640~~	~~540~~	~~958~~
~~TOTAL~~	~~113,497~~	~~122,746~~	~~129,954~~

Fig. 2.3.3 Nigeria's estimated wood requirements. Source: Formecu.

~~Source: FORMECU)~~

The country's estimate of wood resources available has been provided by FORMECU. The supply possibility of fuelwood was estimated at 78.9 million m^3 for 1994. The estimated Nigeria's wood requirement is presented in Fig. 2.3.3. ~~While the summary of Forest plantation Resource in Nigeria is presented in **_Table 2.3.6_**.~~ Fuelwood production takes place in all parts of Nigeria. Although the available fuelwood volume is much higher in the high forest zone, intensity of fuelwood extraction appears much greater in the northern states.

Other possible 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.

2.3.1.2 Technical Assessment of Biomass Energy Technologies

The assessment in this section comprises, biogas, bio-fuels, woodstoves and biomass briquetting technologies.

2.3.1.2a Overview of Biogas and Bio-fuels Technologies

The techniques used for the conversion of organic biomass materials to solid, liquid and gaseous fuels have been in existence for many years in both the developed and developing countries.

I. Biogas Technology

Biogas is a mixture of 60 to 70% methane (CH_4), 23 to 38% carbon dioxide (CO_2), about 2% hydrogen (H_2) and traces of hydrogen sulfide (H_2S). It is produced by the anaerobic (i.e. in the absence of oxygen) digestion (fermentation) of organic materials and its lower heating value is approximately 6 kWh/m^3. Biogas can be used in the household for heating, cooking and lighting; in the community farm; for agricultural and industrial production.

In Nigeria work on biogas started after the Federal Government established the two Renewable Energy Centres at Sokoto and Nsukka in 1982. These two Centres along with many tertiary institutions have been involved in biogas research activities. So far, less than 20 pilot projects on biogas are in existence in the country. The Sokoto Energy Research Centre (SERC) had constructed more than twenty~~en~~ (2~~1~~0) biogas plants ranging from 10-20 m^3 capacity across the country using different substrates such as cow dung, human excreta, piggery waste etc. with a ~~failure~~ success rate of not less than 8~~2~~0%. Similarly the National Centre for Energy Research and Development Nsukka (NCERD) had constructed some field biogas digesters that are all operational.

The UNDP had successfully introduced to Yobe, Jigawa and Kano States the floating drum and plastic balloon and tube types of biogas digesters under the Africa 2000 low technology biogas system. In Kano State, a family of 40 at Kwachiri community has ~~now~~ depended~~s~~ on the UNDP biogas project (using cow dung) since 2003 for their daily cooking needs. Similarly the UNDP introduced biogas technology at some market abattoirs in some Northern States.

2.3.1.2b Technical Characteristics

There are three designs for biogas digesters so far. These are:

I. The Fixed Dome - Consists of an airtight container constructed of brick, stone or concrete, the top and bottom being hemispherical.~~ and the walls straing.~~ Sealing is achieved by building up several layers of mortar on the digesters inner surface. The digester is fed on a semi-continuous basis (usually about one per day) and the gas produced rises to be stored under the upper dome. Typical feedstock for these digesters is animal manure, human excreta and agricultural waste. Gas production from the digester is commonly in the order of 0.1-0.2 volumes of gas to volume of feedstock per day, retention time in the digester being 60 days at 25°C.

II. The Floating Cover – The design of this digester was first developed by Indian's Khadi and Village Industries Commission (IKVIC) and consists of a cylindrical container, the height to diameter ratio being in the order of 2.5-4.1:1, constructed of brick or concrete reinforced with chicken wire. Digester construction strength is not as critical as with the fixed dome type since the only pressure on the walls is the fermenting material, the gas produced floats upwards as the pressure increases. The cover is usually constructed of mild steel. Cost, corrosion and maintenance of the cover have been the main problem of this design. Typical feedstock is cattle manure, which is fed semi-continuously into the digester, displacing an equal volume of slurry, which is drawn out through an outlet pipe. Typical retention time for the feedstock is about 30 days in warm climates and up to 50 days in colder regions. Using cattle manure with 9% solids, gas yields of 0.2-0.3 volumes of gas per volume of feedstock per day have been regularly achieved. The pressure of the gas available depends on the weight of the gasholder per unit area.

III. The Bag Digester – This type of digester comprises of a long cylinder either polyvinyl chloride (PVC) or a material known as red mud, plastic-developed in 1974 from the residues of bauxite smelted in aluminum production plants. Incorporated in the bag are inlet and outlet pipes for the feedstock and slurry and a gas outlet pipe. Gas produced is stored in the bag under a flexible membrane. A complete $50m^3$ – volume digester weighs just 270kg and is easily installed in a shallow trench. Feedstock is fed into the bag semi-continuously with the feed displacing an equal amount of slurry removed from the outlet. Typical retention times vary depending on the substrate used from 60 days at 15-20^oC to 20 days at 30-35^oC. Since the digester has extremely thin walls. It can be solar-heated by direct exposure to the sun. Gas produced from the bags has been found to vary from 0.23-0.61 volume of gas to volume of feedstock per day depending on local conditions and feedstock available. However, this digester is not commonly used.

2.3.1.3 Benefits and Limitations

Biogas has the following benefits:

- The production of energy resources that can be stored and used more efficiently;
- The production of a stabilized residue (the sludge) that retains the fertilizer value of the original material;
- The saving of the amount of energy required to produce and equivalent amount of nitrogen-containing fertilizer by synthetic process
- Potential for partial sterilization of waste during fermentation, with the consequent reduction of the public health hazard of faecal pathogens; and
- Reduction, due to the fermentation process, of the transfer of fungal and other plant pathogens from one year's crop residue to next years crop.

Biogas technology has not made much impact in Nigeria for the following reasons:

- Public awareness on biogas is inadequate;
- Availability of local technical expertise in building biogas plants in the country is limited;
- Biogas construction is relatively costly; and
- There is low sensitivity to environmental protection in the country

2.3.2 Woodstoves and Biomass Briquetting Technologies

The traditional methods of cooking which have been used for centuries with little modifications, involve burning of wood and other crop residues in an open fire, sometimes enclosed by metallic, clay or bricks to act as wind shield. In most cases, three stones are placed around the fire to act as supports for the cooking pots. This method of cooking is very inefficient and a sources of health hazard to the users. The performance of this traditional method is only 5-10%. The fire wood consumption and the energy cooking requirements would thus be relatively high.

Certain critical factors drove international activities on developing fuel-efficient wood stoves throughout the developing world. A primary factor is the "wood fuel crisis" of the early 1980 due to drought in many parts of the world. Increasing attention to population issues and pressure on land resources partly propelled this trend. Addressing the energy situation of the poor in an integrated approach particularly affected this development. Availability of energy, reducing costs and drudgery of women and children as well as indoor air pollution and family health were critical issues.

Table 2.3.3 Improved Wood stoves in Kenya, China and India

Improved stoves	Efficiency (%)	Cost ($US)	Dissemination
Jiko Kenya	25-40	$2 to $5	1 million plus
Maendeleo	15-35	0$.80 to $1.20	100,000
Chinese brick and mortar	20-40	$8 to $9	125 million
Indian mud & clay chulha	10Oct-40	$8 to $10	8 million

Today, many African countries have made significant progress in developing and disseminating improved wood stoves. Kenya has disseminated over one million improved stoves. Globally, India, China and Kenya are world leaders in the development and use of this technology, and Table 2.3.3 indicates parameters for improved woodstoves from these countries.

2.3.2.1 Technical Characteristics of Improved Woodstoves

At present, apart from the few institutions of higher learning which are involved in research and development of efficient woodstoves, the major activities comprising research and optimization, manpower training and dissemination of these stoves remained under the two centers of renewable energy namely Sokoto Energy Research Center and National Center for Energy and Development Nsukka. To date, a number of international and local wood stoves were developed and characterized based on all possible considerations, such as raw materials, cost, as well as other social factors with the following ready for adaptation and commercialization.

I. Single-Hole Metallic WoodStove. Two versions were developed at Sokoto Energy Centre and Energy Research and Development Centre at Nsukka respectively. They were constructed from galvanized medium- and high-grade sheet metal with provision of intake air and firewood at the inlet of the stoves. These stoves have efficiency of over 17% versus less than 10% for the traditional metallic tripod stove (See Annex 1.)

II. Single-Hole Clay WoodStove. In a similar way a stove was constructed from clay which was prepared with binding materials such as grog, millet/rice husk and allowed to dried. The stove was later fired to make it water and fire resistant.

Three types of improved wood stove depending on the family sizes and dishes to be cooked, were designed and developed with three principal features: (i) a close heath (fire box), where combustion of the wood takes place thus protecting the fire from the effects of the wind to reduce heat lost mostly by convection and radiation; (ii) multi-pot design, capable of carrying out more than one pot at a time permitting heat recovery from hot gases that otherwise have gone to waste; (iii) a chimney to provide the necessary draft for bring in air for combustion and removing smoke from the kitchen environment, thereby making it convenient to users.

Other woodstoves developed locally are as follows:

III. Double-hole woodstove. The design was obtained after modifying a similar type of wood stove fabricated and tested in Nepal. A chimney was integrated in this design as shown in Annex1. This type of stove is mainly for the medium size families of 6 to 10 sizes, with efficiency of over 42% as against the most commonly used traditional stoves.

IV. Large size four-hole woodstove. The design was obtained from a similar one fabricated in Ghana after certain modifications. Here also the chimney was integrated in the stove. Such wood stove has been considered for large family size above 10, and recorded efficiency of 45% above the commonly used traditional stoves.

V. Community based improved woodstoves. These were also developed from a similar one fabricated in China after some modifications. This was made of two pot-holes, designed to accommodate large cooking pots of 40 to 60 people at a time. The stove was constructed from heavy channel of angle iron and high gauge iron sheet and cased by burnt bricks to reduce convective and radiation heat losses. A rectangular Chimney of bricks was also incorporated in the stove. The stove recorded an average of 45% efficiency as against the conventional stove. These stoves have been introduced into many Nigerian Prison homes, such as at Zaria, Birnin Kebbi, Sokoto, Gusau and Kuje (Abuja) Prison homes. The performance of these stoves were evaluated after two years and found to have over 40% firewood saving, 22% time saving as against the existing open hearthtt stoves and less hazardous due to the provision of the chimney in the stoves.

2.3.2.2 Economic Competitiveness of Woodstoves

The traditional three-stone stove is cheap and simple to make compared to the improved clay or metal woodstove. However, on the basis of life cycle cost, efficient utilization of fuel wood and other environmental advantages, the improved versions far outweigh the traditional stoves.

Improved woodstoves (with provision of chimney) cost between N550.00 and N900.00 for single-hole clay and metallic and double-hole clay respectively (approx 3 to 4 times as much as traditional improved tripod metallic stove). However, because of the local training received by the local potters and artisans on the design, construction and maintenance of these stoves, the increased production of these stoves has brought down the cost to about 70% now. The combined experiences of our national energy survey, village demonstration project and laboratory investigations proved an average fuelwood saving of 30% and 38% for the single and double hole stove respectively. Based on the average family size of 7, the consumption of fuel wood per family is about N40.00 per day, yielding a total yearly saving of N6120.00 and N7752.00 for the single and double hole stove respectively. Each stove thus pays for itself within about 2 months. Equally, an average saving of 35% was realized for the average consumption of fuel wood of N1000.00 daily from the Nigerian prisons, amounting to N126,000 annually.

2.3.2.3 Benefits and Limitations on Woodstoves

The result so far obtained from these improved wood stoves project (based on laboratory and field experience) has revealed the following results: (i) Reduction of fuelwood consumption by about 40% over the existing traditional methods corresponding to cost saving of about eight thousand naira annually (N8, 000.00) yearly; (ii) Time saving by about 32%; (iii) Reduction in fuelwood consumption of 30-38% corresponding to cost saving of N6,000-N7,500 yearly for the single and double hole stove respectively and average time saving of 30%; and (iv) Guided exit of smoke by the chimney and proper damper setting to serve as a mechanism for the control of fire intensity. Equally, the technology involved in the fabrication of these improved woodstoves is simple and rural people can easily fabricate them.

These stoves can be fabricated by local potters and artisans using available local raw materials. The limitations of the technology include insufficient public awareness, problem of fuelwood alternatives to rural Nigerians, and cost free nature of both the traditional three-stone stove and the firewood for the rural people.

2.3.2.4 Overview of the technology of Biomass Briquetting

Biomass in the form of fuel wood, charcoal, corn-stalks and crops residues, dried solid animal waste, sawdust, millet/rice husk, kernel shells and other crop processing wastes constitute virtually 100% of the traditional cooking and heating fuel in the West African sub-region. The major raw materials resources of biomass for briquettes production are:

(i) **Wood Waste -** this is a waste arising from human operation of wood extracting from forest woodland and plantations and converting it to planks and other “stock”;
(ii) **Agricultural Waste -** these wastes obtainable as a by-product of agricultural activities either during harvesting or processing of the produce such as leaves, baggage, stalks, straws, grain, husk, shells, stalks, etc.;
(iii) **Binders -** should have a high heat value as the briquette, relatively high bonding strength, low cost with no offensive odour emission and minimal need for drying. These binders fall into three categories:

(a) Inorganic Materials: In organic materials and fibers, such as cement and silicate of soda are appropriate for wood fuels but they are poor as they give more ash, reduce the heat value and fall apart while burning.

(b) Organic Materials: organic materials such as starch, tar pitch, resin, glue and gum Arabic usually increase the heat value and create no extra ash. Other materials like fibrous materials may serve as binding agents. The cheapest is hydrated wood fiber and pulped wood waste. Generally, some binders permit the materials to be briquetted while others coat the surfaces.

(c) Starch Binders: such as cassava, corn and others are smokeless but not moisture resistant, and they are normally used in the proportion of 4% (dry basis). Tar, pitch, asphalt and sugar cane molasses are moisture resistant but not smokeless.

2.3.2.5 Technical Characteristics of Biomass Briquetting

Developing countries like India and China are shaping cowdung manually to produce dung cake while in Nigeria, particularly in Northern part of the country, cow dung cakes have been used for cooking and heating for over decades. Much effort have been devoted to making a simple machine for the production of briquettes. A steel pipe provides a good briquetting mold under pressure. Commercial briquetting machines are available which can produce briquettes of varying diameters and lengths and with production capacities as high as 2000 kg/hr. Both hand-operated and motor-driven briquetting machines are similarly available commercially. The press could be plunger or screw type while the die could be of any desired shape, though the cylindrical shape is common.

In Nigeria, several machines developed for briquettes production includes a single cylinder extrusion machine that transforms rice, millet husk and sawdust to briquettes. This machine produced 13kg of briquettes/hour at Sokoto Energy Research Centre, Usmanu Danfodio University, Sokoto, Nigeria. Another machine, Sawdust briquetting Machine (Screw Press), was developed at Obafemi Awolowo University, Ile-Ife. The Machine has press barrel screw shaft, bearing assembly, nozzle or die and 4kw electric motor. It is capable of producing 10kg/hr of sawdust, rice husk and groundnut shells briquettes with 17.8MJ caloric value and 67.94% burning efficiency. Additionally, a simple tabletop close – end die piston process fitted with both a pressure and dial gauge has been used to produce briquette using Rattan furniture waste at the University of Ibadan, Nigeria. The latest development is the briquetting machine developed by the Center for Industrial Studies (CIS) of the Abubakar Tafawa Balewa University (ATBU) Bauchi in collaboration with the Raw Material Research and Development Council (RMRDC), Abuja. This machine has four pistons and cylinders, a hopper with four feed holes table, cover and locking device and a crank arrangement as the major operating parts. This machine, using sawdust and agricultural wastes with suitable binding material, was able to produce 40kg/hr of briquettes based on four compaction and ejection cylinders. However, only two small-scale companies exist in Nigeria, one in Ogun and Kaduna states which produce and market sawdust briquettes as all other development regarding this technology is mostly limited to Research Institutes, Universities and other tertiary institutions in Nigeria.

2.3.2.6 Economic Competitiveness of Biomass Briquetting

Besides the normal domestic cooking, briquettes are used for rural industries, such as small-scale foundries, bricks, kilns and bakeries. However, because of the unpopularity and lack of technological awareness of briquettes production and machinery, there exists only a couple of industries (in Kaduna and Ogun States) involved in the production and marketing of briquettes in Nigeria. Except the few mentioned research and development activities going on in our tertiary institutions. Based on these reasons, the extent of utilization of this technology is negligible and cannot be quantitatively defined as of now.

Briquette Industries Ltd at Ota Ogun State is involved in briquetting of sawdust as alternative to cooking fuel, while that in Kaduna, has not started production. But based on currents heating value of the locally produced briquette it has 6 to 7 times more energy content per kg than the loose biomass not briquetted. Equally the heating flame and temperature obtained in cooking process are better when compare with other renewable energy fuels. The briquettes with about 16.6 MJ calorific value and about 70% burning efficiency in comparison with other solid cooking fuels proved to be cost effective based various cooking performances conducted.

2.3.2.7 Benefits and Limitations on Biomass Briquetting

Technology, which focuses on the conservation of energy and maximum utilization of raw materials, is becoming the most relevant and should continue to receive due attention. The densified fuels produced from wood residues and other agricultural waste products are appealing because the fuel is dry and uniform in size, thus easier to store and ship. The uniformity and increased heating value per unit volume also provides better combustion control and overall combustion efficiency. Benefits of briquettes include:

- Reduced biomass bulk through densification of the materials, with resulting in easier and cheaper transportation.
- Increase of the energy content per unit volume of materials by reducing the moisture content during the compaction processes.
- Product homogeneity obtained (same density particle size and moisture content) from highly heterogeneous group of raw materials.
- Uniform quality of energy per unit feed stock generally assured.
- Highly cohesive fuel product from particular materials that were otherwise difficult to process.
- Increased resistance to breakdown of particles in shipping handling and storage.

2.3.3 Market Situation for Biomass Technologies

This section will consider the situational analysis of the market for the biomass technologies, specifically fuelwood biomass.

2.3.3a.1 Present Demand and Supply Situation for Biomass Technologies

Biomass fuels are overwhelmingly the most important energy for rural households, agricultural production and rural industries. Charcoal has traditionally been the main cooking fuel in some towns and cities, and is still widely used. Charcoal is likely to continue to be an important fuel among low-income urban households, but demand has been stable in recent years and much of the future growth of urban household energy needs will be met by conventional fuels, and in particular electricity and petroleum products unless biomass resources are developed and used more efficiently.

Fuel wood is gathered freely by rural households, from their immediate environment. This includes both trees outside forests, and around homestead, and wood obtained from forest areas where such areas are accessible to rural community. In the urban areas, fuel wood is supplied from the rural areas and usually sold at affordable prices.

Figures 2.3.4 and 2.3.5 show the growth pattern in fuel wood consumption and per capita fuelwood requirements, respectively.

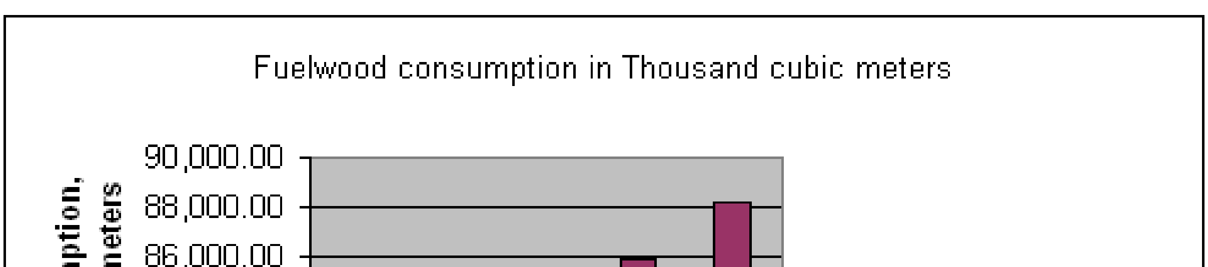
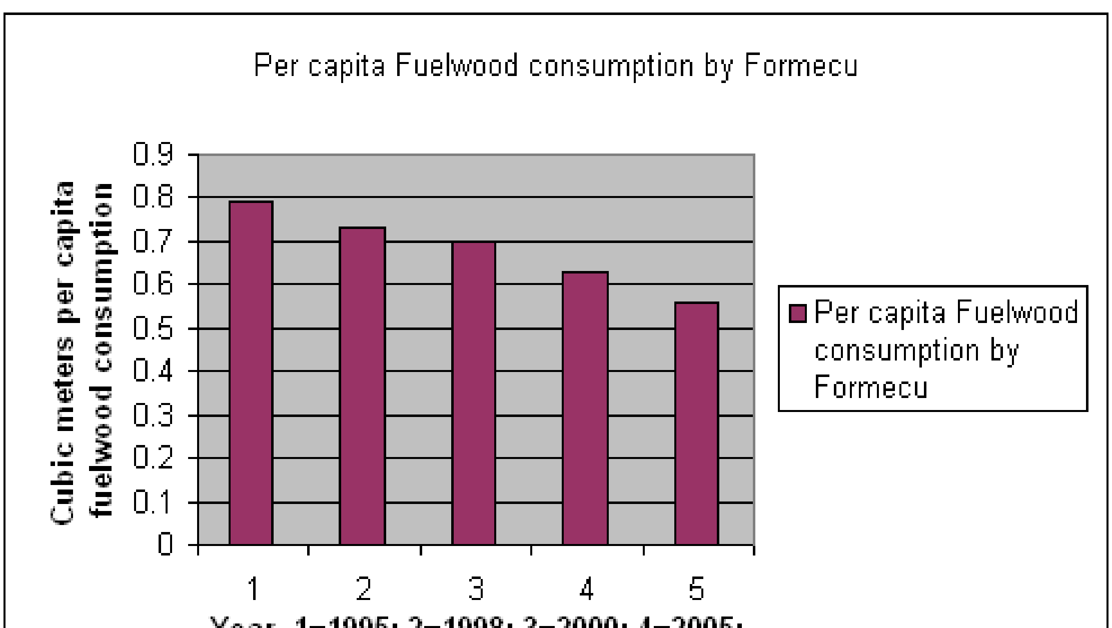


Fig. 2.3.4 Fuelwood consumption in Nigeria in thousand cubic meters.

~~**Table 2.3.9: Fuelwood, past, present and projected consumption '000M³**~~

~~Ear~~	~~Total Consumption '000³~~	~~Tonnes of Oil Equivalent '000 (toe)~~
~~1995~~	~~78,734:98~~	~~18,746:42~~
~~1998~~	~~81,606:68~~	~~19,430:16~~
~~2000~~	~~83,521:14~~	~~19,885:99~~
~~2005~~	~~85,829:61~~	~~20,435:62~~
~~2010~~	~~88,138:07~~	~~20,985:25~~

~~Source: FORMECU~~



~~**Table 2.3.10: Fuelwood, past, present and projected per capita consumption**~~

~~Year~~	~~Fuel Consumption M³~~	~~Kg of Oil Equivalent (KOE)~~
~~1995~~	~~0.79~~	~~188~~
~~1998~~	~~0.73~~	~~173~~
~~2000~~	~~0.7~~	~~167~~
~~2005~~	~~0.63~~	~~149~~
~~2010~~	~~0.56~~	~~134~~

Fig. 2.3.5 Per capita fuelwood consumption in Nigeria, in cubic meters per capita

~~Source: FORMECU~~

Current pressures upon biomass resources and rates of deforestation can be expected to intensify as increasing demand comes into conflict with decreasing supply. The future of biomass fuel consumption in Nigeria must raise cause for concern. Despite the increased penetration of commercial fuels, it can be expected that demand for biomass fuels will be sustained and, in all probability, will increase in the short-to-medium-term. There is at present no viable substitute for the bulk of biomass fuel consumption, which occurs in the rural household sector, and it is difficult to identify where a viable alternative would come from. Projections of future demand support these contentions, and also call into question the ability of country's woody biomass resources to sustain the expected level of demand.

As shown in Table 2.3.4, fuel wood demand is expected to outstrip supply, during the period 1995-2010.

Table 2.3.4: Summary of demand, supply and balance (gap) fuelwood 1995-2010 ('000 M^3).

Year	Projected~~Forecast~~ Requirement	Projected~~Forecast~~ Supply	Balance
1995	78,734:98	76,207:72	-2,527:27
1998	81,606:68	73,147:58	-8,459:10
2000	83,521:14	71,107:49	-12,413:60
2005	85,829:61	67,117:19	-18,712:40
2010	88,138:07	63,126:88	-25,011:10
Source: FORMECU			

In 1995 a deficit of 2.53 million m^3 of fuelwood was forecasted. This was expected to rise to 12:4 million m^3, 18.71 million m^3 and 25 million m^3 in years 2000, 2005 and 2010 respectively.

2.3.3a.2 Key Drivers for the Biogas and Biomass Technology Market

To ensure that energy demand is met in the most cost-effective way, the market will be required to function effectively. This will depend upon:

- *Market Liberalization.* Ensuring a high degree of market liberalization, albeit within government regulatory frameworks.
- *Safety.* Improved safety, capacity and efficiency of energy transport facilities.
- *Technology.* Commitment to R&D and the management of technology and technology transfer to improve energy choice and to protect the environment.
- *International Co-operation.* Co-operation is required at the International level on developing technology and infrastructure, exchanging information and encouraging free markets and access to energy resources.
- *Environment.* Environmental considerations are of equal importance in energy market development. It is necessary to work towards sustainable energy use by incorporating environmental considerations in economic decision making, while continuing to rely on market forces subject to suitable environmental standards.
- *Security of Supply.* The best strategy is to increase energy choice, adaptability to change and international co-operation. Energy security is best achieved and maintained through initiatives that increase energy choices and promote adaptability to change, rather than through subsidizing domestic resource.
- *Energy Efficiency.* Enhancing economic efficiency of energy use is vital to achieve the best utilization of biomass resources and to protect the environment, and should be given a high priority. Energy efficiency should be improved by strategies involving regulation, persuasion, and enhanced R&D for new and more efficient technologies.

2.3.3a.3 Gaps and Barriers to Market Development to biogas and biomass energy resources

The following are some of the gaps and barriers to market development of biogas and biomass energy resources:

(i) Uneven Distribution of Biomass Resource. Biomass resources are distributed particularly unevenly. Uneven distribution of resources also increases transportation costs, which can amount to 25% or more of the cost of fuelwood for instance;

(ii) Low Conventional Energy Prices. Low conventional energy prices hold back the development of alternative supplies even if they benefit most energy users in the shorter term. This report does not advocate high-energy prices per se, but prices, which cover all costs. This would imply some increase in prices, which would help extend available resources, and encourage the bringing on of alternative sources and substitutes. Higher energy prices may eventually create the conditions whereby cheaper services can be delivered;

(iii) Political. Local conflicts and trade disputes may interrupt supply of the resource;

(iv) Financial. The inability of government and companies to finance energy supply from

biomass resources due to other investments competing for funds such as health, education, housing, roads etc.

(v) Institutional. In recent decades many forms of energy supply have effectively been monopolies, usually created at the behest of and protected by the country, and either wholly or partly distanced from the market disciplines of competition. Failure of some monopolies to achieve acceptable levels of efficiency, customer responsiveness and financial returns has led to recent steps being taken by the government towards privatization and the opening up of energy markets;

(vi) Technical. The inability to absorb and utilize the necessary technology and commercial skills; to mobilize energy resources and to convey them to the point of need. This links to the importance of effective management of resources; *(vii) Time.* Time is required to change perceptions, policies, institutions, infrastructures and technology. Time is a significant resource in marshalling in present context, in the absence of emergency conditions and policies; long lead-times are required for the introduction and diffusion of biomass technologies; and *(viii) Environment.* There is the need to control the adverse impact of biomass energy provision and use on the environment. Nigeria is vulnerable and heavily dependent on traditional energy supplies especially fuelwood, which are dwindling as population is rising.

2.3.3b.1 Market Situation for Biomass Woodstoves and Briquetting Technologies

2.3.3b5B.21 Present demand and supply:

The widespread rural diffusion of fuel-efficient cooking stoves has been viewed in the international arena as a promising way to reduce overall fuel wood demand, since an average of over 75 percent of cooking energy is derived from biomass energy is used for cooking. There is also is the direct concern that decreased stocks of fuel wood could lead to a wide spread rural energy shortage and, increaseding reliance on crop wastes and dung to supply household energy.

In Nigeria the increasing price of commercial fuels, (Kerosene, coal, etc.) over the past 10 years explains the persistent use of fuel wood for cooking not only among the rural but even the urban poor. The design changes, marketing as well as training programme on production, use and maintenance of improved woodstove was left in the hand of research centers through the Energy Commission, institutions of higher learning and private organizations without a central co-ordinating body to asses their degree of demand and supply. Lack of data base on both the demand and supply of these technologies continues to be a great barrier to market development. The two energy research centres at Sokoto and Nsukka do sell these improved wood stoves to individual on limited numbers basis, while production and marketing of these stoves are left to individual craft people and potters. Thus it is difficultimpossible to quantify the level of demand and supply of these stoves in Nigeria. Equally, the technology of biomass briquette to date is not established as such, quantification of demand and supply has remained difficult and elusive.

2.3.3b.3 Key Drivers for The Market

The key drivers for the development of the market for improved wood stoves and biomass briquettes in Nigeria are as follows:
(i) Availability of Resource and Technology. Both the improved wood burning stove and biomass resources for briquette production are available in sufficient quantities. However, the level of technology necessary to give the desired appeal and satisfaction remains an important parameter for market development. Nevertheless, the technology involved in the fabrication of these products is so simple that the rural people can easily fabricate them.

(ii) Socio-Economic Behaviour: The technology requirements for the production and marketing with little modification of improved wood burning stoves is quite in line with the existing culture and practice of our local potters and artisans. The manual briquettes production has been practiced in our villages for decades. These factors, which exist as inbuilt behaviors, will accelerate the social acceptance of the two technologies thereby driving the market to full development potential. Generally the products will present a new symbol status to both urban and rural areas.

(iii) Suitability and Efficiency. The ability of improved wood stoves to handle the cooking of a number of dishes simultaneously makes them suitable to many Nigerians. Furthermore, chimneys integrated wood stoves provide better healthy conditions to the people involved in cooking. The much higher efficiency of of the improved stoves increases the chances of faster market penetration. The superior handling and transportation characteristics of briquettes over the loose biomass favours market adoption and penetration. The increase energy content up to 6 times per unit volume of material provides better efficiency of the briquettes.

(iv) Economic Consideration. The established facts on the reduction of fuel wood by 40% over the existing practice, through the use of efficient wood stoves remains one of the most important factors to be considered for the product in the market. This reduction amounts to reasonable savings over short, medium and long terms.

2.3.3b.4 Gaps and Barriers to Market Development:
The gaps and barriers to market development of wood stoves and biomass briquettes are:

- *Technological Constraints.* This includes the limits of scientific knowledge, unsolved engineering problems, the availability of materials, well equipped laboratories and workshops, and ignorance of advanced production techniques.
- *Industrial Constraints.* These technologies are regarded as low level as such industry has not been too eager to embrace them. Thus, they have been left largely in the hands of craft people to develop.
- *Infrastructural Constraints.* This is a general term for the entire energy service, production and delivery system. In the area of biomass energy systems, the nation's industrial capacity especially in the sector of renewable energy development is weak.
- *Education.* The level of public and political awareness of the potentials and benefits of improved wood stoves and biomass briquette in the country is very low both economically and environmentally.

- *Insufficient-Funding.* Inadequate financial and institutional infrastructure is a serious barrier to the rapid uptake and development of renewable energy technologies in Nigeria, particularly for the improved wood burning stoves and biomass briquetting market development.
- *Implementation of the National Energy Policy.* Though the existing National Energy Policy pays some attention to RETs, adequate implementation has not occurred. Other key barriers include the low prices of other conventional fuels.

2.3.4 Cogeneration and Other Biomass 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.

In general, application of cogeneration is based on the heat energy demand of the system, be it in a building, factory, town or city served by district heat or cooling. Table 2.3.5 below shows the great thermal efficiency and carbon emissions reduction advantages of CHP compared to conventional power plant technologies. It is clear from the table that CHP is a carbon-reducing technology. Indeed it has been identified as a significant measure that can be used to meet the Kyoto Protocol CO_2 targets of several EU countries.

Table 2.3.5. Efficiency and carbon emissions of thermal power plant technologies

Item	Power plant technology	Plant efficiency range, %	CO_2 emissions, g/kWh
1	Large central thermal power plants	25 – 40	500 -1000
2	Combined cycle (gas and steam turbine) thermal plants	45 – 55	200 – 300
3	Cogeneration	55 – 80	

The prime mover in a cogeneration system will either be a gas turbine, a steam turbine (or a combination of these in what is known as Combined Cycle Gas Turbine, CCGT) or a reciprocating internal combustion engine, usually a stationary diesel engine. The prime mover drives an electrical generator and the heat from the prime mover can be used with a steam turbine and/or heat exchangers to produce the needed steam or hot water in the most cost-effective way.

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 around 500^oC, 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^oC, which can be used to produce only hot water at 70 – 85^oC, 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.

Provided the installation is based on the heat demand, a surplus of electricity will usually be produced. The surplus electricity can be sold to the electricity utility or to another consumer (an operation known as wheeling in the industry). This technology therefore highlights the importance of the electricity sector reform and regulation and the relevance of the energy-market liberalization process.

If, however, the installation is based on on-site electrical power demand rather than on the site heat demand, then top-up boilers will usually be required to meet the shortfall in heat demand with consequent reduction in the overall plant thermal efficiency.

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 barbojo and other biomass; domestic, commercial, municipal and industrial wastes, etc. It works with new technologies such as fuel cells, micro-turbines, etc.

There are several other modern and more efficient cycles than the simple gas turbine cycle motive power where this is the choice of the CHP motive power source. Among these are the Biomass Integrated Gasification/Gas Turbine (BIG/GT) system; the

Biomass Integrated Gasification/Steam Injected Gas Turbine (BIG/STIG); the Biomass Integrated Gasification/Intercooled Steam Injected Gas Turbine (BIG/ISTIG)

2.3.5 Other Biomass Technologies

2.3.5.1 Energy Crops. One of the most interesting recent developments in biomass energy is the cultivation of crops and trees for the sole purpose of generating energy either by direct combustion in biomass boilers or for the intermediate production of bio-fuels. Short rotation coppices (SRC) are now common in many parts of the world, particularly in Europe and the Americas, where fast growing species of crops and trees such as eucalyptus, oilseeds such as sunflower, soybean and rapeseed (bio-diesel production from fatty acid methyl esters, FAME), and corn and wheat (for ethanol or ethyl tertiary butyl ether, ETBE) are cultivated solely for energy purposes. Brazil pioneered the energy crops (sugarcane) for bio-fuel production field with its ethanol vehicle engine fuel programme of about two decades ago. Ethanol can be used to increase the octane rating of gasoline in blends with gasoline, and Brazil has now developed a 100% ethanol engine for its vehicles. Cellulosic materials, including grasses, trees, etc. can be converted to alcohol as well as directly into gases such as hydrogen, which can be used directly in some engines or for synthesis gas and liquids such as dimethyl ether (DME) and even synthetic gasoline and diesel. Nigeria can also pioneer cassava, sorghum, etc. as energy crops.
The Philippines dendrothermal programme is conceived to generate 200 MW from power plants fuelled with wood from cultivated fast growing trees in a 7000-hectare tree farm by the year 2000. Many countries in the EU have similar energy crops programmes.

2.3.5.2 Energy from agricultural/industrial organic waste. Another interesting development is the on-site generation of energy (as heat and/or electricity) by agricultural and industrial enterprises using process organic wastes such as bagasse and babojo 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 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.

Methanol represents a unique fuel combining the portability of liquid petroleum, the clean, even burning characteristics of natural gas. It is generally believed that methanol has higher potential than ethanol as fuel for transport. In Japan, studies on the utilization of methanol in engines have shown that a mixture of 95% methanol and 5% diesel oil can be used as fuel for diesel engines. In Canada, Studies on large-scale production of methanol from biomass have shown that by 2025 up to 42% of transport fuel could be provided by such mean.

At present, the work on methanol production from wood has passed the demonstration stage. The leaders in this field are: EEC, Sweden, Canada, the U.S. and Brazil. The development work in Sweden has shown that the production cost of methanol from wood is only about 20% higher than that produced from natural gas. Methanol is a fairly volatile liquid which, for direct combustion, can compete with gasoline, low sulfur fuel oil, solvent refined coal, etc. Methanol will also compete with fuels from other local sources. Its potential as automobile fuel has long been recognized.

In Canada, studies on large-scale production of methanol from biomass have shown that by 2025 up to 42% of transport fuel could be provided by such means. At present, the work on methanol production from wood in Canada has reached the demonstration stage with the typical plant capacities of 10,000-50,000 kg~~tons~~ of wood per day. The leaders in this field are Brazil, Sweden, Canada and the U.S. With regards to the economic of methanol production, the development work in Sweden has shown that the production cost of methanol from wood is only about 20% higher than that produced from natural gas.

2.3.6 Biomass Thermal Energy Conversion

The three routes for biomass thermal energy conversion are direct combustion, pyrolysis and gasification.

2.3.6.1 Direct combustion for the generation of heat and power is the most well established technology. There are three types of combustor: fixed bed combustor, fluidized bed combustor and suspension furnace combustor. These combustors, which are commercially available, have been used for the production of heat, steam and electricity. Practically, all types of crop residues can be burned using these combustors to obtain heat energy. For small scale power generation, interest in steam engine has been renewed because it can be operated on almost all types of biomass and has long working life. Steam engines have been installed for field trials in several countries in South America and their feasibilities are being examined.

2.3.6.2 Pyrolysis is an extremely flexible process that can be applied efficiently to almost any organic solid. Pyrolysis is the scientific term for the transformation of organic material into other forms by heating it in the absence of oxygen. The main pyrolysis reaction is the thermal decomposition of ligno-cellulosic material to produce char, oil and gas. Pyrolysis is an extremely flexible process, which can be applied efficiently to almost any organic solid. The quality and quantity of oil, gas and char produced depend on the type of reactor and feedstock properties, reaction conditions and other factors. Energy conversion of up to 80% is impossible. However, in spite of all the research and development activity on pyrolysis, there are relatively few commercial processes designed to produce significant amounts of oil and gas from biomass.

2.3.6.3 Oxygen gasification in Gasifiers to produce medium but gas or synthesis gas is the first and most important step in the production of methanol, which is very promising as transport fuel. Although the production of synthesis gas from wood is a very old technology, more research and development is still needed, because it is very difficult to produce a clean synthesis gas efficiently and economically. At present work on methanol production from biomass has reached demonstration stage with typical plant capacities of 10-50 tons per day. The technology of gasifying crop residues for power generation is still in research and development stage, particularly for small-scale power generation. At present, more gasifiers are being used in process heating compared to power generation.

One alternative in the efforts to utilize available biomass resources, including waste, more effectively is the transformation of these residues into marketable fuel forms. These fuel forms are synthetic gasoline or other liquid petroleum products, synthetic natural gas, and synthetic liquid fuels such as methanol. The choice of the processed form among these alternatives depends on market, overall costs, including the cost of emission control, and the ease with which this fuel form fits into the existing network of supply and distribution.

The gasification of biomass with oxygen to form a gas which is known as synthesis gas is the first and the most important step in the effort to produce methanol from biomass. Methanol represents a unique fuel combining the portability of liquid petroleum, the clean, even burning characteristics of natural gas. It is generally believed that methanol has higher potential than ethanol as fuel for transport. In Japan, studies on the utilization of methanol in engines have shown that a mixture of 95% methanol and 5% diesel oil can be used as fuel for diesel engines. In Canada, Studies on large-scale production of methanol from biomass have shown that by 2025 up to 42% of transport fuel could be provided by such mean.

At present, the work on methanol production from wood has reached the demonstration stage with the typical plant capacities of 10-50 tonnes of wood per day. The leaders in this field are: EEC, Sweden, Canada, the U.S. and Brazil. The development work in Sweden has shown that the production cost of methanol from wood is only about 20% higher than that produced from natural gas. Methanol is a fairly volatile liquid which, for direct combustion, can compete with gasoline, low sulfur fuel oil, solvent refined coal, etc. Methanol will also compete with fuels from other local sources. Its potential as automobile fuel has long been recognized.

2.4 Wind Power

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

2.4.1 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 every year. 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.

2.4.1.1 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.

2.4.1.1a 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.

2.4.1.1b 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.

2.4.1.1c 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

2.4.1.1d 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.

2.4.1.1e 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).

2.4.1.1f 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 is 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 can then be quantified.

2.4.1.1g 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.

2.4.1.2 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.

2.4.1.2a 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.

(ia) 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 2.4.1 Categorization of Wind Power Systems

Installed Power	**Categorization**	**Wind Turbine Capacity RangeSize**
<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.

(iib) 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.

2.4.1.2b4.2 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.

(ia) 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:

Americas	6,905MW	(USA 6,361 MW)
Europe	29,301 MW	(Germany, Denmark and Spain 24, 108 MW)
Asia	3,790 MW	(India 2,125 MW)
Africa	211 MW	
Rest of the World	95 MW	

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).

(iib) Nigeria Wind Energy Utilization

Wind energy utilization in Nigeria is ~~practically minimal~~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 ~~in the center of the town~~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).

2.4.1.2c 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~~a~~) 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~~icient~~ 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~~b~~) 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~~c~~) 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. ~~Figures 3.4 and 3.5 (Annex III) show~~ Both the rotor diameter and the tower heights of ~~the growth in size~~ present-day~~of~~ commercial wind turbine designs have grown remarkably ~~– rotor diameter and tower height respectively~~over the past decade.

2.4.1.3 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. ~~The major components of the cost of a wind energy project are investment, energy generation and operation and maintenance costs.~~

(i~~a~~) 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~~b~~) 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. ~~countries~~.

(iii~~c~~) 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 2.4.2 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~~d~~) Cost Comparison of Wind Energy Technology and Other Energy Technologies

Fig. 2.4.1 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. ~~However, it should be noted that for the Nigeria case, all the costs of wind energy technology will be higher than for the countries discussed in today's market.~~

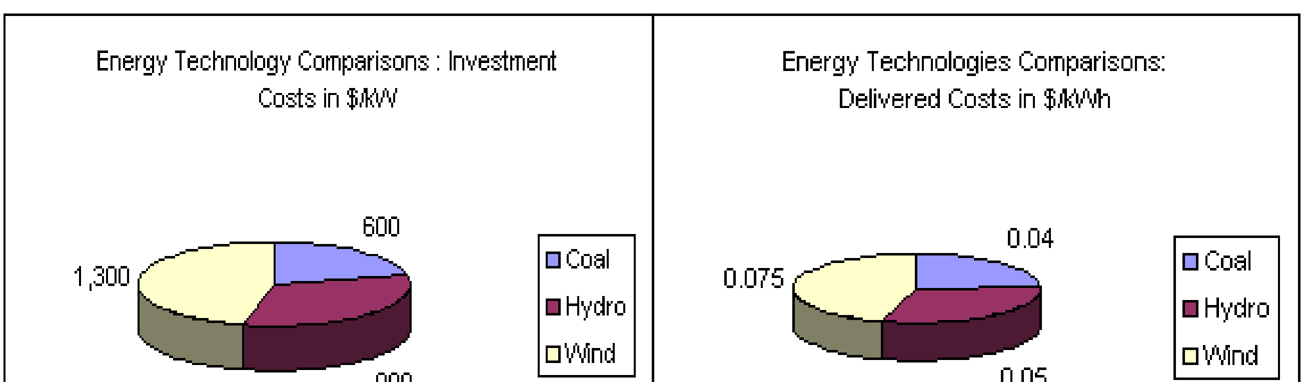


Fig. 2.4.1 Cost Comparison between Wind Energy and other Energy Technologies in China. Source: Brennand, 2002.

~~**Table 2.4.3 Cost Comparison between Wind Energy and Other Energy Technologies in China**~~

~~Energy Technology~~	~~Investment Cost $/Kw~~	~~Delivered Cost $/kWh~~
~~Coal~~	~~600~~	~~0.04~~
~~Hydro~~	~~900~~	~~0.05~~
~~Wind~~	~~1,300~~	~~0.075~~

~~***Source: Brennand, 2002***~~

2.4.1.4 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.

2.4.3 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.

2.4.3.1 Present demand and supply situation

(ia) 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. 4.4.

Table 2.4.2 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**

(iib) 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 ~~established~~ 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.

(iiic) 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~~d~~) Non-grid Hybrid System for Rural Electrification

In many rural areas in Nigeria where there is no access to the national grid or~~and~~ the grid is remote, wind energy could provide~~s~~ 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~~e~~) 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.

2.4.3.2~~5.2~~ 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. ~~Table 2.4.5~~Fig. 2.4.2 presents electricity tariff in Nigeria which is below the prevailing cost of electricity from wind power, thus discouraging potential wind power investors.

~~**Table 2.4.5 Electricity Tariffs in Nigeria**~~

Category	Amount (N/kW-hr)
Residential with single phase meter	4
Residential with 3-phase meter	6.5
Commercial houses with single-phase meter	8
Commercial with 3-phase meter	8.5
Average	**6.75**

~~Exchange rate used: $1 = N135:00; ***Source: NEPA***~~

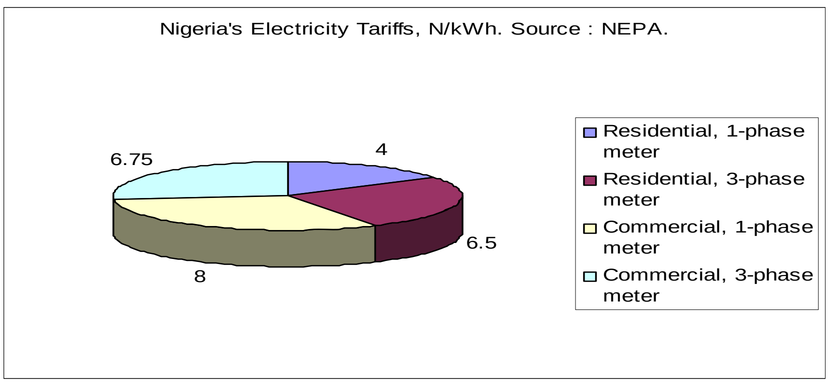


Fig. 2.4.2 Nigeria's electricity tariffs. Source: NEPA

(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 ~~reforms~~ 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. ~~In addition, there is dearth of information and data on wind technology, i.e. performance, efficiency, etc, creating impressions that wind energy is yet to be mature.~~

(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.

2.5 Hydrogen, Marine, Ocean and Geothermal Energy

Hydrogen, marine, ocean and geothermal energy are important in the long-term vision of providing secure, abundant, cost effective and clean sources of energy for Nigeria. Their impacts might not be felt in the next decades to come, but these emerging energy sources will be key to meeting future challenges when the country is weaned of its dependence on hydrocarbons.The National Energy Policy (NEP) seeks to maintain an interest on technological developments on hydrogen, ocean and geothermal energy. The objective is to build research and development capacity to enable Nigeria incorporate these resources into the national energy mix when their costs become competitive.

2.5.1 Hydrogen Energy Resource Situation

Hydrogen provides a solution to the energy needs of Nigerians at a future point when our finite fossil fuels will no longer be available. However, the complete transition to a hydrogen economy will take several decades. There is presently a lack of know-how to deliver clean, affordable, safe and convenient energy for transportation, electricity or stationary uses from hydrogen. To ensure the security of energy supplies in a post-fossil economy, the process of Nigeria's transition to a hydrogen economy must be planned and should start immediately. A clear national vision and road map for hydrogen research and development will help ensure the energy security of future Nigerians.

2.5.1.1 Estimated Hydrogen Energy Resource Base

Hydrogen can be produced from water using various forms of energy. It can also be extracted from anything that contains hydrocarbons, including gasoline, natural gas, biomass, landfill gas, methanol, etc. The resources base is therefore limitless.

2.5.1.1a Status of Hydrogen Energy Database

Information on hydrogen conversion is available worldwide, especially through the Internet. The United States Department of Energy National Renewable Energy Laboratory (NREL) is a world leader in promoting hydrogen energy research. There is no consistent body of research and development activities on hydrogen energy in Nigeria.

2.5.1.2 Technical Assessment of Hydrogen Energy Technologies

Hydrogen energy technologies are maturing and are increasingly meeting energy needs particularly in industrialised countries. The US hydrogen industry alone produces about 9 million tonnes of hydrogen annually for use in chemicals production, petroleum refining, metal treatment and electrical applications. As an energy carrier, this quantity of hydrogen can power about 20-30 million cars or an equivalent of 5-6 million homes.

2.5.1.2a Overview of Hydrogen Energy Technologies

The emerging hydrogen energy technology has the following segments shown in Fig. 2.5.1 : production, delivery/,storage, conversion and end-use technologies.

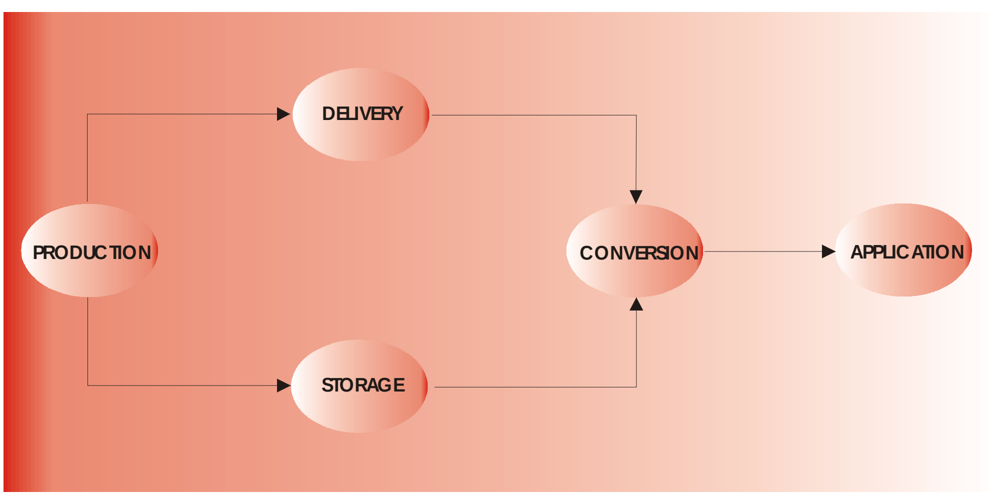


Figure 2.5.1: The Hydrogen Energy System

Hydrogen production from fossil fuels, biomass or water involves thermal, electrolytic or photolytic processes. The distribution of hydrogen from production and storage sites involves pipelines, trucks, barges and fuelling stations. Storing hydrogen for delivery and conversion requires tanks for both gases and liquids at ambient and high pressures. Electricity ~~or~~ and/or thermal energy can be produced using combustion turbines, reciprocating engines and fuel cells. *End-use energy applications* entail the use of hydrogen for portable power in such applications such as mobile phones and computers; or transportation applications such as fuel cell vehicles, fuel additives, internal combustion engines, and in propulsion systems in space shuttles. Other application systems include the use of hydrogen in stationary energy generation systems, including combined heat and power applications.

2.5.1.2c Technical Characteristics of Hydrogen Energy Technologies

The various segments of the hydrogen technology are under development. Efficiency levels are continuously improved and vary between technologies. For instance, fuel cell technologies are increasingly maturing – offering clean, compact and modular energy generation devices that have potentials to revolutionize the production of electricity and thermal energy. Its flexibility, grid independence operation and on-site energy production could be ideal for rural areas with improved economic competitiveness of the technology.

2.5.1.3 Economic Competitiveness of Hydrogen Energy Technologies

Current fuel cell cogeneration power plant in the US costs about US$3000/kW. This has to be reduced considerably for the technology to compete with alternatives. To exacerbate the effect of the high costs of hydrogen energy, the prices of competing fossil fuels are relatively low. In Nigeria, the availability of low-cost fossil fuels is a major disincentive to innovative technologies making an impact in the energy market.

2.5.1.4 Benefits and Limitations of Hydrogen Energy Technologies

A primary benefit of hydrogen energy to Nigeria is its potential for being the energy of last resort in the future. The resource is abundant and inexhaustible. When developed, it will contribute to the nation's energy security in a post-fossil economy. It is also clean and will assist in addressing local and global environmental challenges such as global warming. Fuel cell, for instance, has the potential for meeting remote power needs. However, high prices and low level of R&D activities in Nigeria will constitute a formidable barrier to expanded use of hydrogen energy in the country.

2.5.1.5 Market Situation of Hydrogen Energy Technologies

The hydrogen economy is beginning to emerge in many industrialised economies. However in Nigeria the market is yet to develop. Current reforms in the overall energy market in Nigeria will help shape the possibilities of meeting the future challenges of an economy driven by hydrogen energy.

2.5.1.6 Key drivers for Hydrogen Energy Technology Market

Some drivers supporting the development of hydrogen energy in Nigeria will include growth in energy demand resulting from increasing economic and population growth; accelerated depletion of fossil fuels and increased energy insecurity; commercial availability of hydrogen energy technologies; and environmental considerations, especially climate change. Other drivers that can inhibit hydrogen energy development are: public perception of the safety of hydrogen energy; low cost of fossil alternatives; and poor research and development capacity.

2.5.2 Marine ~~Ocean~~ Energy

The idea of producing useful energy from the world's oceans has existed over several centuries. However, it was not until the oil shock of the early 1970s that serious investments in R&D by several, mostly European countries intensified. As a result of the commitment of these countries to improving ocean energy systems, many of the technologies are closer to commercial viability than ever before. With Nigeria's geographical location, power from the ocean ought to be part of the long-term vision for a secure, cost effective and clean energy future.

2.5.2.1 Marine~~Ocean~~ Energy Resource Situation

Oceans and seas cover more than two-thirds of the earth's surface. They are therefore the world's largest solar collectors. Oceans can produce thermal energy from the sun's heat, and mechanical energy from tides and waves. While the gravitational pull of the moon drives the tides, the wind powers the ocean waves.

2.5.2.2 Estimated Marine~~Ocean~~ Energy Resource Base

Nigeria has an Atlantic Ocean coastline stretching over a distance of about 800 km – from Badagry to Bakassi. Tides in the coastal areas have a height range of 100 – 300 cm and an incursion length of 30 – 40 km on the average. Globally, good tidal energy sites have an average height of about 5 m~~eters~~. The best tidal and wave energy sites are concentrated off the western coast of Europe and spots in Asia.

According to the World Energy Council, the world has an estimated 2 TW wave energy potential and an annual potential contribution of about 2000TWh to the electricity market. As Fig. 2.5.2 indicates, the West African coast has a poor wave energy regime of 10kW/m. Good wave energy sites in Africa include the coast of South Africa with 40-50kW/m; while the coast of the United Kingdom presents some of the world's best potentials of about 70kW/m.

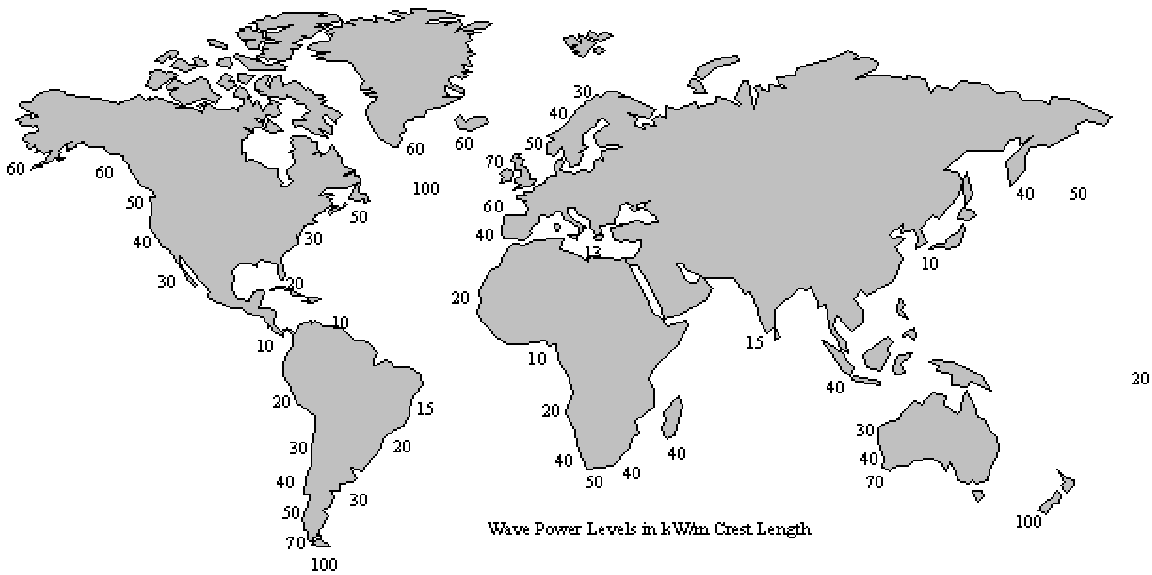


Figure 2.5.2: Global wave power distribution in kW/m of crest length
Source: World Energy Council. www.worldenergy.org/wec-geis/publications/reports/ser/wave

2.5.2.3. Status of Ocean Energy Database, including adequacy and gaps

Nigeria has a good number of institutions with the capacity to carry out research and development activities on ocean energy. These institutions include the Nigerian Institute for Oceanographic and Marine Research in Lagos and other Departments of Oceanography at the universities. However, there is currently no known systematic body of research and development activity in existence in Nigeria.

2.5.3 Technical Assessment of ~~Ocean~~ Energy Technologies

There is a sustained interest in tidal and wave energy across Europe, the US and Asia. The following is a brief overview of the status on tidal and wave technologies.

2.5.3.1 Overview of Tidal Energy Technologies

For tidal differences to be harnessed into electricity, the difference between high and low tides must be at least five meters. Evidence shows that there are perhaps only about 40 such sites on the planet with tidal ranges of this magnitude. The following are the common tidal energy technologies:

(i) Tidal barrage requires a dam, or barrage, across a bay or estuary. Gates and turbines are installed along the dam. When the tide produces a sufficient difference in the level of the water on opposite sides of the dam, the gates are opened, water flows through the turbines, and the turbines turn on electric generator to produce electricity.

(ii) Tidal fence. These are fences that look like giant turnstiles. They can reach across channels between islands or across straits between the mainland and island. The turnstiles spin via tidal currents typical of coastal waters and can generate as much energy as winds of much higher velocity.

(iii) Tidal turbine. Tidal turbines normally look like wind turbines. They are arrayed underwater in rows, as in some wind farms. The turbines function best where coastal current run at between 3.6 and 4.9 knots (approx. 6.5 and 9 km/h). In currents of that speed, a 15meter diameter tidal turbine can generate as much energy as a 60-meter diameter wind turbine. Ideal locations for tidal turbine farms are close to shore in water depths of 20 – 30 meters.

2.5.3.2 Technical characteristics

The technical life of a tidal scheme could be about 120 years or upward for the civil structure. The electrical generating plant may have a technical life of about 40 years. Since the tidal resource is site specific, the plant availability will necessarily vary. Technical efficiency of the plants will also vary from the technology used.

2.5.3.3 Economic competitiveness

Tidal energy projects require high initial capital expenditure. They have very long construction periods and low load factors, leading to long payback periods. This leads to very high overall cost and major challenges in funding a commercial tidal project.

2.5.3.4 Benefits and Limitations of Tidal Energy Technologies

Tidal energy is clean and renewable. However, Nigeria does not seem to have a significant tidal energy resource. Where the resource base is adequate, tidal energy technologies have not fully matured and the cost of construction are very high. Engaging in tidal research and development will keep Nigeria abreast of the international scientific and technological development in this area – both for future energy needs and in the development of science and technology.

2.5.3.5 Overview of Ocean Wave Energy Technologies

Wave energy can be converted into electricity through both offshore and onshore systems. *Offshore systems* are situated in deep water, typically more than 40 meters. Sophisticated bobbing mechanisms use the motion of the waves to power a pump that creates electricity. Some other offshore devices use hoses connected to floats that ride waves. The rise and fall of the float stretches and relaxes the hose, which pressurizes the water, which in turn, rotates a turbine. A third offshore possibility is through specially built seagoing vessels. These floating platforms create electricity by funneling waves through internal turbines. *Onshore wave systems* are usually built along shorelines to extract the energy in breaking waves. There are three known varieties of these onshore technologies: the oscillating water column, the Tapchan, and the pendular device. Of the three technologies, only the oscillating model has had some significant success in utilization.

2.5.3.6 Ocean Thermal Energy Conversions (OTEC) uses the heat energy stored in the oceans to generate electricity. OTEC works best when the temperature difference between the warmer, top layer of the ocean and the colder, deep ocean water is about 20^{o}C. These conditions exist in tropical coastal areas, roughly between the Tropic of Capricorn and the Tropic of Cancer. OTEC uses the temperature difference between the warm upper and the cooler lower layers of ocean water to generate electricity. There are three known types of the OTEC technologies: *closed-cycle*, *open-cycle* and the *hybrid* types. Closed-cycle types use fluid with low-boiling point organic fluids in the turbine cycle together with a heat exchanger; open-cycle OTEC uses the top and lower layer waters directly in an open-cycle configuration. ~~OTEC uses the tropical oceans' warm surface water to make electricity~~T~~; while t~~he hybrid systems combine the features of both.

Some theoretical possibility of harnessing ocean energy off Nigeria's coast exists. However, several technological and market constraints would need to be overcome.

2.5.3.7 Technical characteristics of ocean wave energy

Producing power from waves is technologically challenging. Some of the difficulties include irregularity in wave amplitude, phase and direction. It is therefore difficult to determine the maximum efficiency over time. Secondly, the structural loading in periods of extreme weather conditions such as hurricanes may be as high as 100 times the average loading. Thirdly, the coupling of the irregular slow motion of a wave to electrical generators requires typically more than 500 times greater frequency. Balancing the requirements of having a reliable device on the one hand and an economically viable system on the other hand makes wave power design very complex and challenging.

2.5.3.8 Economic competitiveness

Worldwide, wave energy technologies are still at various stages of commercialization. Nigeria's low wave energy regime along the Atlantic coast does not permit the efficient deployment of today's wave energy technologies.

2.5.3.9 Benefits and limitations

Wave energy is clean and renewable. The development of this resource worldwide will help secure an energy future that is less polluting. However, the wave resource situation precludes a significant investment in Nigeria in the foreseeable future.

2.5.3.10 Market situation of ocean energy technologies

The economics of wave energy technologies presents a key challenge. Even though the operating costs of these technologies are low, they are very expensive to build. With long payback periods, these projects are both difficult to finance and the cost per kilowatt-hour of power produced is presently not competitive.

2.5.3.11 Key drivers for the ocean energy technology market

The development of ocean energy worldwide will likely be driven by cost reduction, responses to climate change, the compatibility of electricity demand variability and wave patterns as well as the development of niche markets in offshore oil and gas production. Ecological impacts on marine life and aesthetic effects are factors that may also count in considering tidal power.

2.5.4 Geothermal Energy

Geothermal energy comes from heat that originates from the Earth. It has two sources: initial heat produced from the formation of the Earth and heat produced from radioactive decay of various isotopes.

2.5.4.1 Geothermal Energy Resource Situation

In 2004 over 9,000 megawatts of electricity were produced from some 250 geothermal power plants in 22 countries around the world. These plants provide reliable base-load power for well over 60 million people, mostly in developing countries. African countries with geothermal energy potential are those that are traversed by the East African Rift Valley. These countries include Djibouti, Eritrea, Ethiopia, Kenya, Tanzania and Uganda. Two known geothermal resources exist in Nigeria, and they are: the Ikogosi Warm Springs in Ondo State and the Wikki Warm Springs in Bauchi.

2.5.4.2 Estimated Geothermal Energy Resource Base

The resource potentials for geothermal energy entrapped in the Earth crust are almost limitless. Beyond the two known geothermal resource areas in Nigeria, high geothermal gradient trends have been identified in the Lagos sub-basin, the Okitipupa ridge, the Auchi-Agbede within the Benin flank/hinge line as well as the Abakaliki anticlinorium.

2.5.4.3 Status of Geothermal Energy Database, including Adequacy and Gaps

There is no consistently developed and maintained database on geothermal energy in Nigeria. This is without prejudice to possible research within departments of geology and petroleum geology in the universities.

2.5.4.4 Technical Assessment of Geothermal Energy Technologies

The following reviews the status of geothermal technology, its key characteristics and competitiveness.

2.5.4.5 Overview of Geothermal Energy Technologies

A geothermal system consists of three main elements: a heat source, a reservoir and a fluid – the last being the carrier for transferring heat from the source to the power plant. Three power plant technologies are being used to convert geothermal fluids to electricity:

- *Dry steam plants* directly use geothermal steam to drive turbines;
- *Flash steam plants*, pull deep, high-pressure hot water into lower-pressure tanks and use the resulting flashed steam to drive turbines; and
- *Binary-cycle plants* that pass moderately hot geothermal water by a secondary fluid with a much lower boiling point than water. This causes the secondary fluid to flash to vapor, which then drives the turbines.
- *Direct thermal applications* of geothermal energy include: hot spring bathing, agriculture, aquaculture, industrial hot water uses, heating of individual and residential districts. Heat pumps have also become widely used in temperate regions.

2.5.4.6 Technical Characteristics of Geothermal Energy Technologies

Geothermal power plants tend to be in the 20 MW to 60 MW range and the capacity of a single geothermal well usually ranges from 4 MW to 10 MW. Typical minimum spacing of 200m to 300m is established to avoid interference. Geothermal power plants have an average availability of about 90% compared to 75% for coal. The The Olkaria I Geothermal Power Station in Kenya has been in operation in over 20 years and has consistently maintained an availability factor of about 98%.

2.5.4.7 Economic Competitiveness of Geothermal Energy Technologies

The economics of geothermal energy is highly variable depending on applications and site-specific conditions. The costs of steam or hot water for direct applications will depend on geothermal steam/hot water temperature and the distance from the well to the point of use. The cost of geothermal power production vary from US¢/kWh 5 -7 for plants less than 5 MW and US¢/kWh 2.5 – 5 for large plants of more than 30 MW for high quality reservoirs. Direct capital costs also vary significantly. Large plants in high quality sites can be as low as US$750/kW and as high as US$2300/kW for small plants.

2.5.4.8 Benefits and Limitations of Geothermal Energy Technologies

Where the resource exists, geothermal energy is a secure energy source. It is available 24 hours a day all the year round. Geothermal plants have high availability factors. Geothermal energy is also environmentally benign and releases minimal emissions. While the running costs of geothermal plants are low, initial costs of well drilling, pipeline construction, resource analysis of drilling information, design of plant and power plant construction is high. Steam or hot fluid cannot be transported efficiently over long distances. Therefore, the choice of the location of power plants is restricted to where reservoirs exist.

2.5.4.9 Market Situation of Geothermal Energy Technologies

Geothermal energy is nonexistent in the Nigerian energy market. This situation can change in the event of major discoveries of commercial geothermal reservoirs as well as major changes in the market for other energy sources.

2.5.4.10 Key drivers for Geothermal Energy Technology Market

Geothermal reservoirs of commercial proportions have ~~not been discovered~~yet to be fully investigated in Nigeria. A market for geothermal energy may emerge only when the existence of a significant resource based can be established.

Chapter 3: Targets

3.1 Introduction

Targets are critical tools in achieving the visions of the REMP. Cumulative targets are established for the following periods:

Short-term : *Year 2005 to 2007*. From the base year in 2005, short-term targets are set to reach initial milestones in the establishment of a framework for delivering on the vision of the REMP. The outcomes of the short-term targets will coincide with broader milestones established by the NEEDS on the expiration of the term of the present Federal Government in 2007.

Medium-term:*Year 2008 to 2015*. Medium-term targets coincide with the Millennium Development Goals target year 2015. This will enable the REMP to measure the contribution of renewable energy to the MDGs and the medium term projections of Nigeria's overall energy sector projections.

Long-term*: Year 2016 to 2025*. Long-term targets provide a twenty-year framework to measure progress on reaching the vision of the REMP. It provides Nigeria with tools to address renewable energy and development issues a decade after the MDGs, and will measure progress on renewable energy development as a proportion of projected national energy sector growth.

In measuring the above, the REMP disaggregates electricity targets from non-electricity targets, and provides an assessment of the implications of the targets. Projects are bases on the High Growth Scenario developed by the ECN. This scenario largely corresponds with NEEDS targets and present developments, particularly in the electricity sector.

3.2 Renewable Electricity Targets

The REMP renewable energy targets outline the expected contribution of renewable energy sources to electricity production in the country. The estimates are based on cumulative capacities expressed in MW.

Electricity Demand Projections for Nigeria

The ECN has carried out an energy demand scenario analysis projecting electricity demand for three scenarios: reference, low growth and high growth up till year 2030 as shown in Table 3.2.1.

Table 3.2.1 Estimates of Annual Peak Electricity Demand (MW)

Scenario	2000	2005	2010	2015	2020	2025	2030
High Growth	4558	6661	9629	13915	20060	28924	41755
Reference	4558	6077	8097	10732	14199	18820	24979
Low Growth	4558	5973	7735	10008	12297	15701	19599

The targets for electricity generation from the five renewable energy sub-sectors in the short, medium and long terms are shown in Table 3.2.2 together with the ECN total electricity demand projections under the High Growth Scenario.

Table 3.2.2: Targets For Electricity Generation(MW)

Sources		2007	2015	2025
Wind		1	20	40
Solar PV		5	120	500
Solar thermal		-	1	5
Small hydro		50	600	2000
Biomass		-	100	800
Total		**56**	**841**	**3345**
ECN High Growth Scenario Projections		7000	14000	29000
Percentage share of projected energy demand		0.8	6	11.53

The Federal Ministry of Power and Steel (FMPS) projects that RE (excluding large hydro plants) should contribute about 10% of the national electricity production in the long-term. The electricity generation targets from RE sources in Table 3.2.2 however fall short of the 10% share of FMPS projections for the short and medium term. It is realistic to expect that the policy and financial mechanisms that would be set up to promote RE will not have been strong enough to achieve the 10% target by 2015. By 2007 and 2015, the contribution of the RE targets to the national electricity supply mix will therefore be only 0.8% and 6% respectively. The 10% target will be achieved by the year 2025.

3.2.1. Short Term Targets – Year 2007

The 56 MW RE target for year 2007 as shown in Table 3.2.3 consists of the following:

Table 3.2.3 Short Term Target(2007)

Sources	Target Demand (MW)	Detailed Description of the Target
Wind	**1**	Wind farm demonstration project
Solar PV	**5**	Solar PV electricity projects, composed of grid-connected and mini-grid systems as well as grid-connectible SHS and stand-alone SHS.
Small Hydro	**50**	There is already an existing small hydro capacity of over 30MW. New planned capacities include, Oyan, Obudu, Evboro, etc.

3.2.2. Medium Term Targets(2015)

The 746 MW RE target for year 2015 as shown in Table 3.2.4 consists of the following:

Table 3.2.4 Medium Term Target

Sources	Target Demand	Detailed Description of Target
Wind	20	More and larger wind farm demonstration and commenced projects.
Solar PV	120	Larger PV electricity projects, composed of grid-connected and mini-grid systems as well as grid-connectible SHS and stand-alone SHS
Solar thermal	1	Programme with a 1 MW demonstration plant using one of the three proved STP technologies
Small hydro	600	Commercial development of small hydro sites in all parts of the country
Biomass	100	Biomass cogeneration/biogas/biofuels electricity generation projects of a total of 100 MW all over the nation.

3.2.3. Long Term Targets(2025)

The 2945 MW RE target for year 2025 as shown in Table 3.2.5 consists of the following:

Table 3.2.5. Long Term Target

Sources	Target Demand	Detailed Description of Target
Wind	40	Commercially-driven and much larger wind farm projects.
Solar PV	500	Larger PV electricity projects, composed of grid-connected and mini-grid systems as well as grid-connectible SHS and stand-alone SHS
Solar thermal	5	National solar thermal electricity programme using one of the three proved STP technologies
Small hydro	2000	Commercial development of small hydro sites in all parts of the country
Biomass	800	Biomass/biogas/biofuels electricity generation projects of a total of 5 MW spread all over the nation.

3.3 Renewable Non-Electricity Targets

The targets for non-electrical energy production from solar thermal, biomass and biogas are shown in Table 3.3.1. The projections for total RE production in 2007, 2015 and 2025 are 361.46, 746.24 and 1096.04 TWh respectively. This constitutes 41%, 16% and 9% respectively of the ECN Final Energy Demand Projection (less the electricity component)

Table 3.3.1: Targets For Non-Electrical Energy Production

Thermal energy analysis	2007.0	2015.0	2025.0
All energy forms (GWh)	193789.0	202128.0	248869.0
Fuelwood & charcoal, (GWh)	144,544	121,352	95,869
Fuelwood & charcoal [Biomass energy]++, (% of total)	74.6	60.0	38.5
Solar thermal share of total thermal energy, (%)	10.0	20.0	40.0
Ren. Energy share of total thermal energy, (%)	84.6	80.0	78.5
Other non-Ren. energy share of total thermal energy, (%)	15.4	20.0	21.5
Ren. Energy share of total thermal energy, (GWh)	163922.9	161777.6	195416.6
Solar thermal share of total thermal energy, (GWh)	19378.9	40425.6	99547.6

Note: Biomass energy has 0, 4.3 and 6 GWh in the short, medium and long terms respectively

Distribution of Solar Thermal Share	Share, (%)			Share, (GWh)		
	2007.0	2015.0	2025.0	2007.0	2015.0	2025.0
All Solar Thermal	100.0	100.0	100.0	19378.9	40425.6	99547.6
Solar Water & Air Heating	75.0	70.0	60.0	14534.2	28297.9	59728.6
Solar Drying & Brooding	18.0	15.0	18.0	3488.2	6063.8	17918.6
Solar Desalination, solar stills, etc.	0.0	1.0	2.0	0.0	404.3	1991.0
Solar Cooking	1.0	2.0	2.0	193.8	808.5	1991.0
Solar refrigeration & A/C & passive architecture	2.0	4.0	5.0	387.6	1617.0	4977.4
Solar pasteurization, sterilization	4.0	3.0	3.0	775.2	1212.8	2986.4
Solar Thermal Electricity	0.0	5.0	10.0	0.0	2021.3	9954.8

The increasing share of solar thermal applications over the three periods will essentially be accounted for by solar water/air heating, solar drying, solar cooking, chick brooding, solar desalination, solar pasteurization, sterilization, passive architecture, solar thermal electricity, etc. However, the remarkable decline in the contribution of non-electricity sub-sectors over the plan period will largely be as a result of the anticipated reduction in the role of fuel wood in the national energy landscape.

3.4 Implications of the Targets

The implications of the targets are that several units of various systems are required as indicated in Table 3.4.1.

Table 3.4.1: Implications of The Targets

	2007		2015		2025
RENEWABLE ENERGY SUB-SECTOR					
WIND					
STAND-ALONE MILLING/WATER PUMPING FOR					
AGRICULTURE	0		8		16
NON-GRID HYBRID FOR RURAL ELECTRIFICATION(1MW)	1		10		20
GRID-CONNECTED WIND FARMS(5MW)	0		1		2
SMALL HYDRO	4		120		200
BIOMASS					
IMPROVED BIOMASS STOVES	1,000,000		2,000,000		3,000,000
BIOGAS DIGESTERS	---		6000		8000
BIOMASS PLANTS	---		40		80
BRIQUETTING PLANTS	30		80		200
SOLAR PV					
SHS	40,000		400,000		4,000,000
WATER PUMPING	2,500		37,500		250,000
COMMUNITY SERVICES	50		1500		10,000
STREET & TRAFFIC LIGHTING	10,000		100,000		500,000
LARGE-SCALE PV PLANTS	----		30		50
SOLAR THERMAL					
SOLAR COLLECTORS	4000		57,100		146,600
SOLAR COOKERS	1,678		51,024		152796
SOLAR DRYERS, CHICK BROODERS, ETC (5KW CAPACITY)	130		1700		6000
SOLAR DESALINATION, STILLS, ETC(2KW CAPACITY)	0		300		1600
SOLAR REFRIGERATION & A/C(MW)	0.075		2		8.5
PASSIVE ARCHITECHTURE (NO. OF DEMO. PROJECTS)	10		100		1000
SOLAR PASTEURISATION, STERILISATION(0.5KW CAPACITY)	300		3500		10,000
SOLAR THERMAL ELECTRICITY(MW)	0		3		16.5
GEOTHERMAL, OCEAN, TIDAL	0		0		0

3.4.1. Solar Energy

Solar PV

The number and capacities of PV systems to be installed in the short (2007), medium (2015) and long (2025) term are shown in Tables 3.4.2, 3.4.3 and 3.4.4 respectively.

Table 3.4.2: Solar PV Installations for Short Term(2007)

APPLICATION	CAPACITY PER UNIT	NUMBER REQUIRED
Solar Home Systems	50W	40,000
Water Pumping	400W	2500
Community Services	10kW	100
Street and Traffic Lighting	100W	10,000
Large Scale PV Plants	---	---

Table 3.4.3 : Solar PV Installations for Medium Term(2015)

APPLICATION	CAPACITY PER UNIT	NUMBER REQUIRED
Solar Home Systems	50	400,000
Water Pumping	400W	37,500
Community Services	10kW	1500
Street and Traffic Lighting	100W	100,000
Large Scale PV Plants	500kW	30

Table 3.4.4 : Solar PV Installations for Long Term(2025)

APPLICATION	CAPACITY PER UNIT	NUMBER REQUIRED
Solar Home Systems	50W	4,000,000
Water Pumping	400W	250,000
Community Services	10KW	10,000
Street and Traffic Lighting	100W	500,000
Large Scale PV Plants	1MW	50

(ii) Solar Thermal

The number and capacities of solar thermal systems to be installed by 2007, 2015 and 2025 are shown in Tables 3.4.5, 3.4.6 and 3.4.7 respectively.

Table 3.4.5: Solar Thermal Systems Installations for short Term(2007)

APPLICATION	CAPACITY PER UNIT	NUMBER REQUIRED
Solar Collectors	2 sq metres	1000
Solar Cookers	1220kj per cooker	1678
Solar dryers, chick brooders etc	5kW	130
Solar desalination, solar stills	2kW	0
Solar refrigeration & A/C.	MW	0.075
Solar passive architecture	--	10
Solar pasteurization, sterilization	0.5kW	300
Solar thermal electricity	MW	0

Table 3.4.6: Solar Thermal Systems Installations for short Term(2015)

APPLICATION	CAPACITY PER UNIT	NUMBER REQUIRED
Solar Collectors	57,100	57,100
Solar Cookers	1220 kj per cooker	51,024
Solar dryers, chick brooders etc	5kW	1700
Solar desalination, solar stills	2kW	300
Solar refrigeration & A/C.	MW	2
Solar passive architecture	-	100
Solar pasteurization, sterilization	0.5KW	3500
Solar thermal electricity	MW	0

Table 3.4.7: Solar Thermal Systems Installations for Long Term(2025)

APPLICATION	CAPACITY PER UNIT	NUMBER REQUIRED
Solar Collectors	2 sq. meters	1,146,600
Solar Cookers	1220kJ per cooker	152,796
Solar dryers, chick brooders etc	5kW	6000
Solar desalination, solar stills	2kW	1600
Solar refrigeration & A/C.	MW	8.5
Solar passive architecture	--	1000
Solar pasteurization, sterilization	0.5kW	10,000
Solar thermal electricity	MW	0

3.5 : Biomass and Biogas

Table 3.5.1 shows the number of biogas digesters, biogas plants, biomass briquettes proposed to be installed in the short, medium and long term.

Table 3.5.1: Biomass and biogas systems installation in the short, medium and long term

Source	2007	2015	2025
	Number to be Installed	Number to be Installed	Number to be Installed
Biogas digesters	0	6000	8000
Biogas plants	0	40	80
Biomass briquettes	30	50	80
Biomass Stoves	300,000	500,000	1,000,000

3.6. Small Hydropower and wind

Table 3.6.1 shows the number of small hydropower and wind systems proposed to be installed in the short, medium and long term.

Table 3.6.1: Small Hydropower and wind systems installations in the short, medium and long term.

Source	2007	2015	2025
Small hydropower	20	600	2000
Wind	1	21	40

Chapter 4: Planned Activities and Milestones

4.1 Introduction

To ensure that the REMP targets outlined in chapter 3 are achieved, concrete activities and milestones have been identified in the short, medium and long term. These activities and milestones are organised under specific sub-sectoral programmes. To address areas of overlap, a Framework Programme for Renewable Energy Promotion that harmonizes cross-cutting issues is planned. None of the proposed programmes are in themselves exhaustive and mutually exclusive. They are therefore dynamic and adaptable to changes within the overall policy, technology and market environments evolving over the two decades of the Master Plan. The Framework Programme will ensure that activities within the various sub-sectoral programmes are mutually supportive. The Master Plan establishes the following programmes:

- Framework Programme on Renewable Energy Promotion
- National Biomass Energy Programme
- National Solar Energy Programme
- National Small Hydro Energy Programme
- National Wind Energy Programme
- Emerging Energy Research and Development Programme

All the cost estimates are in 2005 Naira.

4.2 Framework Programme for Renewable Energy Promotion

Goals and Objectives

1. Policy, Legal and Regulatory Framework

(i) Approval of the Renewable Energy Master Plan (REMP)

(ii) Approval of the Rural Electrification Strategy

(iii) Establishment of Renewable Energy Portfolio Standards (REPS)

(iv) Development of Power Purchase Agreement with Electricity Distribution Companies

(v)Expansion of RE into non-energy sectors

(vi) Review of the Renewable Energy Master Plan

(vii) Enforcement of existing legislation on town planning

(viii) Incorporation of alternative energy sites in town planning arrangements

(ix) Encouragement of incorporation of RE in building development

2. Institutional Framework

(i) Establishment of Renewable Energy Professional & Industry Associations
(ii) Establishment of National RE Development Agency (NREDA) - Long Term
(iii)Technology Production and Testing Centres – Short Term

(iv) Establishment of more meteorological stations

3. Economics and Financing

(i) Suspension of Import Duties

(ii) Mobilisation of donor finance for projects

(iii) Extension of Micro Financing

4. Capacity Building

(i) Training and re-training activities across several renewable energy sectors
(ii) Private sector participation
(iii) Incorporation of RE studies into schools curricula

(iv) Encourage reliable data collection from satellite

5. Public Awareness

(i) Workshops, open days, talk-shops, seminars and conferences on the REMP

(ii) Creation of Website for the Framework Programme

(iii) Mass media coverage of pilot projects
(iv) Establishment of RE Demonstration Centres in villages

6. Inter-Agency/Governmental Collaboration

(i) Annual forums on Renewable Energy Development in Nigeria
(ii) Encouraging technical co-operation among government agencies

7. Research and Development

(i) Budgetary and donor funding RE R&D
(ii) Establishment of RE R & D Fund
(iii) Commercialisation of R&D outputs

8. Monitoring and Evaluation

(i) Establishment of National Steering Committee on REMP
(ii) Establishment of National RE R & D data bank by (i) above
(iii) Production of Annual Reports of RE in Nigeria by (i) above

Table 4.2.A FRAMEWORK PROGRAMME ON RENEWABLE ENERGY PROMOTION

Short Term (2006 - 2007)					**Medium Term (2008 - 2015)**					**Long Term (2016 - 2025)**					
Activity Area	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Participating Agencies**
Policy, legal and regulatory framework	Preparation of Federal Executive Council Memo seeking approval for the REMP	Federal Executive Council Approval of the REMP	2006		Policy, legal and regulatory framework	Consultancy and workshop on Nigeria's RE Portfolio Standards	Establishment of Renewable Energy Portfolio Standards (REPS)	2008	10	Policy, legal and regulatory framework	Review of existing Portfolio Standards	Review of Portfolio Standards	2016	2	Federal, state agencies, private sector, academia and NGOs
		Federal Executive Council Approval of the Rural Electrification Strategy	2006				Development of Power Purchase between RE producers and Electricity Distribution Companies	2008 - 2009				Review of the Renewable Energy Master Plan	2025	30	Federal, state agencies, private sector, academia and NGOs
		Full implementation of the Power Sector Reform Act	2005 - 2007			Mainstreaming RE in integrated rural development	Expanded integration of RE into non-energy sectors (Rural health, education, water supply and communication	2008 - 2025	50						Federal, state agencies, private sector, academia and NGOs
						REMP review	Review of the Renewable Energy Master Plan	2015	30						Federal, state agencies, private sector, academia and NGOs
Institutional framework		Establishment of renewable energy professional & industry associations	2006 - 2007		Institutional framework		Establishment of National Renewable Energy Agency (NREA)	2010							
							Establishment of Technology Testing Centres	2008							
Sub-Total									90					32	122

Table 4.2.B **FRAMEWORK ON RENEWABLE ENERGY PROMOTION (CONTD)**

Short Term (2006 - 2007)					Medium Term (2008 - 2015)					Long Term (2016 - 2025)					
Activity Area	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Participating Agencies**
Economics and Financing		Suspension of Import Duties	2007		Economics and Financing	Institution-building of REF	Establishment of Renewable Energy Fund	2010	50	Economics and Financing	Evaluation Consultancy for Import Duty Suspension	Evaluation of the Suspension of RE import duties	2016	10	Federal, state agencies, private sector, academia and NGOs
		Mobilisation of donor finance for projects (see project concept notes annexed)	2006 - 2025			Development of framework for MFS	Introduction of Micro Finance Schemes for RE	2008	20		Review of Micro Finance Scheme	Expansion of Micro Finance Schemes for RE	2016 - 2025	10	Federal, state agencies, private sector, academia and NGOs
		Introduction of capital subsidies through the Rural Electrification Fund	2006												Federal Institutions
Capacity Building	Training Facility for RE	Coordinating of training activities across several renewable energy sectors	2006 - 2025	100	Capacity Building	Training Facility for RE	Coordinating of training activities across several renewable energy sectors	2005 - 2025	100	Capacity Building	Market Entry capacity building for RE	Enhanced private sector led investments in RE systems	2008 - 2025	100	Federal, state agencies, private sector, academia and NGOs
Public Awareness	REMP National Workshop	Workshop on the REMP	2005	10	Public Awareness	Web and media information project	Websites, print, electronic media and conferencing	2005 - 2025	100	Public Awareness	Web and media information project	Websites, print, electronic media and conferencing	2005 - 2025	100	Federal, state agencies, private sector, academia and NGOs
Inter-Agency Collaboration	Workshop	Convening annual forums on Renewable Energy Development in Nigeria	2007 - 2025	10	Inter-Agency Collaboration	Workshop	Convening annual forums on Renewable Energy Development in Nigeria	2007 - 2025	10	Inter-Agency Collaboratio n	Workshop	Convening annual forums on Renewable Energy Development in Nigeria	2007 - 2025	10	Federal, state agencies, private sector, academia and NGOs
Research and Development	RE technology and market R&D	Increased budgetary and donor funding RE R&D	2006 - 2025	50	Research and Development	RE technology and market R&D	Collaborative research between industry and academia	2008 - 2025	50	Research and Developme nt	RE technology and market R&D	Commercialisation of R&D outputs	2015 - 2025	50	Federal, state agencies, private sector, academia and NGOs
Monitoring and Evaluation		Establishment of National Steering Committee on the REMP and the production of Annual Reports on RE in Nigeria	2005		Monitoring and Evaluation	Monitoring and evaluation project	Annual Reports of RE in Nigeria	2006 - 2025	10	Monitoring and Evaluation	Monitoring and evaluation project	Annual Reports of RE in Nigeria	2006 - 2025	10	Federal Institutions
Sub-Total				170					340					290	800
Grand Total				**170**					**430**					**322**	**922**

4.3 National Biomass Energy Programme

Goals and Objectives

(i) **Know our Biomass Resources Potential**

(ii) **Achieve competence in and domesticate six biomass technologies:**

- improved woodstoves
- biodigester/biogas
- gasification of biomass
- liquifaction of biomass
- briquetting of fine particle biomass
- fast growing trees

(iii) **Data Acquisition Projects**

- Conduct Survey of Biomass energy resources and categories by state, type/source, utilization pattern, thermal & electrical energy derivable there From; energy conversion, technologies.

(iv) **R & D Projects**

- develop, through testing and literature survey, design parameters for a comprehensive list of feedstock.
- establish lab facilities for study of gasification of ligno-cellulosic materials.
- establish lab & research programmes on **liquefaction** of biomass & pilot energy farms
- acquire competence in biomass briquetting through design & production of briquetting machines by 2 No. principles.
- establish pilot fast growing energy crops/trees.

(v) **Market Dev/Promotion Projects**

(a) produce market ready models of improved woodstoves

(b) conduct pilot projects on dissemination/market testing of improved woodstove designs.

(c) conduct public awareness projects, through media on improved woodstoves

(d-f) a, b, c, for biodigester/biogas

(g) establish two plants on **liquefaction** of biomass

(h) establish 6 pilot plants on **liquefaction** of biomass

(i) establish 3 pilot plants on briquetting of biomass

(vi) **Increasing Energy Access**

- achieve the establishment/installation of specified numbers/capacities of equipment or systems for each biomass technology in order to to meet given targets:

- short term targets
- medium term targets
- long term targets

(vii) **Capacity Building**

(a) **Human Capacity**

- Direct training workshops/short courses on improved woodstoves, biodigesters, biomass gasifyers, biomass liquification, biomass briquetting and establishment of energy farms/fast growing tree farms.
- Train the trainers workshops on above technologies and on their dissemination.
- Advanced training overseas on the above technologies and on their dissemination.
- Development & implementation of curricula on the technologies for primary, secondary and tertiary levels (under renewable energy curricula development).

(b) **Manufacturing Capacity**

- Publicize incentives developed for private sector investments in the manufacture of improved woodstoves, biodigesters, biomass briquetting bioliquids production, gasification of biomass
- Over the plan period, establish x_1, x_2, x_3 ………….. x_n factories on above technologies through private, public or joint private/public investments.

(c) **Support Infrastructure**

- Equip R & D Centers and 6 selected Universities for training in Biomass/biogas
- Establish technical standards for biomass/biogas products in collaboration with SON
- Establish testing and certification centers for biomass/biogas equipment.

Table 4.3.A NATIONAL BIOMASS ENERGY PROGRAMME

Short Term (2006 - 2007)					Medium Term (2008 - 2015)					Long Term (2016 - 2025)					
Activity Area	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Participating Agencies**
Data Acquisition	Survey of Biomass energy resources	Obtain comprehensive data on biomass energy resources by State, type, utilization, potential & uses	2006 - 2007	200	Data Acquisition	Management of Biomass Database	Review and updating of available data on biomass resources	2008 - 2015	100	Data Acquisition	Management of Biomass Database	Review and updating of available data on biomass resources	2016 - 2025	100	ECN, FMARD
Capacity Building	Training and retraining Workshops on improved woodstoves & biodigesters	Training and retraining of professionals, operators, craftsmen and rural persons on improved woodstoves & biodigesters	2006 – 2007	60	Capacity Building	Training and retraining Workshops on biomass technologies	Training and retraining of professionals, operators, craftsmen and rural persons on improved woodstoves & biodigesters	2008 - 2015	100	Capacity Building	Training and retraining Workshops on Biomass Technologies	Training and retraining of professionals, operators and craftsmen on the design, operation and maintenance of various biomass technologies	2016 - 2015	80	ECN, NCERD, SERC, NAPEP, FMAARD, NGO's State Govts, Donors.
Capacity Building	Advanced Training on Biodigesters	Advanced training (Overseas and local) on technologies and dissemination of strategies for biodigesters	2006 - 2007	120	Capacity Building	Advanced Training on Biomass Technologies	Short courses and postgraduate programs overseas on the various biomass technologies	2008 - 2015	150	Capacity Building	Advanced Training on Biomass Technologies	Continuation of medium term activities	2016 - 2025	150	ECN, NREA, NCERD, SERC, Tertiary Institutions, others.
Capacity Building	Development of Curricula on biomass energy technologies	Curricula development for primary, secondary and tertiary institutions on biomass technologies	2007	40	Capacity Building	Train the Trainers Workshops on Biomass Technologies	Training of teachers, lecturers, selected local govt. and rural development personnel on the various biomass technologies	2008 - 2015	40	Capacity Building	Train the Trainers Workshops on biomass technologies	Continuation of medium term activities	2016 - 2025	40	ECN, NCERD, SERC, NREA, Educ. Institutions, States, LGAs, FMAARD, NUC,NBTE, NCCE, others.
Capacity Building	Implementation of Curricula on Biomass Technologies	Introduction of curricula on biomass energy technologies in educational institutions	2007	50	Capacity Building	Continuation of short term projects	Training of lecturers, students, selected local govt. and rural development personnel on the various biomass technologies	2008 - 2015	50	Capacity Building	Develop-ment of Curricula on biomass energy technologies	Continuation of medium term activities	2016 - 2025	50	Others.
Capacity Building	Establishment of biomass briquetting plants	3 Nos. of briquetting plants for fine particle biomass are to be established	2006 - 2007	90	Capacity Building	Continuation of short term projects	12 Nos briquetting plants for particle biomass to be established	2008 - 2010	220	Capacity Building	Continuation of Briquetting project from the medium term	36 Nos of briquetting plants for fine particle biomass are to be established	2016 - 2025	600	ECN, Fed., State, Private Investors.
Sub-Total				560					660					1020	2240

Table 4.3.B NATIONAL BIOMASS ENERGY PROGRAMME (CONTD)

Short Term (2006 - 2007)					Medium Term (2008 - 2015)					Long Term (2016 - 2025)					
Activity Area	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Participating Agencies**
Capacity building	Establishment of fuelwood lots	Establish fast growing fuelwood farms	2007	120	Capacity Building	Continuation of short term projects	Expansion of fast growing fuelwood farms	2008 – 2015	360	Capacity building	Continuation of medium term projects	Expansion of fast growing fuelwood farms	2016 - 2025	360	Federal, state, private sector, cooperatives, communities, NGOs, LGAs.
	Establishment of Improved woodstove workshops	3Nos. of small and medium scale manufacturers of improved woodstoves are to be established	2007	42	Capacity Building	Continuation of short term projects	12Nos. of small and medium scale manufacturers of improved woodstoves are to be established	2008 – 2015	126	Capacity Building	Continuation of medium term projects	36Nos of small and medium scale manufacturers of improved woodstoves are to be established (Continuation from previous term)	2016 – 2025	378	ECN, Artisans, Private Investors.
Capacity building	Manufacture of biodigesters	3Nos biodigester production plants are to be established (Continuation from previous term)	2006 – 2007	120	Capacity Building	Manufacture of biodigesters	6Nos biodigester production plants are to be established (Continuation from previous term)	2008 – 2015	240	Capacity Building	Continuation of medium term projects	36Nos biodigester production plants are to be established (Continuation from previous term)	2016 – 2025	1,300	NGOs, Private Investors, ECN, States,Fed., .
Capacity building	Establishment of bio-liquid fuel plants	1,000m3/day capacity bio-liquid fuel plants are to be established	2007	360	Capacity Building	Establishment of bio-liquid fuel plants	1,000m3/day capacity bio-liquid fuel plants are to be established	2008 - 2015	800	Capacity Building	Continuation of medium term projects	10,000m3/day capacity of bio-liquid fuel plants are to be established	2016 – 2025	3,800	
Capacity building	Establishment of energy farms	Establishment fast growing energy farms	2007	80	Capacity Building	Establishment of energy farms	Expansion of fast growing energy farms for bio-liquid fuel production	2008 - 2015	160	Capacity Building	Continuation of medium term projects	Expansion of fast growing energy farms for bio-liquid fuel production	2016 – 2025	220	Private Investors
Market development and Promotion	Production of market ready models of improved woodstoves	Value engineering, market research and re-design of improved woodstoves to meet market expectations and quality standards	2006 – 2007	45	Market development and Promotion	Continuation of short term projects	Value engineering, market research and re-design of improved woodstoves to meet market expectations and quality standards	2008 - 2015	45	Market development and Promotion	Continuation of medium term projects	Value engineering, market research and re-design of improved woodstoves to meet market expectations and quality standards	2016 - 2025	60	Private Investors
	Pilot projects on improved woodstoves	Conduct pilot projects for dissemination of improved woodstoves in rural areas	2006 – 2007	50		Continuation of short term projects	Continuation of short term activities	2008 – 2015	60		Continuation of medium term projects	Conduct pilot projects for dissemination of improved woodstoves in rural areas	2016 - 2025	20	ECN, Private Investors.
Sub-Total				817					1791					6138	8746

Table 4.3.C NATIONAL BIOMASS ENERGY PROGRAMME (CONTD)

Short Term (2006 - 2007)					Medium Term (2008 - 2015)					Long Term (2016 - 2025)					
Activity Area	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Participating Agencies**
Market development and Promotion	Public awareness campaign on improved woodstoves	Promotion of improved woodstoves through the media & village meetings.	2006 – 2007	56	Market development & Promotion	Public aware-ness campaign on improved wood-stoves	Continuation of short term activities	2008 – 2015	60	Market development and Promotion	Continuation of medium term projects	Promotion of improved woodstoves through the media & village meetings.	2016 - 2025	60	ECN
	Production of market ready models of biodigesters	Value engineering and re-design of biodigesters for greater marketability	2006 – 2007	60		Production of market ready models of biodigesters	Continuation of short term activities	2008 – 2015	30		Continuation of medium term projects	Value engineering and re-design of biodigesters for greater marketability	2016 - 2025	30	ECN
	Pilot projects on biodigesters	Establish pilot projects to demonstrate biodigesters	2006 – 2007	60		Pilot projects on biodigesters	Continuation of short term activities	2008 – 2015	120		Continuation of medium term projects	Establish pilot projects to demonstrate biodigesters	2016 - 2025	120	ECN
Sites Identification		Identify all potential project sites in the Country and available biomass resources in each area.	2005 – 2006	30		Sites Identification	Continuation of short term activities	2008 - 2015	90	Sites Identification	Continuation of medium term projects	Identify all potential project sites in the Country and available biomass resources in each area.	2016 - 2025	90	ECN
Technology Assessment and Reviews		Assess and review necessary levels of utilization of biomass energy resources in the country in order to promote the utilization of biomass resources. Developed countries should be approached to promote the transfer of energy technology and training to lift the nation to higher standards of living to benefit the entire nation.	2006 – 2007	10	Technology Assessment and Reviews		Continuation of short term activities	2008 - 2015	10	Technology Assessment and Reviews	Continuation of medium term projects	Assess and review necessary levels of utilization of biomass energy resources in the country in order to promote the utilization of biomass resources. Developed countries should be approached to promote the transfer of energy technology and training to lift the nation to higher standards of living to benefit the entire nation.	2016 - 2025	15	
Sub-Total				216					310					315	841

Table 4.3.D NATIONAL BIOMASS ENERGY PROGRAMME (CONTD)

Short Term (2006 - 2007)					Medium Term (2008 - 2015)					Long Term (2016 - 2025)					
Activity Area	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Participating Agencies**
Biogas Technology/ Diffusion Programme	6 Biogas demonstration project	To make biogas technology popular among Nigerians, there is the need for all three tiers of government to embark upon distribution of biogas plants to a greater extent in order to promote its utilization especially in the rural areas.	2006 – 2007	60	Biogas Technology/ Diffusion Project	12 Biogas demonstration project	Continuation of short term activities	2008-2015	120	Biogas Technology/ Diffusion Project	18 Biogas demonstration project	Continuation of medium term activities	2016 - 2025	180	Federal agencies and academic institutions
Sub-Total				60					120					180	360

Table 4.3.E NATIONAL BIOMASS ENERGY PROGRAMME (CONTD)

Short Term (2006 - 2007)					Medium Term (2008 - 2015)					Long Term (2016 - 2025)					
Activity Area	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Participating Agencies**
Intensive Plantation of fast Growing Trees	Energy Plants Project	Although there have been several tree planting projects in different parts of the Country, the aims have mostly not been geared towards fuel wood production, but for such purposes as afforestation for timber and pulp. Thus, the species and varieties of trees chosen by foresters almost never considered their potentials for fuel wood production. Fuel wood planting can use species with crooked trunks or wood that warps or splits at it dries because these features are not as detrimental to fuel wood as to timber or pulp production. Trees most likely to be useful for fuel wood plantations are those termed "pioneers", which in nature are the first to colonized deforested areas. These species withstand degraded solids as well as exposure to wind and drought. Many are rapid growing.	2007	100	Establish-ment of Wood Farm Lands	Energy Plants Project	Woodlands, forest and on-farm trees are currently the major sources of fuel wood in many countries. For production of fuel wood for local consumption, village forestry or community woodlots should be the ideal. However, there is need to establish woodlands across the country to serve as the sources of raw materials for the future biomass energy industries. Governme nt should establish about 100,000 hectares of woodland by the year 2015.	2008 - 2015	300	Capacity Building	Establishment of fuelwood lots	200 ha of fast growing fuelwood lots are to be established (Continuation from previous term)	2016 - 2025	600	Fed., State, LGAs, Private Investors, Co-operatives.
Capacity Building	Training programmes in Biogas, biofuels, briquetting and woodstoves	Design and implementation of specific training programmes for a broad range of biomass technologies.	2007	40	Capacity Building	Continuatio n of short term projects	Design and implementation of specific training programmes for a broad range of biomass technologies.	2008 - 2015	50	Capacity Building		Continuation of medium term activities	2016 – 2025	100	Fed., State, LGAs, Private Investors, Co-operatives.
Sub-Total				140					350					700	1190

Table 4.3.F NATIONAL BIOMASS ENERGY PROGRAMME (CONTD)

Short Term (2006 - 2007)					Medium Term (2008 - 2015)					Long Term (2016 - 2025)					
Activity Area	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Participating Agencies**
										Establishment of Biomass Co-generation Plants		Government should encourage through incentives the establishment of decentralized biomass power plants for use in the industries. The initial phase of development would involve a number of power plants that can generate as much as 2,500MW of electricity by the year 2025.	2016 – 2025	3000	Federal and state governments in partnership with the private sector
Sub-Total				0					0					3000	3000
Grand Total				**1793**					**3231**					**11353**	**16377**

4.4 National Solar Energy Programme

<u>Goals and Objectives</u>

A. **<u>Solar Thermal Energy</u>**

(i) **Awareness creation and Public Education**

- Develop awareness and public enlightenment programmes for the print and electronic media.
- Develop awareness creation programmes on Solar Thermal Energy for primary and secondary schools.
- Develop awareness creation programmes for National and State Assemblies.
- Workshops for media executives, journalists and reporters.
- Workshop for local government officials, state government officials, school principals and teachers, women and female youth groups.

(ii) **Improvement of Regulatory, Administrative and Institutional Conditions**

- Development modalities for the establishment of Nigerian Renewable Energy Development Agency (NIREDA) and Ministry of Energy (MOE)
- Realise the establishment of NIREDA and MOE.
- Optimize use of the only established NIREDA and MOE.
- Draft legistation and Acts on Solar Thermal marked incentives through appropriate government departments and agencies.
- Draft legistation for a fossil fuel levy Act to finance Solar Thermal Energy.
- Set up Local and regional renewable energy management agencies to promote Solar Thermal Energy at the Local Govt. and State levels.
- Obtain National Assembly accent to the levy Act to finance Solar Thermal Energy.

(iii) **Improvement of Market Competitiveness**

- Design tariff structure for Solar Thermal electricity.
- Obtain necessary approvals for tariff structures
- Effectively use the approved tariff structure for Solar Thermal electricity to leverage renewable energy into the energy mix.
- Mobilize for removal of taxes, VAT, excises, etc on Solar Thermal Energy.
- Develop modalities for institution preferential loans and guarantees, capital subsidies and tax previlages

(iv) **Development of Standards, Codes of Practice and Specifications**

- Develop Codes of Practice as a basic reference document for use in all solar thermal crata heaters/collectors installation, solar dryers for agricultural and industrial installations.

(v) **Research and Development Framework**

- Develop research portfolios in Solar Thermal Energy in solar collector materials like absorber materials, insulators and glazing solar heat storage materials and heat excharger systems.

(vi) **Capacity Building**

- Education, training and retraining required at all levels for artisians, craftsman, technician technologist, engineers, architects, builders, installers, Contractors, Suppliers and Government officials.

- Training for bankers, financiers, managers, NGO's state and local government officials.
- Empower and utilize identified institutions and training facilities that would partner with ECN the education and training requirements.
- Develop education and training materials for solar water heaters/collectors system.

(vii) - Information and Experience exchange and local, regional and international cooperation.

- Develop Networking and information experience exchange strategies with local, state, national, regional and international institutions and organisations.
- Improve on the networking and experience exchange strategies.

(viii) **Pilot Projects Development**

- Develop 10 pilot Projects and four National Solar Thermal Programmes listed in the Solar Thermal Energy Consultant's project.
- Implement the 10 pilot projects and 4 National Solar Thermal Programmes.

(ix) **Development of Testing and Certification Centres and Procedures**

- Develop testing and certification procedures to aid in standards enforcement and sanctions by drawing up of selection criteria.
- Utilize the testing and certification centres and procedures developed.
- Undertake external review, assessment and evaluation of the testing and certification process and procedures.

B. **<u>Solar PV Energy</u>**

(i) **Local Production and Capacity Building**

- Determine exact locations, acquire land and set up PV plants.
- ECN and FMP&S to workout logistics for setting up two PV plants to produce modules based on this film and heterojunction technologies.
- Infrastructural and development of the factory site building.
- Partnership with foreign companies.
- Local production of balance of system components like 1 kw - 10 kW capacities controller (60A).
- Development of utility - tied inverters and other BOS components.
- Recruitment and training of Nigeria Engineers, Physicists, Chemists, Technologists, Technicians and other categories of worker in the

(ii) **Research Development and Training**

- Establish very strong linkage between the two renewable energy research centers and some PV research centres in Europe, America, India, China, Brazil, etc.
- Training of Engineers, Technicians and other workers to be carried out locally.
- Research and development activities continue to ensure locally researched cells and modules have compatible efficiencies.
- Exchange visits between our centres and some overseas centres to determine state if the art equipment to be acquired.
- Acquisition of research equipment.

- Sourcing of fund to install mini module production plants.
- Raw materials Research and Development Council (RMRDC) to initiate research on local raw materials to support the PV products industry
- Collaboration of research efforts between renewable energy research centres and engineering and physical science facilities in our universities.
- Organise training workshops, seminars and conferences at state, zonal and national levels for manpower development. plant.

(iii) **Dissemination of Systems**

- Establish and support at least one PV vendor in each state of the federation.
- Arrange finances to support rural people to acquire solar home systems and ensure private sector participation.
- Installation of PV power in schools, health centres, households, etc between 2006 and 2007.
- ECN and FMP&S plan to distribute 50MW among various sectors of the economy.
- PV integration on the roof of new government, public and private sector owned buildings.
- ECN and FMP&S to demarcate various sectors of the PV market to ensure that on additional 500MW is added by the year 2025.

(iv) **Policy Formulation and Finance**

- Enact government policies and financing mechanisms to encourage the installation of PV systems.

(v) **Establishment of Standards**

- Installation standards and codes of practice are to be setup.
- Establishment of a Renewable Energy Development Agency in the Country.

Table 4.4.A RENEWABLE ENERGY MASTERPLAN PROJECTS AND ACTIVITIES IN SOLAR ENERGY

Activity Area	Short Term				Medium Term				Long Term	
	Project	Description of Activities	Year	Est. Cost Nm	Project	Description of Activities	Year	Est. Cost Nm	Project	Description of Activities
Data Acquisition	National solar radiation database and mapping	Obtain comprehensive data on solar radiation resource and map database	2006/07	40	National solar radiation database and mapping	Solar radiation resource database Mapping continued	2008/15	80	National solar radiation database and mapping	Solar radiation resource database Mapping continued
Capacity Building (Manpower)	Partner training institutions & agencies identification	Identify ECN partner institutions & to develop education & training materials for solar thermal and solar PV technologies. Training target for financiers, NGOs, Bankers, Managers, Public officials, Students, etc.	2006	20	Training Short Courses & Workshops on solar Thermal and solar PV technologies	Training of professionals, operators, craftsmen and others on the design, production, operation and maintenance of solar Thermal & solar PV technologies	2008/15	80	Training Short Courses & Workshops on solar Thermal and solar PV technologies	Training of craftsmen, artisans, women, primary and secondary students and teachers, public officers at local govt. state and national levels, the presidency, judiciary, legislature
Sub-Total				60				160		

Table 4.4.B NATIONAL SOLAR ENERGY PROGRAMME (CONTD)

Activity Area	Short Term				Medium Term				Long Term
	Project	Description of Activities	Year	Est. Cost Nm	Project	Description of Activities	Year	Est. Cost Nm	Project
Capacity Building (Manpower)	Training workshop on solar Thermal and Solar PV technologies	Conduct training workshops with solar Thermal and Solar PV technologies for financiers, NGO's, Bankers, Public Officers, Students, Journalists etc.	2006/07	20	Training workshop on solar Thermal and Solar PV technologies	Training of Teachers , Lecturers, Selected local govt. and Rural development personnel on Solar Thermal and Solar PV technologies	2008/15	80	Training workshop on solar Thermal and Solar PV technologies

	Advanced Training on Solar Thermal and Solar PV technologies	Conduct advanced training on Solar thermal and Solar PV technologies for SMME's and Solar Energy Industry	2006/07	10	Advanced Training on Solar Thermal and Solar PV technologies	Conduct short courses and post graduate programme on Solar Thermal and Solar PV technologies	2008/15	50	Advanced Training on Solar Thermal and Solar PV technologies
	Curricula development on solar Thermal & solar PV technologies	Develop Curricula for Primary, Secondary and Tertiary institutions on solar Thermal & solar PV technologies	2006/07	10	Curricula implementation at the primary, secondary and tertiary institutions	Implement the curricula developed at the various institutional levels	2008/15	30	Curricula implementation at the primary, secondary and tertiary institutions
Sub-Total				40				160	

Table 4.4.C NATIONAL SOLAR ENERGY PROGRAMME (CONTD)

Activity Area	Short Term				Medium Term				Long Term	
	Project	Description of Activities	Year	Est. Cost Nm	Project	Description of Activities	Year	Est. Cost Nm	Project	De of
Capacity Building contd. (Manufacturing and Production)	Establishment of Solar Thermal and Solar PV plants	Development of Business plans for the establishment of two thermal water heater and one solar PV plant	2006/07	10	Establishment of Solar Thermal and Solar PV plants	Involvement of Private Sector partners in the development of two solar water heater and one solar PV plants projects	2008/15	100	Establishment of two solar thermal water heater (one flat plate type and one evacuated tube type) and one solar PV plant (crystalline Si)	Tw the he an PV to est wi sec pa ha ma sh
Capacity Building (support infrastructure)	Provision of teaching and R&D facilities in solar thermal and solar PV technologies	Equipping the National Energy Centres and other Universities with energy R&D capability	2006/07	100	Provision of teaching and R&D facilities in solar thermal and solar PV technologies	Equipping the National Energy Centres and other Universities with energy R&D capability	2008/15	500	Provision of teaching and R&D facilities in solar thermal and solar PV technologies	Co of Me Te act
Sub-Total				110				600		

Table 4.4.D NATIONAL SOLAR ENERGY PROGRAMME (CONTD)

Activity Area	Short Term				Medium Term				Long Term
	Project	Description of Activities	Year	Est. Cost Nm	Project	Description of Activities	Year	Est. Cost Nm	Project
Market Development and Promotion	Pilot Projects on solar thermal technologies	Pilot Projects on solar water heaters: solar dryers, solar cookers and solar absorption and adsorption refrigeration	2006/07	100	Pilot Projects on solar thermal technologies	Continuation of short term pilot projects and development of pilot projects on solar thermal electricity	2008/15	500	Commercialization of pilot projects on solar thermal technologies
	Pilot Projects on solar PV technologies	Pilot Projects on Solar PV in the residential, commercial, industrial sectors	2006/07	500	Pilot Projects on solar thermal technologies	Continuation of Short term activities	2008/15	500	Commercialization of pilot projects on solar PV
	Public awareness campaigns on improved woodstoves	Promotion of improved woodstoves through the media, village meetings etc.			Continuation of short term projects	Continuation of short term activities	2008/15		
	Public awareness campaign on solar thermal and solar PV technologies	Promotion of solar thermal and solar PV technologies through the media, village meetings etc	2006/7	50	Public awareness campaign on solar thermal and solar PV technologies	Continuation of short term activities	2008/15	100	Public awareness campaign on solar thermal and solar PV technologies
Sub-Total				650				1100	

Table 4.4.E NATIONAL SOLAR ENERGY PROGRAMME (CONTD)

Activity Area	Short Term				Medium Term				Long Term
	Project	Description of Activities	Year	Est. Cost Nm	Project	Description of Activities	Year	Est. Cost Nm	Project
Policy, Legal and regulatory framework	Development of Codes of Practice, Standards & Specifications for solar thermal & solar PV technologies	Develop Codes of Practice, Standards & Specifications for solar thermal & solar PV technologies	2006/07	50	Development of Codes of Practice, Standards & Specifications for solar thermal & solar PV technologies	Continuation of the development of codes, standards & specifications	2008/15	80	Development of Codes of Practice, Standards & Specifications for solar thermal & solar PV technologies
Research & Development Framework	R & D in solar thermal & solar PV technologies	Develop research portfolios in solar thermal energy & solar PV	2006/07	50	R & D in solar thermal & solar PV technologies	Implement the R & D portfolios developed in the Short Term	2008/15	100	R & D in solar thermal & solar PV technologies
International, Regional & Inter-Agency Cooperation	Networking	Encourage Development of network of researchers, industry & commerce involved in solar thermal & solar PV technologies	2006/07	10	Networking	Continue the Short Term networking activities	2008/15	50	Networking
Sub-Total				110				230	

Table 4.4.F NATIONAL SOLAR ENERGY PROGRAMME (CONTD)

Activity Area	Short Term				Medium Term				Long Term
	Project	Description of Activities	Year	Est. Cost Nm	Project	Description of Activities	Year	Est. Cost Nm	Project
Policy, legal, & regulatory framework	National RE Production and Testing Center	Establish 6 zonal Testing & Certification centres for solar thermal & solar PV technologies	2006/07	100	Development of Testing & Certification centres & Procedures	Continue the establishment of the 6 Testing & Certification Centres for solar thermal & solar PV technologies	2008/15	100	Development of Testing & Certification centres & Procedures
Public Awareness	Publicity	Develop awareness creation & public enlightenment programmes on solar thermal & solar PV technologies for the print & electronic media; primary & secondary schools; National, State & Local Govt. Assemblies; State & Fed. Ministry Officials; Youth & Women Groups; etc.	2005/06	10	Publicity	Continue the Short Term Activities	2008/15	10	Publicity
Sub-Total				110				110	

Table 4.4.G NATIONAL SOLAR ENERGY PROGRAMME (CONTD)

Activity Area	Short Term				Medium Term				Long Term	
	Project	Description of Activities	Year	Est. Cost Nm	Project	Description of Activities	Year	Est. Cost Nm	Project	D A
Policy, legal, & regulatory framework	Legislation drafting	Draft legislation for a Solar Water Heating Obligation in the residential, commercial & institutional sectors	2005/06	10	Legislation drafting	Draft legislation for a Renewable Electricity Obligation for electricity producers & vendors	2008/15	15	Legislation drafting	t as
Policy, legal & regulatory framework	Tariff design	Design tariff structure for solar thermal and solar PV electricity	2006/07	50	Tariff design	Continue tariff design from the Short Term	2008/15	50	Tariff design	ta
Policy, legal, & regulatory framework	Legislation drafting	Draft legislation for a Fossil Fuel Levy Act to finance solar thermal & solar PV technologies market development	2006/07	50	Legislation drafting	Complete drafting & ensure passage of the Fossil Fuel Levy Act for solar thermal & solar PV technologies	2008/15	50	Legislation drafting	r
Sub-Total				110				115		

Table 4.4.H NATIONAL SOLAR ENERGY PROGRAMME (CONTD)

Activity Area	Short Term				Medium Term				Long Term	
	Project	Description of Activities	Year	Est. Cost Nm	Project	Description of Activities	Year	Est. Cost Nm	Project	D A
Policy, legal, & regulatory framework	Legislation drafting	Draft legislations and Acts on solar thermal & solar PV market incentives through relevant govt. depts. & agencies	2006/07	50	Legislation drafting	Complete drafting & ensure passage of the various legislations & Acts through the appropriate legal structures	2008/15	50	Legislation drafting	r le
Sub-Total				50				50		
Grand Total				**1240**				**2525**		

4.5 National Small Hydro Programme

GOALS AND OBJECTIVES

(i) **Conduct a National Survey for establishment of National Small Hydro Programme (SHP)**

(ii) **Assessment of Agricultural and Industrial Demand**

- Audit of domestic and industrial sectors to identify and quantity the structure of energy supply, demand utilization patterns, and efficiencies and substitution potentials for both small and large use enterprises.

(iii) **Implementation of fiscal measures**

- Ensure implementation of fiscal measures necessary for the achievement of set objectives of the plan.
- Establish linkage between SHP development and expanded access to rural electrification.

(iv) **Establishment of Codes and Standards**

- Develop Codes, Standards, regulations and guidelines on SHP development, energy conservation and use of energy efficient methods, equipment, machinery and technologies in agriculture, industry, building design and construction.

(v) **Development of Institutional Control mechanisms**

- Establish appropriate institutional arrangements and incentives for SHP development
- Establish basic engineering infrastructure for the production of hydro power plants, equipment and accessories.

(vi) **Tariff Development**

- Develop and implement appropriate tariff and pricing structures.

(vii) **Establishment of Information System**

- Organise a National SHP information system to promote and ensure consistent gathering and processing of SHP data.

(viii) **Conduct Workshops and Lectures**

- Establish a strategy for public awareness, education and participation in realization of the goals of the Master Plan.

(ix) **Development of Water Management Plan**

- Review and Improve agreements, monitoring and regulating the use of water in International Rivers flowing through the Country.

(x) **SHP Construction**

- Construct at least one SHP plant in each of the six geopolitical zones of the Country.
- Widespread construction of SHP.

(xi) **Capacity Building**

- Training of personnel on technical and financial aspects;
- Training to ensure adequate supply of manpower.

(xii) **Research and Development (R & D)**

- Design mechanism for certification, equipment standardization, renovation, improvement of equipment efficiency.

(xiii) **Private Sector Participation**

- Invite and interact with the Private Sector through program.
- Full Private Sector Participation.

Table 4.5.A NATIONAL SMALL HYDRO PROGRAMME

Short Term (2006 - 2007)					Medium Term (2008 - 2015)					
Activity Area	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**
National Survey	Establishment of National Small Hydro Potential	Complete National Survey for identification & inventory of potential SHP sites throughout the Federation. Development of a plan & schedule for SHP implementation.	2006 - 2007	18	Domestic Private Sector Participation	Contacts	Enhanced domestic participation in SHP operations.	2008 - 2010		
Assessment of Agricultural & Industrial Demand	Establishment of Agric + Industrial Demand	Audit of the domestic agricultural and industrial sectors to identify & quantify the structure of energy supply, demand, utilization patterns, efficiencies & substitution potentials, for both small & large use enterprises.	2006	6	Evaluation	-	Evaluation and review of short term activities.	2008 - 2010		
Implementation of fiscal measures	-	Ensuring implementation of fiscal measures necessary for the achievement of set objectives of the plan	2007		Rural electrification	Interactions with REB's	Establish linkage between SHP development and expanded access to rural electrification.	2008 - 2010		
Codes and Standards	Establishment of Codes and Standards	Development of codes, standards, regulations and guidelines on SHP development, energy.	2006	5						
Sub-Total				29					0	

Table 4.5.B NATIONAL SMALL HYDRO PROGRAMME (CONTD)

Short Term (2006 - 2007)					Medium Term (2008 - 2015)					L	
Activity Area	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activit y Area**	**P**
Institutional Structure	Development of Institutional Control Mechanism	Establishment of appropriate institutional arrangements and incentives for SHP development and for the promotion and monitoring of the implementation of the approved energy master plan and compliance with the guidelines and regulations.	2006		Local Production	Domestic production of SHP parts.	Establishment of basic engineering infrastructure for the production of hydropower plants equipment and accessories.	2008	200		
Power Purchase Agreements	Tariff Development	Development and Implementation of appropriate tariff and pricing structures.	2006	3							
Information System	Establishment of National SHP Information System	Organise a national SHP information system to promote and ensure consistent gathering and processing of SHP data including development pattern and progress as well as other relevant socio-economic parameters.	2006	4							
Public Aware-ness	Workshops and Lectures	Establishment of a strategy for public awareness, education and participation in the realization of the goals and objectives of the Master Plan.	2005 - 2007	10							
Domestic Private Sector Participation	-	Provide financing to support increased patronage of indigenous entrepreneurs involved in planning, design and construction of hydropower plants.	2006 - 2007	4							
Sub-Total				21					200		

Table 4.5.C NATIONAL SMALL HYDRO PROGRAMME (CONTD)

Short Term (2006 - 2007)					Medium Term (2008 - 2015)					Lo	
Activity Area	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Pr**
Water Resources Management	Water Management Plan	Review and Improvement of agreements, monitoring and regulating the use of water in international rivers flowing through the country.	2005 – 2007	4							
Pilot Schemes	SHP Construction	Construction of at least one SHP plant in each of the six geopolitical zones of the Country.	2006 – 2007	14	Additional Plant capacity	SHP Construc tion	Construction of additional SHP to meet set targets.	2008 - 2015	840	Additional Plant Capacity	SH Co on
Capacity Building	Personnel Training	Capacity building and training on technical and financial aspects of SHP developments.	2006 – 2007	30	Training	Personn el Training	Continued manpower training.	2008 - 2015	120	Training	Per Tra
Research + Development	Undertake Research + Development in relevant areas.	Design mechanism for certification. Equipment standardization, Renovation + Modernization. Improvement of equipment efficiency.	2005 – 2007	36	Research + Development			2008 - 2015	80	Research + Developme nt	
Private Sector Participation	Contacts	Invite and interact with the Private Sector through program.	2006		Private Sector Participation	-	Full private sector participation achieved.	2011			
					Evaluation	-	Evaluation and Review of Short Term Activities.	2009	4	Evaluation	
Sub-Total				84					1044		
Grand Total				**134**					**1244**		

- Small Hydro Programme
FMWR - Federal Ministry of Water Resources
ECN - Energy Commission of Nigeria
AdC - Administrative Cost
REB - Rural Electrification Board
FMST - Federal Ministry of Science and
FMF - Federal Ministry of Finance

4.6 National Wind Energy Programme

GOALS AND OBJECTIVES

Resource Assessment

(i) Comprehensive wind energy resources assessment for Nigeria
(ii) Update and expand the Nigerian Wind Atlas

(iii) Establish a Wind Technology Fund
(iv) Carry out a Feasibility study for a Hybrid Demonstration Plant

(iv) **Capacity Building**
Training and retraining Personnel on wind measurements, windfarm studies, turbine testing, wind atlas analysis and power syst

Institution-Building

(vi) **Establishment of wind test facility**
Detailed study for establishment of a wind technology centre

(vii) **Capacity Addition**
Addition of different sizes of wind plants ranging from 50MW to 500MW all through short to long term periods

Table 4.6.A NATIONAL WIND ENERGY PROGRAMME

Activity Area	Short Term				Medium Term				Long Ter
	Project	Description of Activities	Year	Est. Cost Nm	Project	Description of Activities	Year	Est. Cost Nm	Project
Data Analysis						Analysis of data from existing meteorological stations and the newly acquired data from the 36 potential sites			
						Production of a preliminary/coarse wind resource map.			New metrologi stations
Sub-Total				**150**					

Table 4.6.B NATIONAL WIND ENERGY PROGRAMME (CONTD)

Activity Area	Short Term				Medium Term				Long Term	
	Project	Description of Activities	Year	Est. Cost Nm	Project	Description of Activities	Year	Est. Cost Nm	Project	Descriptio of Activiti
Establishment of a wind test facility	Wind Technology Centre	Detailed study for the establishment of a Wind Technology Centre	2006/07	500	Continuation of short term project	Establishment of a wind test facility	2008/09		Continuation of short term project	Establishn of a wind facility
Capacity Building (Manpower Development)	Training Workshop on wind energy technology	Training of scientists, engineers and technologists on wind measurements, wind farm studies, and wind farm design	2006/07	60	Short term projects continued	Training of scientists, engineers and technologists on Turbine Testing	2008/09	100		Training o scientists, engineers technologi on wind A Analysis
Sub-Total				**560**				**100**		

Table 4.6.C NATIONAL WIND ENERGY PROGRAMME (CONTD)

Activity Area	Short Term				Medium Term				Long Term	
	Project	Description of Activities	Year	Est. Cost Nm	Project	Description of Activities	Year	Est. Cost Nm	Project	Descrip of Activiti
Establishment of a Hybrid demonstration plant	~~Hybrid Demonstration Plant~~	~~Carry out a feasibility study for a Hybrid Demonstration plant~~	~~2006/07~~	~~200~~	Hybrid Demonstration Plant	Carry out a feasibility study for a Hybrid Demonstration plant	2008/15	200		
		Establishment of 1MW Hybrid demonstration plant								
Policy Framework	Establishment of a policy framework	Formulation of a legal/legislative framework	2006/07	10	Continuation of short term project	Establishment of a Wind Technology Fund	2008/09			
Sub-Total				**210**						

Table 4.6.D NATIONAL WIND POGRAMME (CONTD)

Activity Area	Short Term				Medium Term				Long Term	
	Project	Description of Activities	Year	Est. Cost Nm	Project	Description of Activities	Year	Est. Cost Nm	Project	Description of Activities
Capacity Addition					Installation and Commissioning of Wind Power Plant	50MW capacity addition	2008	10,000	Continuation of medium term projects	250MW capacity addition
						50MW capacity addition	2009	10,000		
						50MW capacity addition	2010	10,000		250MW capacity addition
						100MW capacity addition	2011	20,000		250MW capacity addition
						150MW capacity addition	2012	30,000		250MW capacity addition
Sub-Total								**80,000**		

Table 4.6.E NATIONAL WIND ENERGY PROGRAMME (CONTD)

Activity Area	Short Term				Medium Term				Long Term	
	Project	Description of Activities	Year	Est. Cost Nm	Project	Description of Activities	Year	Est. Cost Nm	Project	Description of Activities
Capacity Addition						150MW capacity addition	2013	30,000	Continuation of medium term projects	Building of new wind power plar
						150MW capacity addition	2014	30,000		500MW capacit addition
						150MW capacity addition	2015	30,000		400MW capacit addition
Capacity Building (support infrastructure)									Manufacturing of wind plant equipment	Local manufacturing o wind turbines an other equipment for wind energy deployment in th country and possible export market in the we Africa sub regio and subsequentl other regions in Africa.
Sub-Total				**0**				**90,000**		
GRAND TOTAL				**920**				**170,100**		

4.7 Emerging Energy Research and Development Programme

GOALS AND OBJECTIVES

A. **Hydrogen Energy**

(i) Identification of appropriate Research and Development centers

(ii) Development of proposal for Hydrogen Research and Development by identified research centres and Energy Commission Of Nigeria

(iii) Inclusion of National Energy Research and Development Programme (NERDP) in 2007 Appropriation Bill

(iv) Convene a National Hydrogen Conference

(v) Involvement of Public-Private Partnership in Research and Development

(vi) Convene an International Hydrogen Conference

B. **Ocean Energy**

(i) Identification of appropriate Research and Development Centres

(ii) Development of Proposals for Ocean Energy Research and Development centres and Energy Commission of Nigeria

(iii) Inclusion of National Energy Research and Development Programme (NERDP) in 2007 Appropriation Bill

(iv) Commencement of Ocean Energy Research and Development

(v) Convene first National Ocean Energy Conference

(vi) Convene second National Ocean Energy Conference

(vii) Achievement of a locally developed Ocean Energy Technology Prototype

C. **Geothermal Energy**

(i) Identification of appropriation Research and Development Centres

(ii) Development of Proposals for Geo thermal Energy Research and Development Centres and Energy Commission of Nigeria

(iii) Inclusion of National Energy Research and Development Programme (NERDP) in 2007 Appropriation Bill

(iv) Commencement of Geothermal Energy Research and Development

(v) Convene first National Geothermal Energy Conference

(vi) Convene second National Geothermal Energy Conference

(vii) Nationwide Geothermal exploration

Table 4.7.A EMERGING ENERGY RESEARCH AND DEVELOPMENT PROGRAMME
HYDROGEN ENERGY

Short Term (2006 - 2007)					Medium Term (2008 - 2015)					Long Te	
Activity Area	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**
R&D Centres	Hydrogen Energy R&D Project	Identification of appropriate R&D centres	2006	5	Capacity-building with identified centres	Hydrogen Energy R&D Project	Training and workshop	2009	5	International cooperation on hydrogen R&D	Establishm t of internationa joint-resear on hydroge energy application
Proposal development	Hydrogen Energy R&D Project	Development of proposal for Hydrogen R&D by identified research centre(s) and Energy Commission of Nigeria	2006	2	Research and documentatio n	Hydrogen Energy R&D Project	Project seeks to review the status of knowledge on hydrogen energy worldwide	2009 - 2010	10	Hydrogen energy R&D	Developme of market application for hydroge energy in Nigeria
Appropriatio n	Hydrogen Energy R&D Project	Inclusion of NERDP in 2007 Appropriation Bill	2006			Hydrogen Energy R&D Project				Niche for marked utilisation of hydrogen in Nigeria	Market developmen for hydroge energy
Budget line	Hydrogen Energy R&D Project	Budget line for NERDP R&D	2007			Hydrogen Energy R&D Project					
Commencem ent of research	Hydrogen Energy R&D Project	Commencement of Hydrogen R&D research	2007	10	National Hydrogen Conference	Hydrogen Energy R&D Project	Convene a National Hydrogen Conference	2012	5		
					Public-private partnership in R&D	Hydrogen Energy R&D Project	Ensuring that Public-private partnership in R&D is achieved	2015	10		
					International Hydrogen Conference	Hydrogen Energy R&D Project	Convene an International Hydrogen Conference	2015	10		
Sub-total				17					40		

Table 4.7.B EMERGING RESEARCH AND DEVELOPMENT PROGRAMME

OCEAN ENERGY

Short Term (2006 - 2007)					Medium Term (2008 - 2015)					Long Te	
Activity Area	Project	Description of Activities	Year	Est. Cost Nm	Activity Area	Project	Description of Activities	Year	Est. Cost Nm	Activity Area	Project
R&D Centres	Ocean Energy R&D Project	Identification of appropriate R&D centres	2006	5	Capacity-building with identified centres	Ocean Energy R&D Project	Training and workshop	2009	5	International cooperation on Ocean R&D	Establishmen t of international joint-research on Ocean energy applications
Proposal development	Ocean Energy R&D Project	Development of proposal for Ocean R&D by identified research centre(s) and Energy Commission of Nigeria	2006	2	Research and documentation	Ocean Energy R&D Project	Project seeks to review the status of knowledge on Ocean energy worldwide	2009 - 2010	10	Ocean energy R&D	Developmen of market applications for Ocean energy in Nigeria
Appropriation	Ocean Energy R&D Project	Inclusion of NERDP in 2007 Appropriation Bill	2006			Ocean Energy R&D Project				Niche for marked utilisation of Ocean in Nigeria	Market development for Ocean energy
Budget line	Ocean Energy R&D Project	Budget line for NERDP R&D	2007			Ocean Energy R&D Project					
Commencement of research	Ocean Energy R&D Project	Commencement of Ocean R&D research	2007	10	National Ocean Conference	Ocean Energy R&D Project	Convene a National Ocean Conference	2012	5		
					Public-private partnership in R&D	Ocean Energy R&D Project	Ensuring that Public-private partnership in R&D is achieved	2015	10		
					International Ocean Conference	Ocean Energy R&D Project	Convene an International Ocean Conference	2015	10		
Sub-Total				17					40		

Table 4.7.C EMERGING RESEARCH AND DEVELOPMENT PROGRAMME
GEOTHERMAL ENERGY

Short Term (2006 - 2007)					Medium Term (2008 - 2015)					Long T	
Activity Area	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Project**	**Description of Activities**	**Year**	**Est. Cost Nm**	**Activity Area**	**Proje**
R&D Centres	Geothermal Energy R&D Project	Identification of appropriate R&D centres	2006	5	Capacity-building with identified centres	Geothermal Energy R&D Project	Training and workshop	2009	5	International cooperation on Geothermal R&D	Establishr of interna joint-resea on Geothe energy applicatio
Proposal development	Geothermal Energy R&D Project	Development of proposal for Geothermal R&D by identified research centre(s) and Energy Commission of Nigeria	2006	2	Research and documentation	Geothermal Energy R&D Project	Project seeks to review the status of knowledge on Geothermal energy worldwide	2009 -2010	10	Geothermal energy R&D	Developm of market applicatio for Geoth energy in Nigeria
Appropriation	Geothermal Energy R&D Project	Inclusion of NERDP in 2007 Appropriation Bill	2006			Geothermal Energy R&D Project				Niche for marked utilisation of Geothermal in Nigeria	Market developm for Geoth energy
Budget line	Geothermal Energy R&D Project	Budget line for NERDP R&D	2007			Geothermal Energy R&D Project					
Commencement of research	Geothermal Energy R&D Project	Commencement of Geothermal R&D research	2007	10	National Geothermal Conference	Geothermal Energy R&D Project	Convene a National Geothermal Conference	2012	5		
					Public-private partnership in R&D	Geothermal Energy R&D Project	Ensuring that Public-private partnership in R&D is achieved	2015	10		
					International Geothermal Conference	Geothermal Energy R&D Project	Convene an International Geothermal Conference	2015	10		
Sub-Total				**17**					**40**		
Grand Total				**51**					**120**		

A breakdown of the total required investment for all the programmes outlined in the Master Plan follows.

4.8 Programme Budget

Meeting the targets of the Renewable Energy Master Plan will demand significant investments in renewable energy systems. Table 1.6 presents an overview of estimated costs for these investments for all activities outlined in chapter four of the Master Plan.

Table 4.8: Projected Investment Summary

S/No.	**Programmes and Activities**	**ST (Nm)**	**MT (Nm)**	**LT (Nm)**	**Total (Nm)**
FRAMEWORK PROGRAMME FOR RENEWABLE ENERGY PROMOTION					
	Activity				
1	Policy, legal and regulatory framework	0	90	32	122
2	Institutional framework	0	0	0	0
3	Economics and Financing	0	70	20	90
4	Capacity Building	100	100	100	300
5	Public Awareness	10	100	100	210
6	Inter-Agency Collaboration	10	10	10	30
7	Research and Development	50	50	50	150
8	Monitoring and Evaluation	0	10	10	20
	Sub-Total	**170**	**430**	**322**	**922**
	BIOMASS				
1	Data Acquisition	200	100	100	400
2	Capacity Building: Manpower	1082	2246	6,978	10,306
3	Market Development and Promotion	271	315	290	876
4	Site Identification	30	90	90	210
5	Technology Assessment & Review	10	10	15	35
6	Biogas Technology/Diffussion Programme	60	120	180	360
7	Intensive Plantation of fast growing trees	100	300	600	1000
8	Capacity Building	40	50	3100	3190
	Sub-Total	**1,793**	**3,231**	**11,353**	**16,377**
	SOLAR				
1	Data Acquisition	40	80	100	220
2	Capacity Building: Manpower	60	240	260	560
3	Capacity Building : Manufacturing and Production	10	100	100	210
4	Capacity Building; Support Infrastructure	100	500	800	1400
5	Market Development and Promotion	650	1100	1100	2850
6	Research and Development Framework	50	100	200	350
7	International, Regional and Inter-Agency Cooperation	10	50	100	160
8	Public Awareness	10	10	50	70
9	Policy, legal, & regulatory framework	310	345	500	1155
	Sub-Total	**1240**	**2525**	**3210**	**6975**

SMALL HYDRO

S/No.	Activity	ST (Nm)	MT (Nm)	LT (Nm)	TOTAL (Nm)
1	National Survey	18	0	0	18
2	Assessment of Agricultural & Industrial Demand	6	0	0	6
3	Implementation of Fiscal measures	0	0	0	0
4	Codes and Standards	5	0	0	5
5	Institutional Structure	0	200	0	200
6	Power Purchase Agreement	3	0	0	3
7	Information System	4	0	0	4
8	Public Awareness	10	0	0	10
9	Domestic, Private Sector Participation	4	0	0	4
10	Water Resource Management	4	0	0	4
11	Pilot Schemes	14	840	1,500	2,354
12	Capacity Building	30	120	120	270
13	Research and Development	36	80	100	216
14	Private Sector Participation	0	4	6	10
	Sub-Total	**134**	**1244**	**1,726**	**3,104**
	WIND				
1	Data Acquisition	150	100	140	390
2	Data Analysis	0	0	200	200
3	Establishment of a wind test facility	500	0	100	600
4	Capacity Building: Manpower	60	100	0	160
5	Establishment of a Hybrid Demonstration Plant	200	0	0	200
6	Policy Framework	10	0	0	10
7	Capacity Addition	0	170,000	380,200	550,200
8	Capacity Building; Support Infrastructure	0	0	30,000	30,000
	Sub-Total	**920**	**170,200**	**410,640**	**581,760**
	NEW ENERGY RESEARCH & DEVELOPMENT PROGRAMME **A. Hydrogen Energy**				
1	Research and Development Centres	5	5	50	60
2	Proposal Development	2	10	50	62
3	Appropriation	0	0	30	30
4	Budget Line	0	0	0	0
5	Commencement of Research	10	25	0	35
	Sub-Total	**17**	**40**	**130**	**187**
	B. Ocean Energy				
1	Research and Development Centres	5	5	50	60
2	Proposal Development	2	10	50	62
3	Appropriation	0	0	30	30
4	Budget Line	0	0	0	0
5	Commencement of Research	10	25	0	35
	Sub-Total	**17**	**40**	**130**	**187**

	C. Geothermal Energy				
1	Research and Development Centres	5	5	50	60
2	Proposal Development	2	10	50	62
3	Appropriation	0	0	30	30
4	Budget Line	0	0	0	0
5	Commencement of Research	10	25	0	35
	Sub-Total	**17**	**40**	**130**	**187**
	GRAND TOTAL	**4,308**	**177,750**	**427,641**	**609,699**

Implementing the REMP will demand an estimated investment portfolio of 4billion, 178billion and 610billion Naira, in the short (2005 – 2007), medium (2008 – 2015) and long term (2016 – 2025), respectively.

Financing these investments will depend on the mobilization of resources from Governments at all levels, the domestic private sector and international sources. International investments will include Foreign Director Investments, Grants and projected revenues from carbon credits.

Chapter 5: Strategy and Implementation Issues

To realize the objectives and achieve the targets and milestones set out in the REMP, clear strategies and implementation issues will be addressed. The following is an overview of key strategies and implementation issues:

5.1 Policy, Legal and Regulatory Framework

As the nation faces the challenges of ensuring the availability of easily sourced and competitively priced energy supply, it is incumbent on Government to create the appropriate policy framework of legal, fiscal and regulatory instruments that would attract domestic and international investments. Such framework will involve actions that all stakeholders must take to in order to achieve a sustainable energy future in which renewable energies play an important role.

Clear rules, legislation, roles and responsibilities of various stakeholders along every stage of the energy flow from supply to end use sector are key elements of the overall policy framework needed to promote renewable energy technologies. Given the breath of the policy space, no single policy instrument is appropriate for every application or renewable energy technologies or socio-political conditions. Hence, a mix of appropriate and effective policy instruments are proposed.

5.1.1 Creating a Level Playing Field

A key priority policy objective is to transform energy market so that it can function efficiently and effectively. In achieving this objective it is important to create a level playing field in the energy market by adequately addressing the present market distortions and giving incentives to market operators for the introduction of RE systems and encouraging consumers to have access to RE products. Without addressing these concerns it will be impossible for renewable energy technologies to compete.

5.1.2 Renewable Portfolio Standard (RPS)

Beyond creating a level playing field, another key element of the overall framework is the setting of firm and realistic portfolio standards for renewable energies. Portfolio standards refer to minimum targets of renewable energy contents of the overall energy supply to specific areas. Essentially, a policy should be put in place that will require that a certain percentage of annual electricity and thermal energy use in the country comes from renewable energy. Such a portfolio will be all inclusive for all renewable energy forms in the country. It will set the minimum requirement of renewable energy in the overall energy mix in the country as well as the target quantity and year of entry into the energy mix. It will also include the target quantity and target year of each specific renewable energy form in the overall renewable energy requirement. In many cases, regulatory instruments, including legislation are often used to achieve the targets.

5.1.3 Fiscal Incentives

Another element of the policy framework is the creation of innovative incentives to encourage the renewable energy technology supply companies at the initial stage. A preferential policy of customs duty exemption for imported components of renewable energies will enhance their penetration into the national energy equation. Other most commonly applied incentives that may be necessary include tax credits, capital incentives (investment assistance in the form of grants and allowances, and operational cost grants), and long term preferential loans. Tax credits are given as exemptions, reductions, or accelerated depreciation. They can be used to reduce the investment costs of renewables and attract investors. Deductions of income tax and of profit tax for corporations and higher write-off possibilities in the initial years for investors or users (accelerated depreciation allowance) have in many countries proved to be powerful means to stimulate the use of renewables.

Capital incentives are given, for example in the form of investment grants, for the purchase and installation of renewable energy systems. Direct investment grants are of particular importance when the technology to be assisted is still far away from being competitive, since other financial assistance such as loans and tax breaks by and large cannot sufficiently guarantee an economical operation. Direct grants offer the advantage that they directly increase the investor's liquidity, and even small amounts often act as an important psychological incentive for investment. Their disadvantage however is that the grants are paid out regardless of the performance or extent to which the installation operates.

Government strategy to provide incentives should not be limited to the supplier of the RET. To further encourage rapid dissemination of renewable energies, government strategy should also extend to provision of subsidies to the first cost or the investment cost to the end-user of the RET. This will enhance overall access to energy to a larger population of the poor in the society. Micro finance schemes are particularly useful vehicles to deliver such support.

Any capital incentive policy should follow pre-established rules that are clear and transparent to all parties, and provide incentives for cost minimization. In addition, incentives should be temporary, with clear phase-out scheme. Incentives for renewable energy should be spread out over time in order to facilitate planning for producers and investors; the assistance should be dependable, with short processing time. Introduction of elements of competition into the financial support system prepares the producers of RET plants better for the market (e.g. the British Non-Fossil Fuel Obligation); and incentives should be reviewed on an ongoing basis to determine their impact and efficiency of use of funds.

5.1.4 Market Incentives

With firm targets for renewable energy entry into the national energy mix established, the stage is set for a market to develop. However, the major obstacle of renewable energy development globally is creating a market for a product that is not yet cost-competitive. Hence, this calls for highly innovative incentive policies. This obstacle is being addressed in many countries through government-led initiatives and entrepreneurial response. Some of these initiatives include fixed price or fixed payment system and fixed capacity or fixed quantity target pursued by competitive mechanisms. payment system and fixed capacity or fixed quantity target pursued by competitive mechanisms.

The fixed price approach is often based on guaranteeing the renewable based power producers a fixed price that takes care of the generation cost, loan repayment, interest and a reasonable profit. International bench-marking helps ensure that prices are not too high. This approach, which is being practiced in Germany and Denmark, is non-competitive but easy to administer, and encourages a large amount of development and local ownership particularly under a deregulated electric power regime.

The generous feature of this approach is that it is usually for a limited time as prices are subject to review and are typically phased down as the renewable sector gains economic strength through cumulative projects.

The bidding for contracts in the fixed quantity/competitive bidding approach may be based on price per kWh, or on the amount of capital grant required. This approach which is being practiced in the UK, often results in the lowest prices for renewable energy based generated electricity and thus the lowest initial unit investment. Although, competitive approaches differ in detail, they have a common factor which is that, fewer renewable energy development projects come to fruition than is the case with fixed payment systems.

Systems of competitive bidding for license areas or concessions, which has long been in use in the petroleum industry, or in rural electrification programmes in countries such as Chile can help to accelerate market development for renewable energy. The concessionary approach refers to the prior delineation of license areas big enough to support very large wind power or small hydro plant. Its major advantage is that, it enables the government in an orderly way to match invitations for large projects with declared national targets for power supply. By this, the government could plan and create a succession of very large power plants, the size of which could justify transmission over long distances from under-populated areas to areas where appreciable market exists. It also allows the government to determine the scale of the projects and the speed of their deployment.

In the near and medium term of this Master Plan, it is proposed that the government adopts the fixed price or fixed payment approach due to its advantages which will most likely enhance access to renewable energy. Furthermore, the prices are still subject to review especially as the renewable energies gain economic strength through cumulative RE projects. In the long term, market franchise and free market system may be adopted.

5.1.5 Power Purchase Agreement

Developers of RE based electricity projects e.g. wind farms or solar PV need to sell the generated electricity to electric utilities. Since most of the RE generated electricity is yet to be cost competitive with the fossil-fuel generated electricity, selling price will have to be carefully considered. That is because the RE based electricity developer will desire a price that will cover the production cost as well as some profit. At the same time, because the electric utility has the options of getting electricity from more cost-effective energy sources, it might not find it economically reasonable to buy from RE based producers at a higher price.

Hence, the Power Purchase Agreement (PPA) is an important arrangement that needs to be put in place. This will allow the responsibilities and rights of the electric utility and RE based producers to be clearly stated and agreed upon. The PPA sets the terms by which power is marketed and/or exchanged. It determines the delivery location, power characteristics, price, quality, schedule, and terms of agreement and penalties for breach of contract. Legally, binding long-term PPAs are a must as they provide comfort to the developers as well as lenders, and would also encourage the expansion of renewable electricity development in the country. Hence, a model PPA that would be generally applicable and acceptable to all stakeholders needs to be developed.

There are two major institutional barriers to creating PPA. First, the utility grid/distributor holds substantial market power over small scale RE based producers. While the utility grid has many potential alternative sources of power, the wind energy producer is solely dependent on the grid for its market. There is therefore little incentive for the distributor to enter into negotiations in good faith, and there is even no incentive for the distributor to recognize the externalities from RE based production and thereby agree to pay a price higher than the avoided cost of power of equal value to its system from the least-cost alternative source. This can be resolved by using the Renewable Portfolio Standard earlier on discussed.

Second, negotiations over terms are exceedingly complex and expensive and the expense itself is a barrier to even initiating an effort to establish a RE based energy project. However, this problem can be reduced by establishing a PPA that is subject to specific adjustments under specific conditions. For instance, since the major difficulty in developing a PPA is to determine the price at which power is to be transferred, then it is best to make a clear regulation about the nationwide unified price for RE based power.

PPA is practiced in a well deregulated electricity market. Since Nigeria is already going into a deregulated electricity market, PPA will of necessity be an important component for the system operators. This has been taken into consideration by making it one aspect of the proposed electricity reform bill. It is hoped that in the implementation of its provision that some of the issues raised above will be taken into consideration.

5.1.6 Integration of RE into non-Energy Sector Policies

Activities in the energy sector affect those in the other sectors because energy is an input into all economic activities. Similarly, policies in other sectors affect energy demand and supply. In order to achieve the overall developmental objectives, it is important to implement coherent and integrated policies. In particular it is imperative to incorporate renewable energy policies into non-energy sector policies. The key areas are in rural development including rural electrification, poverty alleviation, agriculture, transport, industry and infrastructural development. For example, government should encourage every housing unit to incorporate solar energy systems in their designs.

5.2 Institutional Framework

In Nigeria, the present coordination between government ministries, parastatals and agencies responsible for rural development and renewable energy development is weak and rather complex. Unlike oil and gas, no agency has a clear mandate to oversee the development of renewable. Against this background, a new initiative is required which should promote renewable energy in the country, and at the same time encourage efficiency in the provision and use of all types of energy form; raise the quality of management and training in energy provision and use; heighten public awareness of energy-related issues; encourage local institutional reforms to help meet policy goals; reduce environmental problems.

5.2.1 Establishment of Nigeria RE Development Agency

There are a few ministries and government agencies whose roles and responsibilities affect renewable energy technologies. The Energy Commission of Nigeria which is under the Federal Ministry of Science and Technology has as one of its mandate the responsibility for strategic energy planning policy coordination and performance, monitoring of the entire energy sector, laying down guidelines on the utilization of energy types for specific purposes, developing recommendations on the exploitation of a new source of energy. Renewable energy is therefore a key component of this mandate. The Commission does not have an implementation mandate. Under the supervision of the Commission we have two renewable energy centres located at Sokoto and Nsukka with the mandate for research and development for renewable energy. Without doubt there is a need to strengthen the existing national renewable energy centers in terms of adequate funding for Research and Development (R&D). In addition the ECN as the apex energy coordinating agency should be reinforced.

There are other agencies that have significant renewable energy components in their programmes; such as Nigerian Metrological Services (NIMET), Nigerian Building and Road Research Institute (NBRRI), Project Development Institute (PRODA), Federal Institute of Industrial Research Oshodi (FIIRO), Federal Ministry of Environment, Federal Ministry of Science and Technology, Federal Ministry of Power and Steel, and a few Universities and Polytechnics.

In spite of the above mentioned agencies, there is inadequate institutional capacity, and lack of effective inter-sectoral communication and co-ordination to promote renewable energy use in the country. The creation of a Nigerian Renewable Energy Agency will go along way to address the institutional issues enumerated above. With time the Agency can grow into a full Ministry of Non-Conventional Energy as is the case in some developing countries like India. In addition the other levels of government (State and Local) should also be encouraged to set up units which will plan, manage and implement renewables energy systems. For effectiveness there should be coordination between the federal, state and local government levels to avoid duplication of efforts and to learn from each other’s experience and promote rapid proliferation of success stories.

5.2.2 Standardization of RE Products

Industry standards and permits can prevent inferior hardware from getting into the marketplace and eroding investor and customer confidence, while also addressing potential sources of opposition such as noise and visual impact (applicable to wind farms and solar thermal on rooftops). Therefore, Standard Organization of Nigeria (SON) should establish RE standards in collaboration with relevant research institutes which can be designated as RE Technology Centres, and relevant stakeholders. In addition, such test centres will gather data on performance of the deployed RET so that their suitability to local conditions is known. Such information will be necessary when planning to adapt imported technology to suit local conditions.

5.2.3 Encouraging the emergence of RE Professional/Industry Associations

In many countries the emergence of professional and industry association has been a key driving force for the promotion of renewable energy technologies. In Nigeria only one of such professional body exists - the Solar Energy Society of Nigeria. Other professional associations for wind energy, small hydro or biomass will be useful. In addition the setting up of trade /industry associations will certainly help provide pressure/advocacy group which will develop the renewable energy industry. For instance, the establishment of the Nigerian Wind Energy Association (NIWEA) will create a forum for the emerging wind energy industry group to interact with other similar existing associations on wind energy both on the regional and national levels such the European Wind Energy Association (EWEA), Indian Wind Energy Association (INWEA). The trade association provides another forum for exchange of ideas and discussion on common problems facing the industry.

5.3 Economics and Financing

Even though they have low O&M costs, most RETs have high up-front capital cost compared to their conventional energy alternatives. Apart from the higher capital costs most RET face the barrier of being perceived as untested technologies. Given these twin barriers to RET, investors face higher risks and uncertainties when making investment decisions. Therefore in a capital constrained economy like Nigeria, where there are many competing demands for available scarce capital resources, the promoters of RET face the problems of high transaction costs and restricted access to capital.

The RET also faces some economic barriers from the end users, especially the poor. Given the low income and therefore limited purchasing power of the poor, the big challenge is to find ways to empower the poor to pay upfront costs of new RETs. Therefore, new and innovative financial tools and measures are needed to address this barrier.

5.3.1 Suspension of RE Import Duties

Most RET are imported e.g. solar PV, wind turbines, and will still be imported in the near future. The current import duty tariffs on their components are high, thereby contributing to high capital cost. As a cost reduction strategy it is proposed that government should impose zero import duties and taxes on RET in the near and medium term. The implementation of this strategy has to be monitored very closely to avoid unscrupulous business men from taking undue advantage of this tariff waiver by fraudulently reclassifying other imported goods as RET.

In the long term, cost reduction strategy will revolve around having a substantial local manufacturing capability and efficient production system. This can only happen if the nation embarks on a comprehensive capacity development initiative and R&D programme.

5.3.2 Establishment of a Renewable Energy Fund (RE-Fund)

In order to implement various incentives, initiatives and programmes that will promote the adoption of RET, it is proposed that a RE Fund be created by government. The funds will provide resources for providing incentives, micro-credit schemes, training, R&D, building up rapidly the initial market volume, local expertise, user awareness, appropriate technology adaptation, quality standards and entrepreneurial activities. One major sustainable source of financial resources for the Fund is to impose a 0.1% of money accruing from export crude. The Fund is to be managed by the proposed National Renewable Energy Agency (NREA).With time, there should be a shift from capital based to production based incentives.

5.3.3 Funds from Multilateral and Donor Communities

Multilateral organizations such as the World Bank, UN, International Finance Corporation, African Development Bank, fund renewable energy projects. In particular the Global Environment Facility (GEF) has a strong portfolio of renewable energy projects. For instance, GEF has funded many PV projects all over the world. Within the Kyoto protocol of the United Nations Framework Convention on Climate Change (UNFCCC) the Clean Development Mechanism (CDM) is also a source of funds for RET. Unfortunately while many developing countries have benefited from these global initiatives, Nigeria is yet to fully participate. There is therefore the need to strengthen the focal points for GEF and UNFCCC in Nigeria so the country may submit project proposals for funding. It is imperative that Government makes contacts, cooperates or enters into global partnerships with these agencies for needed support and funding.

5.3.4 Innovative Credit Schemes

One of the major challenges of poverty reduction is how to increase energy services to the poor, especially in the rural areas. The poor in rural areas have limited ability to pay the high upfront cost of energy systems. Demand load in such poor and remote areas are usually very low. Hence, rural energy supply enterprises face a high-risk, low margin, low volume and high transaction costs. Historically, affordability of rural energy has been addressed through government subsidies, donor programmes and private cash sales of small systems. However the weight of evidence in Nigeria as in many developing countries shows that this model has not brought about the required increase in access to modern energy for sustainable development.

This is a major drawback for RET because of high up-front capital cost. Converting high up front payment to streams of small payments over along time is a possible strategy to overcome this problem of high initial cost. This will entail granting of credits, which cannot be done effectively without a developed, and supporting financial system. Therefore credit risk is a major issue. Even when the credit issue can be surmounted, it is important that energy services are used to generate income. If the rural poor demand energy services only for lighting, listening to radio or watching TV, rural households will not have sufficient income to pay for the energy services on a sustainable basis. This approach will end up “lighting up poverty”. Beyond micro credit and income generation, other approaches include: vendor-supplied credit, leasing, cooperatives, and rental models.

Mainstreaming and integrating energy projects into non-energy sectors such as water supply, sanitation, health, cottage industry and education will also ensure the effectiveness of promoting renewable energy utilization for development. Avoiding stand alone renewable energy projects in the rural area is the beginning of wisdom in tackling the lack of energy access and poverty nexus in the rural setting.

5.3.5 Creating an Enabling Investment Climate

The investment needed for RE development cannot be provided by government sources alone. In any case given the drive towards reforms that emphasizes liberalization, privatization and restructuring, private sector (local and foreign) investments will be needed. Therefore the creation of enabling environment conducive to investment will have to be put in place. Also adequate provision of infrastructural facilities should be provided to reduce the cost of doing business in the country.

Related to this is the need to involve the local financial sector in RE development. This will certainly entail awareness and capacity development for operators in the financial sectors. In addition, the scope of ventures capital financing (e.g. National Risk Fund PLC) should be expanded to include investing in emerging RET.

5.4 Capacity Building

Human and institutional capacity building at all levels is required to sustain the scientific, engineering and technical skills relevant for the design, development, fabrication, installation and maintenance of RETs. In particular, capacity building in four areas are most essential, namely; training of manpower to install, operate and maintain RETs, development of manufacturing capabilities, development of critical mass of scientists, engineers, economists etc. for R&D, and design and effective functioning of institutional framework.

A comprehensive training programme including training the trainers, vocational training, short courses, and workshops will be designed and implemented in the various geographical zones of the country. This will involve creating training and extension centres in the country. The breadth of the training programme must recognize the multidisciplinary nature of RE, and therefore there must be conscious efforts to include training not only for engineers and technicians but also for other disciplines especially social sciences and law. One effective way of developing capacity is to build training components in to all donor funded demonstration projects.

The educational system has a major role to play in the overall capacity building. Hence RE energy education should be integrated as part of the syllabus of secondary and tertiary levels. Capturing the interest and attention of young people is also a vital stimulant to the acceptance of the RE technologies involved. Another way of doing this is the introduction of RE technologies both for electricity and thermal use in the energy mix of both secondary and tertiary institutions.

5.5 Public Awareness

Awareness of the opportunities offered by renewable energies and their technologies is low among public and private sector stakeholders. This lack of information and awareness creates a market distortion that results in higher risk perception for potential renewable energy projects. The general perception is that RET 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.

There is therefore a need for dissemination of information on RE resource availability, benefits and opportunity to the general public in order to raise public awareness and generate activities in the sector. Such process is key to building public confidence and acceptance of RET. Providing information to selected stakeholder groups like the investors can help mobilize financial resources needed to promote RET projects.

The proposed NREDA and non-governmental organizations (NGOs) can assist in increasing public awareness through the following strategies:

- Information brochures on dissemination of renewable energy systems
- Mass media coverage of pilot projects.
- Aggressive country-wide effort campaign approach on the dissemination and implementation of RE systems.
- Enlightenment campaign by NGOs and environmental managers.
- Sponsored documentaries, programs, adverts, billboards, etc. in the electronic and print media.
- Using opinion molders as vehicles for dissemination of RE technologies/systems.
- Using Website to disseminate information.

5.6 Inter-Agency Collaboration (including public-private partnership)

As already discussed, the present coordination between the government ministries, parastatals and agencies responsible for rural development and renewable energy development is weak and rather complex. The current governance structure suffers from the responsibility for renewable energy development not being clearly assigned to a single government institution as is the case with oil and gas. A National Renewable Energy Development Agency has been suggested as an implementing Agency, while the Energy Commission of Nigeria will retain her responsibility as the apex policy formulation and monitoring body.

There should be an inter-agency forum to harmonize and coordinate the activities of the various units not only at the Federal but also at the States and local government level. One such forum is the Technical Committee of the Energy Commission of Nigeria which has representatives from many Ministries, parastatals and professional bodies. Empowering such a committee to be more functional will certainly allow for cooperation and coordination of policies and programmes.. The Technical Committee could be expanded to include states and local government representatives.

Another kind of coordination that is necessary is between public and private sectors. First, it is important to engage the private sector in production, marketing and adoption of renewable energy technologies, creating a market environment where companies innovate, compete and ultimately profit from these investments. Second, private sector participation and ownership in the renewables development process increase political support and the likelihood of success. There is therefore the need to harmonise the roles of the public and private sector. Market facilitation organizations which are public-private entities that support market growth through networking, partner matching, information dissemination, market research, user education, business-deal identification and facilitation, technical assistance, consulting services, financing, and policy advocacy or advice (e.g. Winrock International) are necessary to support the development of Renewable Energy in the country.

Moreover, great demand exists for international cooperation, experience exchange, coordination of programmes, technology transfer, and collaboration with donor and financing organizations and institutions. Action at the national level must be supplemented at the bilateral, multilateral, and regional levels (research, joint ventures, joint projects, etc.). Such international collaboration and cooperation often leads to transferring knowledge and to developing local skills for producing and deploying components of and entire renewable energy systems.

5.7 Research and Development

The past three decades have seen the development and maturing of RET. This process has been possible largely through extensive global programs of research, development, demonstration, (R,D&D) and financial incentives most especially in the developed countries. If Nigeria is to optimally benefit from the application of RET it must have a credible R&D infrastructure for adapting and modifying imported RET to local conditions, set a stage for innovation and local manufacturing of RET, derive applicable business models, and appropriate policies. R&D is also needed to address the social and cultural dimensions of deploying RET to secure their contribution to sustainable and participatory development.

Designing and ensuring the success of RET R&D programmes will require the articulation of near-term as well as long-term goals and targets.

5.7.1 Funding of Research

Government needs to make adequate funds available to the two Energy Research Centres on renewable energy in the country as well as other individuals and research groups in institutions of higher learning involved in similar research work. A substantial part of the money that comes into the proposed Renewable Energy Fund should be channeled into R, D & D.

5.7.2 Collaborative Research between Industry and Academia

The synergy of both private sectors initiated and supported R & D and public sector funded R & D cannot be overstated in any sector. Therefore targeted industry-academic research collaboration programs should be encouraged with financing from the private sector. Another type of collaborative efforts involving joint projects between local researchers and their counterparts in other sub-regions and internationally will help to sharpen the local researcher's skills to the benefit of local industry.

5.7.3 Commercialization of R&D Output

Research and development should be accompanied by preparation for commercialization so that successful projects can rapidly be put to practical use. Research is not an end in itself. The purpose of R&D is to produce technologies for practical use. The final stage of a successful R&D programme is commercialization, the movement of a functioning technology into the marketplace. As scientific and technical advances are made, economic and institutional barriers to commercialization should also be addressed, so that if technical success is achieved in R&D programmes, commercialization can take place rapidly.

5.8 Monitoring and Evaluation

Effective monitoring and evaluation is crucial to realizing the objectives and targets of the REMP. This will provide tools to measure progress against set milestones and provide opportunities to review strategies It is therefore essential that a formal monitoring and evaluation strategy be put in place to ensure the success of the implementation of the REMP.

5.8.1 Establishment of National Steering Committee and State Coordinating Units

To continuously provide monitoring and evaluation of the programmes under this master plan, a National Steering Committee (NSC) representing key stakeholders will be constituted. The NSC will ensure that programme are focused, that milestones are reached and that the overall objectives are attained. It is proposed that the Energy Commission of Nigeria (ECN) serve as the secretariat of NSC and charged with the responsibility of consolidating work programmes and budgets.

For effective monitoring of individual projects in their States a coordination unit (CU) should be established in each state. The NSC will oversee the work of the CU and evaluate, consolidate, and harmonize the reports coming from the different CUs. An annual workshop should be held to consider progress made and disseminate lessons learnt to the wider public.

Chapter 6: Risk Identification and Analysis

Several factors will challenge the successful implementation of planned activities and milestones and may jeopardize the realization of the targets and objectives of the REMP. These potential risk factors include policy and political changes, uncertainties in the energy market, instability in the macroeconomic framework, international shocks, operational risk (inadequate public awareness, human resources and raw materials availability) and risks associated with neglect of infrastructure.

Identification and analysis of these risks will allow stakeholders in the renewable energy economy to factor in these risks, or seek alternative approaches to reaching national renewable energy targets and objectives.

6.1 Policy and Political Risks

Several policy and political risks confront the renewable energy sector. These risks include the following:

- *Outlined policies not adopted.* Sound policies elaborately developed by government might at the end of the day not be adopted, and when adopted may not be implemented to significant levels. Several policy documents, including Vision 2010, several Rolling Plans and the recent NEEDS and SEEDS documents have reserved key roles for renewable energy. Such policy attention may not necessarily translate into tangible changes in actions of government. Strategies in addressing such implementation risks include the setting of realistic targets, identification of make-or-break implementation issues, outlining concrete activities to address risks and proactively securing the political will to reach agreed targets.

  The proposed RE bill which is currently before the National Assembly should be passed in to law in order to overcome some of these problems.

- *Policy inconsistency, instability and contending interests within Government.* A certain risk will prevail when elements of the REMP are not properly aligned to the overall economic policy thrust of the government or are at cross-purposes to some broader energy policy objectives. This may result in policy inconsistencies and poor performance of the Master Plan. Inconsistencies may also result with frequent changes in policy thrusts, for instance in trade policies. Endemically unpredictable, particularly in the application of tariffs and exemptions, transaction costs at ports, customs clearance procedures, and the use of import bans on goods, merchandize, products, equipment and production machinery; tariff and non-tariff barriers poses great risk on investment in RE.

  When government is irresolute as a result of poor planning or pressure from contending interests, the overall objectives of the Master Plan may be compromised. To address these risks, it is not enough to design rational and ambitious plans, meeting the concerns and interests of all relevant stakeholders is important in reducing potential conflicts and inertia. Greater chances of success will be achieved when key stakeholders participate fully, and where implementation agencies are properly equipped.

- *Risk of policy implementation short sightedness.* A certain degree of policy short sightedness characterizes the implementation of policies of the country. Even when energy policy documents encourage long term planning, few concrete actions are taken to build the groundwork for meeting future security, economic, social and environmental challenges. The large income from finite hydrocarbons and present abundance of conventional energy resources may becloud the future challenges of a growing population and declining resource base. Accelerated energy policy reforms where pricing increasingly reflect the opportunity cost of resource use will stimulate conservation and a price regime that encourages investments in renewables.

- *Lack of continuity in government policies.* The present government has embarked on several reforms leading to increased liberalization of the energy market, and potentially creating opportunities for renewable energy to make increased market entry. Uncertainties loom over the policy direction of the government that will succeed the present one. In an atmosphere where continuity of policy is often lacking, the risk of a new government discarding prevailing reforms is real. Accelerating the pace of implementation of the REMP and rapidly institutionalizing its activities will assist in entrenching the key activities and achieving its objectives.

- *Socio-cultural conflicts.* Local conflicts and trade disputes often interrupt supply of some RE resources and end products. Restive youths and armed bandits, long-drawn trade disputes, electoral malpractices and endless election petitions – all create a political atmosphere that is not supportive of investments, including potential renewable energy businesses.

6.2 Market Risks

Price distortions, poor regulatory environment and inadequate infrastructure characterize current energy market conditions in the country. This has reduced the scope for competition, growth and innovation in the market. Such market conditions create a disincentive for market entry for mature RE technologies such as solar photovoltaic, small scale hydro and wind power; and make hydrogen, ocean and geothermal energy systems prohibitive.

The energy market in Nigeria is on the verge of vital reforms. These include the power sector reform, solid minerals, oil and gas and specific initiatives on renewable energy. The outcome of these converging agenda will introduce a more vibrant energy market that will stimulate growth, build infrastructure, increase competition and create a basis for investments in tomorrow's energy systems. The innovations that will follow will be important in reducing market constraints for RE systems.

However, growing the renewable energy sector will depend on a stable macroeconomic framework. Already the NEEDS outlined a number of risks that are inherent in the Nigerian economy, and they include:

- high cost of doing business in Nigeria which constrains investment and industrial production;
- weak infrastructure; poorly implemented incentives, especially fiscal and tariff regimes;
- massive smuggling, counterfeiting, and dumping of products;
- lack of standardization required for international competitiveness;
- unfavourable international trade rules;
- national trade policy stance which is endemically unpredictable, particularly in the application of tariffs and exemptions, transaction costs at ports, customs clearance procedures, and the use of import bans on goods, merchandize, products, equipment and production machinery;
- tariff and non-tariff barriers which on the average exceed those of other ECOWAS countries;
- corruption and public sector mismanagement of policy programmes and projects;
- excessively high percentage of the population in the poverty bracket and
- near insignificant contribution of the manufacturing sector to the GDP – NEEDS document states that manufacturing accounts for less than 1 per cent of Nigeria's GDP.

These factors constrain the development of more rational and liberal macroeconomic framework that is supportive of market development for renewable energy. The following specific factors constitute major risks for the success of the REMP:

- *Weak purchasing power*. The level of poverty in Nigeria is high, and increasing. This reduces opportunities to embark on fuel switching from traditional to modern renewable uses. Certain renewable technologies are comparatively expensive. Even low cost improved woodstoves seem increasingly beyond the affordability of the extreme poor that make up about 70 percent of the population. The risk of increasing poverty will therefore compromise the objectives of the REMP. The situation may change if current reforms in years to come begin to reduce poverty, and when middle class preferences change to greener energy options. Increased emphasis on the provision of micro finance will also assist in boosting the ability of the poor to afford new and cleaner energy options.

- *Inadequate access to investment capital*. There is a major shortage of investment capital, leading to high interest rates. Several promising projects, especially in new areas like renewable energy investments suffer setbacks due to the scarcity of funds from banks and financial institutions. The reforms in the financial sector aimed at creating more solid financial institutions and also warehousing some of Nigeria's current external reserves will help bolster the financial market and improve overall access and cost of credits.

- *High initial cost for electricity generation.* Even though, conventional energy prices are assumed to hold back the development of alternative energy supplies, but the fact of the matter is that the RE systems for electricity generation are more expensive at the initial investment. However in the long run, the capital investment is cheaper than the conventional sources.

- *Poor infrastructure.* Poor infrastructure increases transaction costs and reduces the profitability of businesses. Roads, telecommunication – and in fact, access to energy is important for local manufacturing of renewable energy systems and components.

- *Macroeconomic factors.* Changes in the Nigerian economy or contagion from the global economy can result in significantly unstable conditions for the Nigerian currency. The generally upward movement of the exchange rate of the Naira to all international currencies, high interest rate, unfriendly tax regime and exercise duty and other levies are great risk to local manufacturing industry, which needs to source in the international market for machinery, parts, and in many cases raw materials that are not locally available. Currency depreciation poses major risks for investment plans by both private and public sectors. It is therefore important that the REMP is viewed within a broader macroeconomic context where exchange rate stability is important in long-term efforts to develop the renewable energy sector.

- *Non-implementation of financial incentives.* The REMP's vision is premised on the immediate imperative to make the playing field among competing energy sources more even. It also envisages a rapid increase in financial incentives to support the growth and development of renewable energy in Nigeria. However, there is always a risk that the implementation of these agreed incentives might fall short of the requirements of the sector. Non-implementation or withdrawal of government incentives such as subsidies would result in low return on investment, which could ultimately lead to project abandonment.

- *Willingness to pay.* Unfortunately, Nigeria has not been able to develop the culture of prompt loan repayment as many other African countries especially in southern and eastern sub-regions have successfully done. This is a great threat and risk to renewable energy market development, as loans would necessarily have to be repaid in order to sustain and expand the market. The fund managers also are a great risk to the market as examples of failed banks and national project funds that have been mismanaged are many. The state of public utilities, are worrisome glaring example of public reluctance to pay bills. Utility's unintelligible tariff and billing have to be avoided in the new renewable energy market.

- *Counterpart funding.* Projects requiring counterpart funding have found Nigeria wanting in the past, with the result that programmes and projects get off to a delayed or slow start and in some cases a no-start at all. Investing in realistic projects and increased political will to back them up is essential.

6.3 International Development Risks

In an increasingly interdependent world, globalization in the movement of capital, technology, goods and ideas transcend boundaries and subject plans like the REMP to pressure. Of particular importance to the success of the REMP is the global market for renewable energy technologies and the actions of other governments and international agencies.

- *Global market risks*. Several international developments with strong impacts on the successful implementation of the REMP are outside Nigeria's control. For instance, while the objectives of the REMP are premised on lowering the cost of renewable energy technologies, such as PVs, phenomenal growth in demand from developed countries, primarily USA and Germany, have kept the price of solar modules at a high level. Local incentives in other countries can both influence the prices of our renewable import, and will also determine the appetite of major manufacturers of these technologies to venture into our markets.

- *International cooperation risks*. Multi-lateral agencies such as the World Bank, UNDP, ADB as well as bilateral agencies such as USAID have contributed greatly to lifting renewable energy from relative obscurity to the mainstream of energy policy making. Much of the planned activities of the REMP are expected to be financed from international sources of funding. This constitutes a major risk factor that must be managed to prevent the crumbling of the main pillars of the REMP. Managing other related issues such as democracy, economic reforms and good governance is important in securing international support for clean and renewable energy programmes.

6.4 Standards and Quality Control Risks

A major constraint to the development of the renewable energy market in Nigeria is the poorly established standard and quality control of locally manufactured and imported technologies. Creating quality assurance is a precondition for building consumer confidence and in growing the market for renewable energy. Three important dimensions to issues of quality include the perception potential users, poorly developed regime for standard setting and testing as well as professionalism among operators.

- *Perception of untested technologies*. Much of the technologies envisaged in the REMP are "new", or non-conventional. This is so much the case for improved fuelwood burning stoves as they are for biogas plants or solar water heaters. Potential users are worried about their efficacy or complexities in using them. The perception that most of these systems are untested technologies can only countered by increased public awareness and policy reform that makes them more affordable.

- *Poorly developed standards and testing procedures.* Presently, there are no testing centers for both locally made and imported renewable energy technologies. Consequently the requisite regulatory environment does not exist. This results to sub-standard technologies that harm the market. The REMP recommends the strengthening of agencies responsible for quality control and standards for product entering the Nigerian market with emphasis on RE technologies.

- *Entry of unqualified people in the field.* The lack of professional associations and strong entrepreneurship in emerging renewable energy businesses, particularly solar PV and improved woodstoves result in people without the relevant professional background to enter the industry. They achieve bad publicity for the industry and make market growth difficult.

6.5 Research and Development Risks

A vibrant R&D capacity and infrastructure is crucial in achieving several objectives of the REMP. Building the capacities to launch and sustain programmes are major concerns.

- *R&D capacity risk.* Achieving the targets of the RE will depend on the identification of appropriate resource centres and professionals to lead the long term R&D programmes. The conditions of Nigeria's R&D institutions fall short of expectations in several respects, including funding, infrastructure, professional morale, etc. Poor economic conditions in the country have also reduced the stock and quality of existing scientists. Achieving set targets and milestones are therefore difficult under these conditions.

  Identifying vibrant resource centres can assist in mitigating R&D capacity risks. Such a long term and collaborative programme should be overseen by a strong board and should be submitted to periodic monitoring and evaluation.

- *R&D funding risk.* Funding for R&D has always been in short supply in Nigeria. This may be more so for research on futuristic energy systems. Leveraging adequate financial resources to launch and sustain R&D programmes, including the proposed NERDP will therefore be challenging.

  Part of the failure to raise enough financial resources for R&D efforts in Nigeria is the over-dependence on public budgets. A mitigation strategy will focus on expanding the scope for funding by actively engaging international agencies, the private sector and fostering international collaboration among R&D centres.

6.6 Environmental Risks

Despite the known fact that renewable energy represents a cleaner alternative, certain environmental risk occurs, and these include:

- *Distortion of the environment.* Large and small hydro plants are known for their impacts on fish life. Wind turbines are also likely to affect bird life and cause noise pollution. Poorly managed biofuel consumption may also result deforestation. In some situations, the production of liquid fuels from biological sources may consume so much conventional energy that their environmental effects might be questionable. In addition to these environmental externalities, what to do with these technologies when their life span expires is also an important issue. Several environmental tools could be useful in addressing these concerns, and they include environmental impact assessment, environmental audits and environmental strategic planning.

- *Human dislocation and resettlement*. Hydro power plants are known to cause dislocation to local livelihoods, including farming, fishing and transportation. In severe cases, they lead to resettlement of communities. These environmental trade-offs must be properly assessed, and alternative approaches to meeting energy needs considered.

- *Esthetics*. Several clean and renewable energy forms unfortunately might not be so pleasant to behold. Wind farms, for instance arouse significant resentment by environmentalist, as they seem to deface natural environments. Large PV farms as currently obtainable in Germany and the US also invoke such concerns, handling of domestic waste such as excreta for biogas generation will as well pose some problems.

Annex: Project Concept Notes

The following concept notes provide ideas on potential renewable energy projects on a range of energy sources and technologies. The concepts presented here are not exhaustive. The objective is to develop a repository for project ideas that could be further developed and implemented by any stakeholder alone, or in partnership with others.

Potential Project Concept Notes: Biomass

1. ***Project Title:*** Biomass Energy Programme		
2. ***Potential Implementation Organizations:*** Federal, States and Local Government, Federal Ministry of Agriculture and Natural Resources, Rural Development Agencies, Federal Ministry of Power and Steel. Energy Centres and NGO's. To be supervised by the ECN**.**		
3. ***Potential Implementation Partners:*** UNIDO,UNDP, IDB, World Bank WHO and Private Sector.		
4. ***REMP Strategic areas:***	Renewable Energy Sub-Sector (s)	Biogas and other Biomass
		- Biogas Diffusion Programme - Establishment of Wood Farm lands - Establishment Of Biomass Power Plants - Establishment of Decentralize Biomass power Plants for Industrial Applications
5. ***Implementation Period:*** 2005 – 2025		
6. ***Project Overall Rationale and Objectives:*** Biomass has several attractions as energy source. Unlike conventional fossil fuel, resources, which are unevenly distributed over the earth's surface and are finite in magnitude, biomass is a widely available resource that can be produced renewably. Biomass conversion appears to be more economically attractive in most cases. Hence, serious thoughts must be given to the idea of using Biomass as an energy source. Studies have shown that Biomass utilization as energy has significant advantages and it deserve serious attention.		
7. ***Project Specific Objectives:*** To promote biogas utilization among Nigerians especially in the rural areas and to contribute to the national grid and also make our industries less dependent on national grid.		
8. ***Expected Outcomes:*** The project is expected to generate biogas and electric power from biomass for various applications in the country.		
9. ***Planned Activities to Achieve Outcomes:*** To make biogas technology popular among Nigerians, there is the need for all the three tiers of government to embark upon distribution of biogas plants to a greater extent in order to promote its utilization especially in the rural areas. Biogas plants, if correctly operated and maintained, would improve the technical abilities and economic capacity of Nigerian farmers and rural dwellers. To do this, the government should first identify all potential project sites in the country and available biomass resources in each area and then jointly try to construct more than 6,000 biogas plants across the country each year. The Government through the relevant agencies should also establish biomass power plants, that can contribute to the National grid. The government should also establish 100,000 hectares of woodland each year within the project period in order to establish national reliance on wood for electricity generation in the country.		

10. ***Project linkage to national priorities, action plans and program:*** The project is a very important project and should not be left out in the National Development programme.
11. ***Stakeholders involved in Project:*** Government agencies involved in rural development, rural dwellers, private sectors, Ministries of Agriculture, Power and Steel, petroleum, and Solid Minerals, States and Local Governments and Research Institutes.
12. ***Implementation Arrangement:*** The Government at State, Local and Federal level should provide the funds, while the Energy Commission of Nigeria should co-ordinate. To be able to implement this project, the Federal Government through relevant government agencies, NGO and International organization should be able to carry out the following activities prior to the commencement of the projects:- Public Consultations and Education, Identification of Project Sites, Assessment for Environmental Consequences of Biomass Energy Conversion, Identification of Research and Development needs, Training and Manpower Development Programmes and Adopt the Master Plan on Renewable Energy Activities.
13. ***Estimated Budget and Information on how costs will be met:*** About N3.5B should be made available to the co-ordinating agency each year between 2005 – 2025 for the execution of this project. The fund can be raised through budgetary provisions and by taxing all the industries operating in Nigeria 2% of oil revenue and 5% of profit generate from NEPA could be set aside for this project also.

Potential Project Concept Notes: Biomass Continued

<table>
<tr><td colspan="3">1. Project Title: Improved Re-enforced Clay Stove Development and utilization Programme</td></tr>
<tr><td colspan="3">2. Potential Implementation Organizations: Energy Commission of Nigeria in Collaboration with Ministry of Environment and Ministry of Agriculture (Fed. Dept. of forestry, FEPA), CERD, SERC ADP and NGO’s</td></tr>
<tr><td colspan="3">3. Potential Implementation Partners: Federal Ministry of Agriculture and Federal Ministry of Environment, FEPA, CERD, SERC ADP and NGO’s</td></tr>
<tr><td rowspan="2">4. REMP strategic areas. Ecologically balanced environment through energy utilization.</td><td>Renewable Energy Sub-sector (s)</td><td>Improved Re-enforced Clay Woodstoves</td></tr>
<tr><td>Area (s) of Intervention</td><td>Energy efficiency for economic growth and Job creation.</td></tr>
<tr><td colspan="3">5. Implementation Period: 2005 – 2025.</td></tr>
<tr><td colspan="3">6. Project Overall Rationale and Objectives Factors such as problems of fire wood alternativewhich is usually obtained by self collection with associated problems of accesibilility and affodability of alternative fuels called for an improvement in our existing cooking practice. The overall rationale isthe judious use of fuelwood, reduction in cooking time and to eliminate smoke hazards to our women folk through the intergration of chimney to the stoves</td></tr>
<tr><td colspan="3">7. Project Specific Objectives: Reduction of firewood through the efficient energy cooking systems conservation and effective utilization of other biomass as cooking fuels. Development of fast growing tree species to supplement the existing firewood consumption’s.</td></tr>
<tr><td colspan="3">8. Expected Outcomes: To revolutionise the cooking systems through the use of efficient woodstoves particularly in rural areas of Nigeria, thereby reducing the quantity of fuelwood-wasted daily during the cooking activities as a result of heat losses.</td></tr>
<tr><td colspan="3">9. Planned Activities to Achieve Outcomes:
- Establishment of capacity building programme for the improved wood stoves projects.
- Establishment of standards to cater for the nation’s cooking culture.</td></tr>
</table>

- Train the trainers programme to mass-produce the stoves to cover at least 40% of the Nigerian homes by 2025, Country- wide effort campaign approach on improved woodstoves dessimination. - Introduction of 50% subsidy to all household puchasing improved woodstoves. - Development of fast growing tree species for the improved woodstoves. - Monitoring and control of the planned activities and review on matters arising on the implementations. - Establisment of National biomass energy network for co-ordination and dissemination of improved woodstoves - Complete transfer of improved woodstoves manufacture, marketing, and sales to private sectors. - Monitoring and evaluation of the set objective's be continued for sustainability of the project
10. ***Project linkage to national priorities, action plans and program:*** - Sustainable and affordable energy options - Poverty reduction under socio-economic acceptability. - Ecological balanced environment and economic growth.
11. *Stakeholders involved in Project:* Local Communities, Environmentalist NGO's Forestry and Energy Conservation Agencies (FEPA, GEF Fed. Department of Forestry etc) ECN and National Energy Centres (SERC, CERD etc).
12. *Implementation Arrangement*: Energy Commission of Nigeria through its relevant research contres, federal ministry of environment and Agriculture' Environmental NGO's with several relevant agencies.
13. *Estimated Budget and Information on how costs will be met:* The improved woodstove projects can be successfully initiated and implemented with little or even no funds. As our local potters and Artisan are currently implementing the projects at small-scale level based on their expertise. However for reasonable mass production, under the REMP the sum of N2.8 billion to N3.8 billion naira would be reasonable to initiate small-scale woodstoves fabrication factory and N800m to N1.2 billion Naira for the targeted intervention for the next 20 years. The amount could be generated through government Ecological funds, International donors and related private sector.

Potential Projects Concept Notes: Woodstoves

1. ***Project Title*:** Community based improved wood burning stoves programme		
2. ***Potential Implementation Organizations*:** Energy Commission of Nigeria in Collaboration with Ministry of Environment and Ministry of Agriculture (Fed. Dept. of forestry, FEPA), CERD, SERC ADP and NGO's		
3. ***Potential Implementation Partners***: Federal Ministry of Agriculture and Federal Ministry of Environment, FEPA, CERD, SERC ADP and NGO's		
4. ***REMP strategic areas. Ecologically balanced environment through energy utilization.***	Renewable Energy Sub-sector (s)	Improved community based woodstoves
	Area (s) of Intervention	Energy efficiency for economic growth and Job creation
5. ***Implementation Period***: 2005 – 2025.		
6. Project Overall Rationale and Objectives Factors such as problems of fire wood alternative which is usually obtained by self collection with associated problems of accessibility and affordability of alternative fuels called for an improvement in our existing cooking practice. The overall rationale is the judicious use of fuelwood, reduction in cooking time and to eliminate smoke hazards to our women folk through the integration of chimney to the stoves		
7. ***Project Specific Objectives***: Reduction of substantial amount of fuelwood through the efficient energy cooking system in community based setup. Optimum conservation of energy through the efficient community based brick stoves. Development and utilisation of fast growing free species to supplement the existing firewood consumption.		
8. ***Expected Outcomes:*** To reduce pressure on the existing forest through the efficient utilization of cooking fuel of an improved version of stove with expected reduction in consumption by at least 30-40% before 2025.		
9. **Planned Activities to Achieve Outcomes**: - Establishment of capacity building programme for the improved wood stoves projects. - Establishment of standards to cater for the nation's cooking culture. - Train the trainers programme to mass-produce the stoves to cover at least 40% of the Nigerian homes by 2025, Country- wide effort campaign approach on improved woodstoves dissemination. - Introduction of 50% subsidy to all household purchasing improved woodstoves. - Development of fast growing tree species for the improved woodstoves. - Monitoring and control of the planned activities and review on matters arising on the implementations. - Establishment of National biomass energy network for co-ordination and dissemination of improved woodstoves - Complete transfer of improved woodstoves manufacture, marketing, and sales to private sectors. - Monitoring and evaluation of the set objective's be continued for sustainability of the project		
10. ***Project linkage to national priorities, action plans and program:*** Sustainable and affordable energy options - Poverty reduction under socio-economic acceptability. - Ecological balanced environment and economic growth.		

11. ***Stakeholders involved in Project:*** Local Communities, Environmentalist NGO's Forestry and Energy Conservation Agencies (FEPA, GEF Fed. Department of Forestry etc) ECN and National Energy Centres (SERC, CERD etc).
12. ***Implementation Arrangement*****:** Energy Commission of Nigeria through its relevant research centres, federal ministry of environment and Agriculture' Environmental NGO's with several relevant agencies.
13. ***Estimated Budget and Information on how costs will be met:*** The improved community based wood burning stoves is equally not very capital intensive and technologically appropriated with available material virtually everywhere in Nigeria. The sum of N1.7 billion Naira only will be adequate to install the planned community based improved versions of brick stoves. The estimated budget can be met through the intervention of Federal Government budget ecological funds such GEF, Environmental NGO's, Private sector participation and other countries special grants.

Potential projects concept notes: Woodstoves continued

1. ***Project Title*****:** Improved Metallic Wood burning stoves Development Programme		
2. ***Potential Implementation Organizations*****:** Energy Commission of Nigeria in Collaboration with Ministry of Environment and Ministry of Agriculture (Fed. Dept. of forestry, FEPA), CERD, SERC ADP and NGO's		
3. ***Potential Implementation Partners***: Federal Ministry of Agriculture and Federal Ministry of Environment, FEPA, CERD, SERC ADP and NGO's		
4. ***Sustainable environment through efficient energy utilization***	Renewable Energy Sub-sector (s)	Improved Metallic stoves
	Area (s) of Intervention	Efficient Energy Utilisation for economic growth and Job creation.
5. ***Implementation Period***: 2005 – 2025.		
6. Project Overall Rationale and Objectives Factors such as problems of fire wood alternative which is usually obtained by self collection with associated problems of accessibility and affordability of alternative fuels called for an improvement in our existing cooking practice. The overall rationale is the judious use of fuelwood, reduction in cooking time and to eliminate smoke hazards to our women folk through the integration of chimney to the stoves		
7. ***Project Specific Objectives***: Reduction of firewood through the efficient energy cooking systems conservation and effective utilization of other biomass as cooking fuels. Development of fast growing tree species to supplement the existing firewood consumption's.		
8. ***Expected Outcomes:*** To revolutionalise the cooking systems through the use of efficient woodstoves particularly in rural areas of Nigeria, thereby reducing the quantity of fuelwood-wasted daily during the cooking activities as a result of heat losses.		
9. **Planned Activities to Achieve Outcomes**: - Establishment of capacity building programme for the improved wood stoves projects. - Establishment of standards to cater for the nation's cooking culture. - Train the trainers programme to mass-produce the stoves to cover at least 40% of the Nigerian homes by 2025, Country- wide effort campaign approach on improved woodstoves dissemination. - Introduction of 50% subsidy to all household purchasing improved woodstoves. - Development of fast growing tree species for the improved woodstoves. - Monitoring and control of the planned activities and review on matters arising on the implementations. - Establishment of National biomass energy network for co-ordination and dissemination of improved woodstoves - Complete transfer of improved woodstoves manufacture, marketing, and sales to private sectors. - Monitoring and evaluation of the set objective's be continued for sustainability of the project		
10. ***Project linkage to national priorities, action plans and program:*** Sustainable and affordable energy options - Poverty reduction under socio-economic acceptability. - Ecological balanced environment and economic growth.		

11. *Stakeholders involved in Project:* Local Communities, Environmentalist, NGO's Forestry and Energy Conservation Agencies (FEPA, GEF Fed. Department of Forestry etc) ECN and National Energy Centres (SERC, CERD etc).
12. *Implementation Arrangement*: Energy Commission of Nigeria through its relevant research centres, federal ministry of environment and Agriculture' Environmental NGO's with several relevant agencies.
13. *Estimated Budget and Information on how costs will be met:* The improved metallic stove is one of the efficient wood burning stoves planned for the intervention. The raw material which is galvanised iron sheet is available in Nigerian Markets. The budgetary requirement of N1.7 billion Naira only would be required for the intervention. The amount can be met through Federal budget, ecological funds such as GEF, Environmental NGO's, Private Sector share participation and other countries special grants.

Potential Projects Concept Notes: Biomass Briquetting

1. ***Project Title*****:** Multi cylinder biomass briquetting programme

2. ***Potential Implementation Organizations*****:** Energy Commission of Nigeria in Collaboration with Ministry of Environment and Ministry of Agriculture (Fed. Dept. of forestry, FEPA), CERD, SERC ADP and NGO's

3. ***Potential Implementation Partners***: Federal Ministry of Agriculture and Federal Ministry of Environment, FEPA, CERD, SERC ADP and NGO's

4. ***REMP strategic areas:*** Ecologically balanced environment through supplementation of energy	Renewable Energy Sub-sector (s)	Biomass briquetting
	Area (s) of Intervention	Capacity building job creation and sustainable energy security.

5. ***Implementation Period***: 2005 – 2025.

6. Project Overall Rationale and Objectives: Conservation and maximum utilization of wood and agricultural waste to provide alternatives to fuelwood and reduce over dependence on depletable fuelwood mostly used for domestic energy supply.

7. ***Project Specific Objectives***: To supplement the firewood cooking fuels thereby reducing firewood consumption and minimizing pressure on the already depleted forest with additional environmental protection.

8. ***Expected Outcomes:*** It is expected that by the year 2025 the biomass briquttes will provide at least 8 to 10% of the fuelwood required by supplement.

9. **Planned Activities to Achieve Outcomes**:
- Demonstrating the technical feasibility studies on the agricultural biomass resources to categories them for biomass briquette production and those for land fertilizer.
- Aggressive mass production of biomass briquette
- Conducting studies on indigenous expertise to manufacture and operate the briquetting plants.
- Introduction of subsidy and other financial incentive such as lower profit tax and tax holidays on the importation of equipment for the briquettes manufacturing.
- Production and promotion of domestic cooking stoves designed for briquettes.
- Localization of expertise in briquettes production by 2025 and meeting the 8 to 10% supplements for fuelwood based on proper monitoring and control.
- Establishment of biomass energy networks for co-ordination and dissemination of briquette fuels.
- Localization of expertise to manufacture and operate briquetting plants
- Complete Transfer of biomass briquetting, marketing and sales to private sectors.
- Monitoring and Evaluation of the planned activity be continued

10. ***Project linkage to national priorities, action plans and program:***

Sustainable and affordable energy options
- Poverty reduction under socio-economic acceptability.
- Ecological balanced environment and economic growth.

11. ***Stakeholders involved in Project:***

Local Communities, Environmentalist NGO's Forestry and Energy Conservation Agencies (FEPA, GEF Fed. Department of Forestry etc) ECN and National Energy Centres (SERC, CERD etc).

12. *Implementation Arrangement*:

Energy Commission of Nigeria through its relevant research centres, federal ministry of environment and Agriculture' Environmental NGO's with several relevant agencies.

13. *Estimated Budget and Information on how costs will be met:*

The biomass briquetting projects to achieved the required average industrial set up ranges from N1,000,000:00 to N2,500,000:00 for equipment, raw materials and personnel. To successfully utilize small and middle scale project on briquetting. However, for the expected target of 20years the sum of N2,5 billion Naira will be required for the programme which can be met through Government, International donors and NGO's intervention.

Potential Projects Concept Notes: Biomass Briquetting Continued

1. ***Project Title*****:** Development of Screw shaft briquetting Machine for sawdust rice husk and groundnut shells briquettes.		
2. ***Potential Implementation Organizations*****:** Energy Commission of Nigeria in Collaboration with Ministry of Environment and Ministry of Agriculture (Fed. Dept. of forestry, FEPA), CERD, SERC ADP and NGO's		
3. ***Potential Implementation Partners***: Federal Ministry of Agriculture and Federal Ministry of Environment, FEPA, CERD, SERC ADP and NGO's		
4. ***REMP strategic areas. Ecologically balanced environment through energy utilization.***	Renewable Energy Sub-sector (s)	Biomass Briquetting using screwshaft
	Area (s) of Intervention	To provide job creation and sustainable energy security.
5. ***Implementation Period***: 2005 – 2025.		
6. Project Overall Rationale and Objectives Factors such as problems of fire wood alternative which is usually obtained by self collection with associated problems of accessibility and affordability of alternative fuels called for an improvement in our existing cooking practice. The overall rationale is the judicious use of fuelwood, reduction in cooking time and to eliminate smoke hazards to our women folk through the integration of chimney to the stoves		
7. ***Project Specific Objectives***: To supplement the firewood cooking fuels thereby reducing firewood consumption and minimizing pressure on the already depleted forest with additional environmental protection.		
8. ***Expected Outcomes:*** It is expected that by the year 2025 the biomass briquttes will provide at least 8 to 10% of the fuelwood required by supplement.		
9. **Planned Activities to Achieve Outcomes**: - Establishment of capacity building programme for the improved wood stoves projects. - Establishment of standards to cater for the nation's cooking culture. - Train the trainers programme to mass-produce the stoves to cover at least 40% of the Nigerian homes by 2025, Country- wide effort campaign approach on improved woodstoves dissemination. - Introduction of 50% subsidy to all household purchasing improved woodstoves. - Development of fast growing tree species for the improved woodstoves. - Monitoring and control of the planned activities and review on matters arising on the implementations. - Establishment of National biomass energy network for co-ordination and dissemination of improved woodstoves - Complete transfer of improved woodstoves manufacture, marketing, and sales to private sectors. - Monitoring and evaluation of the set objective's be continued for sustainability of the project		
10. ***Project linkage to national priorities, action plans and program:*** Sustainable and affordable energy options - Poverty reduction under socio-economic acceptability. - Ecological balanced environment and economic growth.		

11. ***Stakeholders involved in Project:*** Local Communities, Environmentalist NGO's Forestry and Energy Conservation Agencies (FEPA, GEF Fed. Department of Forestry etc) ECN and National Energy Centres (SERC, CERD etc).
12. ***Implementation Arrangement*****:** Energy Commission of Nigeria through its relevant research centres, federal ministry of environment and Agriculture' Environmental NGO's with several relevant agencies.
13. ***Estimated Budget and Information on how costs will be met:*** The screwshaft briquetting machine for the production of briquettes using the raw materials of rice, millet, sawdust and groundnut shells can be successfully developed in Nigeria. The sum of N2.4 billion Naira would be required for the intervention, which can be met through several funding organisations, such as Federal Government budget, ecological funds, CDM, mechanisms, NGO's and private sector contributions.

Potential Projects Concept Notes: Small Scale Hydro

1.	***Project Title:*** Small Scale Hydro Power (SHP)		
2.	***Potential Implementation Organizations***: River Basin Development Authorities, Rural Electrification Boards (REB), State and Local Governments with ECN supervision and coordination.		
3.	***Potential Implementation Partners***: NEPA, World Bank, UNDP, International Development Banks		
4.	***REMP strategic areas***:	*Renewable Energy Sub-sector(s)*	Small of Scale Hydro Power
		Area(s) of Intervention	National Resources Identification and Inventory, Resources Assessment, Public Awareness, Financing, Layout of Development Program.
5.	***Implementation Period***: Present to Yr. 2025		
6.	***Project Overall Rationale and Objectives:*** Favourable and integral component of a diversified and expanding energy structure. Provision of supply to growing and unsatisfied demand by the Nation's majority but substantially neglected population. Resource Conservation.		
7.	***Project Specific Objectives***: Meet local demands, promote cost effective consumption of local energy resources, stimulate rural area industrialization, power cottage industries, discourage rural-urban migration, improve local awareness, raise community standard of living, rural development		
8.	***Expected Outcomes*****:** Generation of hydropower and supply to local communities and, perhaps, the National Grid; Creation of employment; Industrialization; Improvement of local access and road network; Development of local Communities; Contribution of local resources to National Development.		
9.	***Planned Activities to Achieve Outcomes***: In the short term up to Yr. 2007 – adopt Master Plan, complete national survey and inventory of potential Small –Scale Hydro Power (SHP) sites, develop codes and standards, establish national information system, evaluate existing SHPs, establish adequate infrastructure for personnel training, staff training, commence construction of one SHP plant in each of seven geographical zones of the country, and provide funding including support from International Donor Agencies to cover tasks. Over the medium-term through yr 2015-monitoing of Master Plan performance, continuing contact with Donor Agencies, implementation of codes and standards, continued manpower training, Nigerianization of SHP operations, construction of additional SHP plants, continued financing by Government and Donor Agencies. In the long-term period ending Yr. 2025, uncompleted tasks of the medium-term would be concluded and construction of SHPs to full national capacity.		

10.	***Project linkage to national priorities, action plans and program***: SHP development should be integrated, under high priority, into the National Development Plan and Budgeting.
11.	***Stakeholders involved in Project***: Local communities, Individuals, the Private Sector, Local and State Governments, River Basin Development Authorities, NEPA, Rural Electrification outfits, and the Federal Government via the ECN.
12.	***Implementation Arrangement****:* The ECN would identify, initiate and coordinate actions (via studies, field works and project reports); works to be done through individual experts or consultancy firms. Lead site agency should be the River Basin Development Authority. Initial project operation can be the responsibility of the Rural Electrification Board until eventual Privatization of the development.
13.	***Estimated Budget and Information on how costs will be met:*** Up to ₦20 Billion to be required annually in the next 10 yrs beginning presently with about ₦5 billion/annum, and increasing at ₦4 billion per year. Funding through annual budget of the Federal Government and assistance from International Donor Agencies. Additional support from State and Local Governments.

Potential Projects Concept Notes: Solar PV

1.	***Project Title****:* Solar Photovoltaics		
2.	***Potential Implementation Organizations***: Federal,Ministries of Mines and Power, Water Resources, Health, Education, Communications, Petroleum Resources, Rural Electrification Boards (REB), Renewable Energy Research Centres, State and Local Governments with ECN supervision and coordination.		
3.	***Potential Implementation Partners***: NEPA, World Health Organisation, World Bank, UNDP, International Development Banks, Cooperative Societies.		
4.	***REMP strategic areas***:	*Renewable Energy Sub-sector(s)*	Solar Energy
		Area(s) of Intervention	National Resources Identification and Inventory, Resources Assessment, Public Awareness, Financing, Local Production, Layout of Development Program.
5.	***Implementation Period***: Present to Yr. 2025		
6.	***Project Overall Rationale and Objectives:*** Incorporation of Solar-photovoltaics into the national energy supply mix, particularly in the remote, rural communities. Provision of electricity for water pumping, village electrification, vaccine refrigeration, education/research(computers, teaching aids, documentaries), communications(telephony, television, radio), pipeline and metal structures corrosion control.		
7.	***Project Specific Objectives***: To harness the abundant solar energy resources for electricity generation to meet local demands for healthcare, water supply, lighting, education, job creation in the rural areas, sensitise the local population on the potentials of solar electricity, rural development.		
8.	***Expected Outcomes*****:** Generation of solar electricity and supply to local communities and, perhaps, the National Grid. Improvement in the standard of living and poverty reduction in the country through the creation of employment; industrialization; provision of social infrastructure in local Communities; harnessing of the potentials in the rural communities to foster national development.		

9.	***Planned Activities to Achieve Outcomes***: Between 2005 and 2007, begin implementation of REMP, install demonstation projects, capacity building and training in the renewable energy centres, install two pilot production plants for modules, develop codes and standards, establish financing mechanisms to promote the dissemination of PV. In the medium term, increase the local production capacity of plants to include newer technologies, increase funding of the research centres for basic research on cells, modules and systems, monitor the realization of REMP objectives in PV particularly as it affects rural electricity infrastructure development. Increase the megawatt power output from solar photovoltaics systems up to 50MW. Mount workshops, seminars and intensive training of local technicians, craftsmen, artisans to support the increasing dissemination of PV systems. In the long term, from 2016 to 2025, further increase in the production capacity of plants to meet the demand for solar modules and balance of system components in the West African subregion; dissemination of about 500MW of PV systems, including utility-tied systems; research on high-effciency cells to meet world-class efficiencies; evaluation of outcomes to ascertain to what extent they meet REMP objectives.
10.	***Project linkage to national priorities, action plans and program***: Solar-PV development should be linked to the overall national development plan, particularly to the rural development initiatives of the three tiers of government; the National Economic Empowerment for Development Strategies(NEEDS).
11.	***Stakeholders involved in Project***: The Federal Government through the Ministries of Power and Steel, Health, Education , Communication, Water Resources. State and Local Governments; Local communities, Individuals, the Private Sector, NEPA, Rural Electrification outfits; the Energy Commission of Nigeria as the overall coordinator of the REMP projects.
12.	***Implementation Arrangement:*** The ECN would collaborate with local and international Agencies on technical and financial assistances required for project implementation, it will monitor and regulate the activities of the stakeholders to ensure compliance with standards. The Renewable Energy Research Centres will be involved in carrying out surveys, feasibility studies, R&D, training and manpower development to support the project implementation.
13.	***Estimated Budget and Information on how costs will be met:*** About ₦5 Billion to be required annually in the next two years up to 2007 and increasing to ₦7 Billion/annum up to 2015. About ₦10 Billion/annum would be required from 2016 up to 2025. Funding through the annual budgets of the Federal, State and Local Governments, the private sector and International agencies will meet the cost requirements.

Potential Projects Concept Notes: Solar Thermal

<table>
<tr><td colspan="3">1. Project title: National Solar Heating Programme (NASHP)</td></tr>
<tr><td colspan="3">2. Potential implementing organizations: Energy Commission of Nigeria in collaboration with other stakeholders such as the Ministries of Environment and of Health.</td></tr>
<tr><td colspan="3">3. Potential implementing partners: SERCC, NERDC, CERD, UNDP/GEF</td></tr>
<tr><td rowspan="2">4. REMP strategic areas: Renewable energy adoption to meet energy targets</td><td>Renewable energy subsector(s)</td><td>Solar thermal energy</td></tr>
<tr><td>Area(s) of intervention</td><td>Technology adoption, capacity building, job creation</td></tr>
<tr><td colspan="3">5. Implementing period : 2005 – 2025</td></tr>
<tr><td colspan="3">6. Project overall rationale and objectives: To replace a significant fraction of low temperature (< $80^{o}C$) heating applications in the domestic, commercial, institutional and industrial sectors, thereby resulting in thousands of tonnes of avoided carbon dioxide into the environment while releasing the fossil fuels and biomass that would otherwise have been used for more useful work.</td></tr>
<tr><td colspan="3">7. Project specific objectives: To meet or exceed the specific targets set for the following:
Solar water and air heaters
Solar cookers
Solar dryers and brooders
Solar stills, pasteurizers, desalination, & sterilizers</td></tr>
<tr><td colspan="3">Expected outcomes:
• Specific targets for each solar heating technology met or exceeded in target year
• Significant contribution of solar thermal to the national energy mix as set in the targets
• Creation of thousands of jobs for artisans, technicians, engineers, bankers, project managers
• Development of a virile solar thermal energy manufacturing base in the ECOWAS sub-region
• Development of an internationally competitive and export-oriented solar thermal industrial base by the mid-term of 2015</td></tr>
<tr><td colspan="3">9.Planned activities to achieve the outcomes:
• Enact the National Solar Heating Obligation ordinance or bill at the local, state and national assemblies for solar water heaters on all new buildings (commercial, government, hospitals, clinics, and institutions)
• Provide attractive fiscal market incentives for the adoption of solar heaters in the domestic, commercial, and industrial sectors through specific Solar Thermal Market Incentive Programmes (STMIP)
• Standards Organization of Nigeria (SON), together with other stakeholders such as the building industry and relevant professional bodies, to develop;
• Codes of Practice and Codes of Conduct/Ethics for manufacturers and vendors,
• Performance & Technical Standards for: solar water air heaters; solar dryers; solar cookers; solar stills; etc.</td></tr>
</table>

- Minimum Specifications to be met for solar thermal products for the Nigerian market
- Testing procedures, certification scheme, product quality and safety assurance criteria, compliance strategy, standards enforcement and corrective, implementable sactions
- Product standardization methodology for the Nigerian solar thermal energy industry
- Launch training and certification programmes for artisans, technicians, engineers, business community, banking community, public sector officials, etc. on solar thermal technologies through the national energy centres and other higher institutions and NGOs as soon as possible within the year 2005

10. *Project linkage to national priorities, action plans, and programs:*
- NEEDS programme document
- NAPEP
- National Environmental Protection and Sustainability Programmes
- National economic growth
- Renewable Rural Energy Programme in the Department of Rural Development, Ministry of Agriculture and Rural Development

11. *Stakeholders involved in project:*
- Government Ministries and Agencies
- Private sector companies and CBOs & NGOs
- International agencies such as UNDP/Global Environmental Facility, GEF
- National energy centres and other higher institutions of learning and research

12. *Implementation arrangement:* The implementing agency is the Energy Commission of Nigeria, ECN, which will coordinate, monitor, assess, evaluate and direct the programme.

Estimated budget and information on how costs will be met: the USD 100 million to be met from:
- Federal government budget
- Allocation of a share of excess crude oil earnings and returned loot from national treasury
- National Non-Fossil Fuel Obligation, NNFFO
- International agencies particularly Global Environmental Facility which has approved grants for similar projects in other countries in the recent past.

Potential Projects Concept Notes: Solar Thermal Continued

1. *Project title:* National Solar Cooling Programme (NASCooP)		
2. *Potential implementing organizations:* Energy Commission of Nigeria in collaboration with other stakeholders such as the Ministries of Environment and of Health.		
3. *Potential implementing partners:* SERCC, NERDC, CERD, UNDP/GEF		
4. *REMP strategic areas:* Renewable energy adoption to meet energy targets	*Renewable energy subsector(s)*	Solar thermal energy
	Area(s) of intervention	Technology adoption, capacity building, job creation
5. *Implementing period :* 2006 – 2025		
6. *Project overall rationale and objectives:* To replace a significant fraction of grid electricity used for compression refrigeration and air conditioning in the commercial, institutional and industrial sectors, thereby resulting in thousands of tonnes of avoided carbon dioxide into the environment while releasing the electricity that would otherwise have been used for more useful work in manufacturing and production activities.		
7. *Project specific objectives:* To meet or exceed the specific targets set for :solar refrigeration and air conditioning of large commercial and institutional buildings		
Expected outcomes: • Specific targets for solar refrigeration and air conditioning (Solar R/AC) technology met or exceeded in target year 2015 • Significant contribution of Solar R/AC to the national R/AC mix by 2015 in commercial and institutional buildings, in no case should it be less than 50% • Creation of thousands of jobs for artisans, technicians, engineers, bankers, project managers • Development of a virile solar R/AC manufacturing base in the ECOWAS sub-region • Development of an internationally competitive and export-oriented solar R/AC industrial base by the end of the plan period 2025		
9.*Planned activities to achieve the outcomes:* • Enact the National Solar Cooling Obligation ordinance or bill at the local, state and national assemblies for solar air conditioning of all new buildings (commercial, government, hospitals, clinics, and institutions) • Provide attractive fiscal market incentives for the adoption of solar cooling in the domestic, commercial, and industrial sectors through specific Solar Cooling Market Incentive Programmes (SCooMIP) • Standards Organization of Nigeria (SON), together with other stakeholders such as the building industry and relevant professional bodies, to develop; • Codes of Practice and Codes of Conduct/Ethics for manufacturers and vendors, • Performance & Technical Standards for: solar R/AC equipment • Minimum Specifications to be met for solar R/AC products for the Nigerian market • Testing procedures, certification scheme, product quality and safety assurance criteria, compliance strategy, standards enforcement and corrective,		

implementable sanctions
- Product standardization methodology for the Nigerian solar R/AC industry
- Launch training and certification programmes for artisans, technicians, engineers, business community, banking community, public sector officials, etc. on solar thermal technologies through the national energy centres and other higher institutions and NGOs as soon as possible within the year 2005

10. *Project linkage to national priorities, action plans, and programs:*
- NEEDS programme document
- NAPEP
- National Environmental Protection and Sustainability Programmes
- National economic growth
- Vaccine preservation and National/International health programmes of the Federal Government and such agencies as the WHO, e.g. the recent polio vaccination program

11. *Stakeholders involved in project:*
- Government Ministries and Agencies
- Private sector companies and CBOs & NGOs
- International agencies such as UNDP/Global Environmental Facility, GEF
- National energy centres and other higher institutions of learning and research

12. *Implementation arrangement:* The implementing agency is the Energy Commission of Nigeria, ECN, which will coordinate, monitor, assess, evaluate and direct the programme.

Estimated budget and information on how costs will be met: the USD 50 million to be met from:
- Federal government budget
- Allocation of a share of excess crude oil earnings
- National Non-Fossil Fuel Obligation, NNFFO
- International agencies particularly Global Environmental Facility which has approved grants for similar projects in other countries in the recent past.

Potential Projects Concept Notes: Solar Thermal Continued

<table>
<tr><td colspan="3">1. Project title: National Solar Passive Architecture Programme (NASPAP)</td></tr>
<tr><td colspan="3">2. Potential implementing organizations: Energy Commission of Nigeria in collaboration with other stakeholders such as the Ministries of Environment and of Works and Housing.</td></tr>
<tr><td colspan="3">3. Potential implementing partners: SERCC, NERDC, CERD, UNDP/GEF</td></tr>
<tr><td rowspan="2">4. REMP strategic areas: Renewable energy adoption to meet energy targets</td><td>Renewable energy subsector(s)</td><td>Solar thermal energy</td></tr>
<tr><td>Area(s) of intervention</td><td>Technology adoption, capacity building, job creation</td></tr>
<tr><td colspan="3">5. Implementing period : 2005 – 2025</td></tr>
<tr><td colspan="3">6. Project overall rationale and objectives: To reduce significantly the building energy consumption in the commercial, institutional and industrial sectors, thereby resulting in thousands of tonnes of avoided carbon dioxide into the environment while releasing the electricity and other energy forms that would otherwise have been used for more useful work in manufacturing and production activities.</td></tr>
<tr><td colspan="3">7. Project specific objectives: To meet or exceed the specific targets set for :solar passive architecture, particularly of large commercial and institutional buildings</td></tr>
<tr><td colspan="3">Expected outcomes:
• Specific targets for solar passive architecture met or exceeded in target year 2015
• Significant contribution of solar passive architecture to the national building mix by 2015 in commercial and institutional buildings, in no case should it be less than 25%
• Creation of thousands of jobs for architects, draughtsmen, artisans, technicians, engineers, bankers, project managers, project developers, etc.
• Development of a virile passive architecture design and technology base in the ECOWAS sub-region
• Development of an internationally competitive and export-oriented solar solar passive architecture and industrial base by the end of the plan period 2025</td></tr>
<tr><td colspan="3">9.Planned activities to achieve the outcomes:
• Enact the National Solar Passive Architecture Obligation ordinance or bill at the local, state and national assemblies for incorporation of solar passive design into all new buildings (commercial, government, hospitals, clinics, and institutions)
• Provide attractive fiscal market incentives for the adoption of solar passive architecture in the domestic, commercial, and industrial sectors through specific Solar Passive Architeccture Market Incentive Programmes (SPAMIP)
• Standards Organization of Nigeria (SON), together with other stakeholders such as the building industry and relevant professional bodies, to develop;
• Codes of Practice and Codes of Conduct/Ethics for manufacturers and vendors,
• Performance & Technical Standards for: solar passive equipment
• Minimum Specifications to be met for solar passsive products for the Nigerian market
• Testing procedures, certification scheme, product quality and safety assurance criteria, compliance strategy, standards enforcement and corrective,</td></tr>
</table>

implementable sanctions

- Product standardization methodology for the Nigerian solar passive industry
- Launch training and certification programmes for artisans, technicians, engineers, business community, banking community, public sector officials, etc. on solar thermal technologies through the national energy centres and other higher institutions and NGOs as soon as possible within the year 2005

10. *Project linkage to national priorities, action plans, and programs:*

- NEEDS programme document
- NAPEP
- National economic growth
- State and National Housing Programmes
- United Nations Habitat Programme

11. *Stakeholders involved in project:*

- Government Ministries and Agencies
- Private sector companies and CBOs & NGOs
- International agencies such as UNDP/Global Environmental Facility, GEF National energy centres and other higher institutions of learning and research

12. *Implementation arrangement:* The implementing agency is the Energy Commission of Nigeria, ECN, which will coordinate, monitor, assess, evaluate and direct the programme.

Estimated budget and information on how costs will be met: the USD 25 million to be met from:

- Federal government budget
- Allocation of a share of excess crude oil earnings and national loot returned from abroad
- National Non-Fossil Fuel Obligation, NNFFO
- International agencies particularly Global Environmental Facility which has approved grants for similar projects elsewhere.

Potential Projects Concept Notes: Solar Thermal Continued

<table>
<tr><td colspan="3">1. Project title: National Solar Thermal Electricity Programme (NASTEP)</td></tr>
<tr><td colspan="3">2. Potential implementing organizations: Energy Commission of Nigeria in collaboration with other stakeholders such as the Ministries of Power and Steel, Environment and of Health.</td></tr>
<tr><td colspan="3">3. Potential implementing partners: SERCC, NERDC, CERD, UNDP/GEF</td></tr>
<tr><td rowspan="2">4. REMP strategic areas: Renewable energy adoption to meet energy targets</td><td>Renewable energy subsector(s)</td><td>Solar thermal energy</td></tr>
<tr><td>Area(s) of intervention</td><td>Technology adoption, capacity building, job creation</td></tr>
<tr><td colspan="3">5. Implementing period : 2005 – 2025</td></tr>
<tr><td colspan="3">6. Project overall rationale and objectives: To engage solar thermal electricity into the national electricity energy mix thereby resulting in thousands of tonnes of avoided carbon dioxide into the environment.</td></tr>
<tr><td colspan="3">7. Project specific objectives: To meet or exceed the specific targets set for solar thermal electricity in 2015 and 2025 respectively.</td></tr>
<tr><td colspan="3">Expected outcomes:
Specific targets for solar thermal electricity technology met or exceeded in the target years
Significant contribution of solar thermal electricity to the national energy mix as set in the targets
Creation of thousands of jobs for artisans, technicians, engineers, bankers, project managers
Development of a virile solar thermal electricity manufacturing base in the ECOWAS sub-region
Development of an internationally competitive and export-oriented solar thermal electricity industrial base by the end of 2025 target year</td></tr>
<tr><td colspan="3">9.Planned activities to achieve the outcomes:
Enact the National Fossil Fuel Obligation law at the National Assembly mandating the electricity vendor companies to a minimum stipulated percentage from renewable electricity sources, of which solar thermal electricity is a prominent part
Provide attractive fiscal market incentives for the private sector participation through specific Renewable Electricity Market Incentive Programmes (REMIP)
Standards Organization of Nigeria (SON), together with other stakeholders such as the electricity industry and relevant professional bodies, to develop;
Codes of Practice and Codes of Conduct/Ethics for manufacturers and vendors,
Performance & Technical Standards for: solar thermal electricity technologies, systems, and components
Minimum Specifications to be met for solar thermal electricity systems, components and products for the Nigerian market
Testing procedures, certification scheme, product quality and safety assurance criteria, compliance strategy, standards enforcement and corrective,</td></tr>
</table>

implementable sactions

- Product standardization methodology for the Nigerian and ECOWAS solar thermal electricity industry
- Launch training and certification programmes for artisans, technicians, engineers, business community, banking community, public sector officials, etc. on solar thermal technologies through the national energy centres and other higher institutions and NGOs as soon as possible within the year 2005

10. *Project linkage to national priorities, action plans, and programs:*

- NEEDS programme document
- NAPEP
- National economic growth
- Renewable Rural Energy Programme in the Department of Rural Development, Ministry of Agriculture and Rural Development

11. *Stakeholders involved in project:*

- Government Ministries and Agencies
- Private sector companies and CBOs & NGOs
- International agencies such as UNDP/Global Environmental Facility, GEF
- National energy centres and other higher institutions of learning and research

12. *Implementation arrangement:* The implementing agency is the Energy Commission of Nigeria, ECN, which will coordinate, monitor, assess, evaluate and direct the programme.

Estimated budget and information on how costs will be met: the USD 500 million to be met from:

- Federal government budget
- Allocation of a share of excess crude oil earnings
- National Non-Fossil Fuel Obligation, NNFFO
- International agencies particularly Global Environmental Facility which has approved grants for the first solar thermal electricity projects in Egypt, India, Mexico and Morocco of approximately US$200 million in year 2000.

Potential Projects Concept Notes: Wind Energy

1. *Project title*: **Wind Resource Assessment**		
2. *Potential implementing organizations*:		
3. *Potential Implementation Partners*:		
4. *REMP strategic areas*:	*Renewable energy sub-sector(s)*	
	Area(s) of intervention	
5. *Implementation period*:		
6. *Project overall rationale and objectives*: **Presently, only a few wind maps for limited sites are available, and there is no national or local wind atlas in the country. Hence, there is the to develop wind maps and atlases for the country that will provide information about the quantity, quality, distribution and utilization possibilities to determine the commercial feasibility of wind energy generation and decision making on investments. The overall objective of the project is to develop a comprehensive wind maps and atlases for the country and establish a local wind assessment capability.**		
7. *Project specific objectives:* **These include:** **i. To develop wind maps and atlases for the country;** **ii. To develop a comprehensive wind energy database;** **iii. To provide necessary information/data for decision making on investment in wind energy development in the country;** **iv. To build institutional and technological capacity in the country through transfer of technical know-how regarding wind resource assessment as part of a national wind energy programme**		
8. *Expected outcomes*: **i. Wind maps;** **ii. Wind atlases;** iii. **Local capacity development on wind resource assessment**		
9. *Planned activities to achieve outcomes*: **i. To source for a reputable technical consultant (either a company or an institution) for the project;** **ii. To raise a national team for the project comprising all federal ministries, agencies and parastatals involved in renewable energy in the country. The team should also include private sector, universities and research centre/institutions involved in renewable energy development;** **iii. To set the terms of reference (TOR) and time-table for the project;** **iv. To periodically monitor and evaluate the progress of the project with respect to the TOR.**		
10. *Project linkage to national priorities, action plans, and programs*:		
11. *Stakeholders involved in project*:		
12. *Implementation arrangement*:		
13. *Estimated budget and information on how costs will be met*:		

Potential Projects Concept Notes: Wind Energy Continued

<table>
<tr><td colspan="3">1. Project title: Detailed Wind Farm Measurement Feasibility Study</td></tr>
<tr><td colspan="3">2. Potential implementing organizations:</td></tr>
<tr><td colspan="3">3. Potential Implementation Partners:</td></tr>
<tr><td rowspan="2">4. REMP strategic areas:</td><td>Renewable energy sub-sector(s)</td><td></td></tr>
<tr><td>Area(s) of intervention</td><td></td></tr>
<tr><td colspan="3">5. Implementation period:</td></tr>
<tr><td colspan="3">6. Project overall rationale and objectives:
The results of a wind resource assessment project will be the identification of particular sites that appear promising for wind farm development. When such sites have been identified, detailed site-specific measurements are carried out through the erection of a meteorology mast. Actual measurements are needed because the power output of a wind farm is sensitive to wind speed. Hence, the overall objectives of the project are the measurements to obtain detailed and reliable information on variation in wind speeds and direction over the year, the wind speed frequency distribution, etc. in order to determine the viability or otherwise of the wind farm project.</td></tr>
<tr><td colspan="3">7. Project specific objectives:
i. To select a site for project feasibility analysis;
ii. To carry out the necessary wind measurements;
iii. To carry out an environmental impact assessment (EIA) of the project;
iv. To determine the viability or otherwise of a wind farm project;
v. To build institutional and technological capacity in the country through transfer of technical know-how regarding planning, implementation and operation of wind farms as part of national wind energy programme.</td></tr>
<tr><td colspan="3">8. Expected outcomes:
i. Project feasibility report;
ii. Capacity building on wind farm measurement feasibility study.</td></tr>
<tr><td colspan="3">9. Planned activities to achieve outcomes:
i. To select a site for implementation of the project;
ii. To source for a reputable technical consultant (either a company or an institution) for the project;
iii. To raise a national team for the project comprising all federal ministries, agencies and parastatals involved in renewable energy in the country. The team should also include private sector, universities and research centre/institutions involved in renewable energy development;
iv. To set the terms of reference (TOR) and time-table for the project;
v. To periodically monitor and evaluate the progress of the project with respect to the TOR.</td></tr>
<tr><td colspan="3">10. Project linkage to national priorities, action plans, and programs:</td></tr>
<tr><td colspan="3">11. Stakeholders involved in project:</td></tr>
<tr><td colspan="3">12. Implementation arrangement:</td></tr>
<tr><td colspan="3">13. Estimated budget and information on how costs will be met:</td></tr>
</table>

Potential Projects Concept Notes: Wind Energy Continued

1. *Project title*: **Non-Grid Hybrid System Demonstration Project**

2. *Potential implementing organizations*:

3. *Potential Implementation Partners*:

4. *REMP strategic areas*:	*Renewable energy sub-sector(s)*	
	Area(s) of intervention	

5. *Implementation period*:

6. *Project overall rationale and objectives*:

Access to electricity in the rural areas has been put at about 20%. In many rural areas of the country, there is no access to national grid essentially due to economy of scale and the remoteness of the national grid to such areas. Wind energy, therefore, provides a cost effective option for rural electrification. However, wind is intermittent; hence, it can be augmented with either a photovoltaic (PV) system or a diesel generator plant. This hybrid system could be highly patronized in the country for promoting sustainable energy development, and by implication, sustainable development generally. The overall objective of this project, therefore, is to demonstrate the viability of the hybrid system to boost rural electrification programme and promote sustainable development in the country.

7. *Project specific objectives*

i. **To build a non-grid hybrid system comprising wind energy and either PV system or a diesel generator plant;**

ii. **To provide some initial results and documentation regarding the behaviour of a wind hybrid system for rural electrification in the country;**

iii. **To build capacity on the design, building and maintenance of a non-grid wind hybrid system in the country;**

8. *Expected outcomes*:

i. **Establishment of a wind hybrid system;**
ii. **Documentation on the behavioural pattern of the system;**
iii. **Capacity building on the installation and maintenance of a wind hybrid system;**
iv. **Ability to replicate the project in any other part of the country without employing an international consultant (transfer of technical know-how).**

9. *Planned activities to achieve outcomes*:

i. **To select a site for implementation of the project;**
ii. **To source for a reputable technical consultant (either a company or an institution) for the project;**
iii. **To raise a national team for the project comprising all federal ministries, agencies and parastatals involved in renewable energy in the country. The team should also include private sector, universities and research centre/institutions involved in renewable energy development;**
iv. **To set the terms of reference (TOR) and time-table for the project;**
v. **To periodically monitor and evaluate the progress of the project with respect to the TOR.**

10. *Project linkage to national priorities, action plans, and programs*:

11. *Stakeholders involved in project*:

12. *Implementation arrangement*:

13. *Estimated budget and information on how costs will be met*:

Potential Projects Concept Notes: Wind Energy Continued

<table>
<tr><td colspan="3">1. Project title: A National Wind Energy Technology Centre</td></tr>
<tr><td colspan="3">2. Potential implementing organizations:</td></tr>
<tr><td colspan="3">3. Potential Implementation Partners:</td></tr>
<tr><td rowspan="2">4. REMP strategic areas:</td><td>Renewable energy sub-sector(s)</td><td></td></tr>
<tr><td>Area(s) of intervention</td><td></td></tr>
<tr><td colspan="3">5. Implementation period:</td></tr>
<tr><td colspan="3">6. Project overall rationale and objectives:
Lack of manufacturing capacity of wind energy components will slow down the rapid introduction of wind power into the national electricity supply mix. Experiences from other developing countries like China, India and Egypt show that it is necessary to have some local manufacturing capability as well as technical capacity for maintenance of wind turbines and other components, in order to facilitate a large scale development of wind power. The overall objective of this project is therefore, to establish a wind energy technology centre with a demonstration wind farm, wind turbine test facilities and wind energy assessment tools, to support and demonstrate the ability of Nigeria to manufacture, supply and maintain locally produced wind turbines and other components; and also for the purposes of research, development, development and deployment of wind turbines and other components in the country and even in Africa.</td></tr>
<tr><td colspan="3">7. Project specific objectives
i. To build facilities with control room, test room, classrooms, offices and workshops for the manufacture, repair and maintenance of wind power components;
ii. To supply and install test station equipment;
iii. To set up instrumentation and testing of wind turbines;
iv. To introduce the centre to, and corporate with international test stations for test station activities and other possible collaborative activities;
v. To build institutional and technological capacity in the manufacture, installation, repair and maintenance, instrumentation and testing of wind turbines and other wind power components and on wind energy assessment, as part of a national wind energy programme;
vi. To carry out research, development, demonstration and dissemination of wind energy.</td></tr>
<tr><td colspan="3">8. Expected outcomes:
i. A national wind energy technology centre;
ii. Capacity building on manufacture, installation, instrumentation and testing, repair and maintenance of wind turbines and other components;
iii. Active research and development on wind energy components</td></tr>
<tr><td colspan="3">9. Planned activities to achieve outcomes:
i. To select a site for implementation of the project;
ii. To source for a reputable technical consultant (either a company or an institution) for the project;
iii. To raise a national team for the project comprising all federal ministries, agencies and parastatals involved in renewable energy in the country. The team should also include private sector, universities and research centre/institutions involved in renewable energy development;
iv. To set the terms of reference (TOR) and time-table for the project;
v. To periodically monitor and evaluate the progress of the project with respect to the TOR.</td></tr>
<tr><td colspan="3">10. Project linkage to national priorities, action plans, and programs:</td></tr>
<tr><td colspan="3">11. Stakeholders involved in project:</td></tr>
<tr><td colspan="3">12. Implementation arrangement:</td></tr>
<tr><td colspan="3">13. Estimated budget and information on how costs will be met:</td></tr>
</table>

Potential Projects Concept Notes: Hydrogen, Ocean and Geothermal Energy

<table>
<tr><td colspan="3">1. Project title: New Energy Research and Development Programme (NERDP)</td></tr>
<tr><td colspan="3">2. Potential implementing organizations: Energy Commission of Nigeria in collaboration with other agencies</td></tr>
<tr><td colspan="3">3. Potential Implementation Partners: SHESTCO, NIMOR, CERD, SERC, NERDC</td></tr>
<tr><td rowspan="2">4. REMP strategic areas:
Research and Development</td><td>Renewable energy sub-sector(s)</td><td>Hydrogen, Ocean and Geothermal Energy</td></tr>
<tr><td>Area(s) of intervention</td><td>Research and Development
Capacity Building</td></tr>
<tr><td colspan="3">5. Implementation period: 2005 – 2025</td></tr>
<tr><td colspan="3">6. Project overall rationale and objectives: The overall objective is to conduct research and development on hydrogen, ocean and geothermal energy with a view to preparing these energy sources to play important roles in meeting the energy challenges of Nigeria in a post-fossil economy.</td></tr>
<tr><td colspan="3">7. Project specific objectives: The specific objectives include:

• Providing Nigeria a vision and road map for a post-fossil economy
• Integrating hydrogen into the national energy mix by 2025
• Developing R&D capacity and producing prototypes for tidal and wave technologies
• Providing resource assessment and conducting exploration of geothermal energy
• Positioning Nigeria at the forefront of emerging energy technologies research and development</td></tr>
<tr><td colspan="3">8. Expected outcomes:
• Future national energy security ensured
• Access to energy services to all social segments achieved
• Cost-effective energy services in the future achieved
• Cleaner national energy system developed</td></tr>
<tr><td colspan="3">9. Planned activities to achieve outcomes:
• Identification of relevant centers
• Development of proposals
• Provision of budget lines
• Launching of R&D
• Peer review through international conferences
• Development of technology prototypes
• Development of niche markets</td></tr>
<tr><td colspan="3">10. Project linkage to national priorities, action plans, and programs:

• National security
• Economic growth
• Poverty reduction</td></tr>
</table>

• Environmental sustainability
11. *Stakeholders involved in project*: • Governmental agencies • Private sector • International agencies and R&D centres
12. *Implementation arrangement*: Energy Commission of Nigeria in collaboration with several agencies
13. *Estimated budget and information on how costs will be met*: USD 50 million to be met through: • Federal Government budget • International agencies • Private sector contribution

Annex: Stakeholders Consulted

Centre for Energy Research and Development, Obafemi Awolowo University, Ile Ife
Department of Industrial Technology and Energy Research (DITER) of the Federal Ministry of Science and Technology
Department of Power, Federal Ministry of Power and Steel, Department of Power
Energy Commission of Nigeria
Faculty of Agriculture, UDUS
Federal Department of Forestry
Federal Ministry of Agriculture
Federal Ministry of Environment
Federal Ministry of Science and Technology, Department of Industrial Technology & Energy Research
Federal Office of Statistics
Forest Management, Evaluation and Co-ordinating Unit
International Institute for Tropical Agriculture (IITA), Ibadan
Lagos State University
National Centre for Energy Research and Development (NCERD)
National Planning Commission, Directorate of Infrastructure and Public
National Planning Commission, Directorate of Rural Development
Nigeria Meteorological Agency, Federal Ministry of Aviation
RISØ National Laboratory, Denmark
Sokoto Energy Research Centre
Sokoto State Ministry of Agriculture
United Nations Development Program, Abuja
United Nations Development Program, Sokoto
Utilities

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Features an Overview of European Programs on Ocean Energy

Ocean Thermal Energy Conversion
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Features Information on OTEC, Including its Applications and Resources.

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EUROPA: Energy & Transport
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