**STATUS OF RENEWABLE ENERGY IN NIGERIA**

**BACKGROUND BRIEF FOR**


**An International Conference**
**On Making Renewable Energy A Reality**
**November 21-27,**
**Abuja/Port Harcourt/Calabar, Nigeria**

**ORGANISED BY:**

**ONE SKY-Canadian Institute of Sustainable Living**
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## 1.0 INTRODUCTION

*"I'm convinced the development of renewable energies is a win-win strategy for both industrial and developing countries. Renewables bring together climate protection, poverty reduction, technology development and the securing of jobs"*
*- Jurgen Trittin, German Federal Environment Minister*

Renewable Energy (**RE**)[1] has been talked about for more than thirty years while fossil fuels have increased in use and declined in supply. While significant gains have been made we are currently challenged to make the switch to renewable energy in time to avoid significant environmental and climatic changes. At the recent World Summit on Sustainable Development (WSSD), held in Johannesburg in 2002, energy was one of the most contentious issues. Setting targets for new renewable energy (defined as modern biomass, solar, wind, small-scale hydro, geothermal and marine) as well as reducing perverse and harmful energy subsidies was hotly debated. In the end no target was agreed upon. However, at the final plenary session more than thirty countries announced their commitment to promoting renewable energy sources and setting their own goals. As part of this, Germany agreed to host "Renewables 2004"- a conference in Bonn that will focus on a way forward to substantially increase the proportion of new renewable energy in both industrialized and developing countries (Energetic Solutions, 2004)

One Sky[2], in conjunction with its partners, is hosting an International Conference on "Making Renewable Energy a Reality" in November 2004 in Nigeria. The conference, entitled – ***Energetic Solutions*** **(ES)**, is bid to take the conference in Bonn one step further by "providing a venue for developing a local plan, complete with targets for renewable energy, in a challenging context", which is Nigeria; a country that has been feared "may fall into a fossil fuel trap in spite of the available renewable energy resources".

This background paper was commissioned in order to provide the **ES** participants with a common understanding of the status of **RE** in Nigeria. The information items covered in the paper have been gleaned from available scientific publications sourced from internet and private collections. The Energy Commission of Nigeria (ECN) and Center for Energy Research and Development (CERD), Obafemi Awolowo University (OAU), Ile-Ife provided

[1] Renewable Energy includes solar, wind, hydro, oceanic, geothermal, biomass, and other sources of energy that are derived from "sun energy", and are thus renewed indefinitely as a course of nature. Forms of useable energy include electricity, hydrogen, fuels, thermal energy and mechanical force.
More broadly speaking, Renewable Energy is derived from non-fossil and non-nuclear sources in ways that can be replenished, are sustainable and have no harmful side effects. The ability of an energy source to be renewed also implies that its harvesting, conversion and use occur in a sustainable manner, i.e. avoiding negative impacts on the viability and rights of local communities and natural ecosystems (WCRE)

[2] One Sky - The Canadian Institute of Sustainable Living (www.onesky.ca).One Sky's mission is to promote sustainable living globally. It was founded to foster a global perspective on environmental and social issues with a particular emphasis on the links between the developing world and Canada. One Sky explores and promotes practical solutions and appropriate technologies for our environmental, social and economic challenges. One Sky started in the year 2000 in Smithers, BC to form an international partnership with Sierra Leone.

the National Energy policy document and a brief on CERD, respectively. Also, a brief on the Jigawa State Solar Village-Electrification was provided by Solar Electric Light Fund (SELF). In addition, the outcomes of two (2) previous national meetings related to **RE** were reviewed, namely: (i) National workshop on "Energizing Rural Transformation in Nigeria: Scaling up Electricity Access and Renewable Energy Market Development", March 19-20, 2001, Abuja, Federal Ministry of Power and Steel & Co; (ii) National Stakeholders Forum on Rural Industrialization and Development through RETs, December 2002, Abuja, UNIDO & the Energy Commission of Nigeria (ECN).

In this background paper, indications have been provided on the following:

- Renewable energy potentials in Nigeria
- Level of political support for renewable energy in Nigeria
- Capacity development in Nigeria
- Current industry capacity
- Renewable energy project Initiatives
- Future prospects for renewable energy
- Barriers to renewable energy and priorities for action

## 2.0 RE RESOURCES / POTENTIALS IN NIGERIA

Nigeria is an energy resource rich country (fig.1) blessed with both fossil such as crude oil, natural gas, coal, and renewable energy resources like solar, wind, biomass, biogas, etc. Similarly, Nigeria is also human resource rich with a total population of 88.5 million by the 1991 population census, and an annual population growth rate of about 2.8% (Akinbami et al, 2001)

### 2.1 Nigeria's Energy Scene

The National energy supply is at present almost entirely dependent on fossil fuels and firewood (convenstional energy sources) which are depleting fast.

According to Chendo (2001) recent estimates indicated that the reserve for crude oil stood at about 23 billion barrels in 1998, natural Gas 4293 billion $m^3$ at the beginning of 1999, made up of 53% associated gas and 47% non associated gas. Coal and lignite stood at 2.7billion tones, tar sands at 31 billion barrels of oil equivalent and large scale hydropower at 10,000MW.

Tables 1 and 2 show various conventional and non-conventional energy sources and their estimated reserves in Nigeria.

**Table 1: Nigeria's Conventional Energy Resources (Chendo, 2001)**

| Resources | Reserve | Resources in Energy units (billion toe) | % Total Conventional Energy |
|---|---|---|---|
| Crude Oil | 23 bilion barrels | 3.128 | 21.0 |
| Natural Gas | 4293 billion $m^3$ | 3.679 | 24.8 |
| Coal & Lignite | 2.7 billion tones | 1.882 | 12.7 |
| Tar Sands | 31 billion barrels of oil equivalent | 4.216 | 28.4 |
| Hydropower | 10,000 MW | 1.954 (100 years) | 13.1 |
| Total | Conventional/commercial Energy Resources | 14.859 | 100% |

**Note:**

| | | |
|---|---|---|
| Toe | = | Tonnes of oil Equivalent |
| 1 barrel of Oil | = | 0.136 tonnes of oil |
| 100$m^3$ of Natural Gas | = | 0.857 toe |
| 1 Tonne of coal | = | 0.697 toe |
| 100 kWhr (Primary energy) | = | 0.223 toe |

**Table 2: Nigeria's Non Conventional Energy Resources (Chendo, 2001)**

| Resource | Reserves | Reserves (billion toe) |
|---|---|---|
| Fuelwood | 43.3 Million tones | 1.6645 (ove 100 years) |
| Animal Wastes & Crop Residue | 144 Million Tonnes/Year | 3.024 (Over 100 years) |
| Small Scale Hydro Power | 734.2 MW | 0.143 (over 100 years |
| Solar Radiation Wind | 1.0 kW per $m^2$ land area (peak) | - |
| Wind | 2.0 – 4.0 m/s | - |

**Note:**

| | | |
|---|---|---|
| 1000 kWhr (primary energy) | = | 0.223 toe |
| 1 Tonne of Fuelwood | = | 0.38 toe |
| 1 Tonne of Agric waste | = | 0.28 toe |
| 1 Tonne of Drug Cakes | = | 0-.21 |

**Energy Supply Mix in Nigeria**

The 1995 distribution of energy consumption (Figure 2), typifies the current energy supply mix in the country. It shows that of the total energy consumption, the share of natural gas was 5.22%, hydroelectricity took 3.05%, fuelwood had the lion share of 50.45% and petroleum products had 41.28% share. This further confirms the fact that presently, renewable-energy use in the country is split essentially between hydroelectricity and traditional fuel wood (Akinbami, 2001).

**Economic Sectors and Energy Patterns**

From the energy point of view, the Nigerian economy can be disaggregated into industry, transport, commercial, household and agricultural sectors. However, the household sector presently dominated energy consumption in Nigeria. This makes it the most important energy sector of the Nigerian economy (Oladosu and Adegbulugbe, 1994)

The household sector has consistently accounted for over half of Nigeria's total domestic energy consumption. In 1989 its share was about 65% (Figure 3). This alone is enough to highlight the importance of the sector in the Nigerian energy system. However, an analysis of the final energy composition of this consumption is even more revealing.

According to Oladosu and Adegbulugbe (1994), the energy consuming activities in the sector are cooking, lighting and operation of electrical appliances (non-substitutable electricity). In 1989 the shares of these activities in final energy consumption were 91%, 6% and 3% respectively. Total final energy consumption was 487 PJ. The major energy carriers are fuelwood, kerosene, liquelified petroleum gas (LPG) and electricity. Small amounts of charcoal and coal are also used. Fuelwood is mainly consumed in this sector and accounted for over half of total national energy consumption in 1989. A small amount is consumed in

rural industries and the commercial sector. This means that fuelwood constitutes about 80% of total residential final energy consumption (figure 4).

**Nigeria's Energy Resources likely Depletion Time**

In a 1997 analysis, Akinbami (1997) arrived at the following estimates:
By year 1989, Nigeria's oil reserve is expected to have reached 20 billion barrels and production should have also increased from 1.89 million barrels per day (mbpd) to 2.5 mbpd. This implies that the reserve/production ratio or the depletion time of Nigeria's **crude oil** if there no further efforts to increase the reserve and if he production still remains at the expected 1989 level, may be within the next **25-30 years** . Presently, the natural gas reserve stands at 106 tillion cubic feet (tcf) (about 178 billion barrels of oil equivalent) and by 2010, another 60 tcf (about 10 billion barrels of oil equivalent) is expected to have added to the reserves if the drilling activity continues at current levels. This will bring total natural gas reserve to 166 tcf (about 27.8 billion barrels of oil). Production of gas ranges between 2200-2500 million cubic feet per day (about 369,000-420,000 barrels of oil per day). The annual Capacity of Nigeria's liquelified natural gas (LNG) project is 4.6 million tones (41.96 million barrels of oil equivalent per annual. The nation's international trade volume in liquiefied natural gas (LNG) is expected to reach about 5.5 billion $m^3$ (about 33. million barrels of oil equivalent) in 2000 and between 12-15 billion $m^3$ (about 72-90 million barrels of oil equivalent) in 2010. Using the production upper figure which amounts to 153.3 million barrels of oil equivalent per annum, then the depletion time of Nigeria's **natural gas** may be in the next **180 years**. Coal is very abundant in Nigeria and estimate of reserves is over 2.75 billion tones of which about 639 million tones is proven. As at 1990, production was 157,000 tonnes but this is expected to increase especially with the recent acceptance of Nigeria coal as of high grade value. Assuming an average modest production figure of about 500,000 tonnes per annum and if there is no addition to the proven reserve, this will make the nation's **coal** depletion time to be **1,278 years** from now. However, the reserve/production ratio of coal may be less than this bearing in mind that there is the likelihood of increased demand for Nigeria's coal globally.

Akinbami (1997) also indicated that a comparison between the historical consumption and supply patterns reveals that the demand for wood (especially fuelwood) outstrips the natural regeneration of the forestry stock. At the present rate, the nation's forestry stock may well be depleted within 50 years if the trend is allowed to continue.

## 2.2 Renewable Energy Potentials

**Small Scaled Hydro Power**

Aliyu and Elegba (1990) indicated that the country is, at least, reasonably endowed with large rivers and some few natural falls. The Rivers Niger and Benue with several tributaries constitute the Nigerian river system which offers some potential renewable source of energy for economically viable large hydropower development. In addition, several scores of small rivers and streams also exist within the present split of the country into eleven River Basin Authorities, some of which maintain minimum discharge all the year round (Figure 5).

The total technically exploitable hydropower potential based on the country's river system is conservatively estimated to be about 10,000 MW of which only 19% is currently being tapped or developed. Deserving more attention in Nigeria than hitherto, therefore, is the potential contribution of distributed small hydro schemes for dispersed energy needs of scattered rural communities (Aliyu and Elegbam, 1990).

Aliyu and Elegba are of the view that from the definitions and classifications of various hydro Schemes provided in Table 3, the small, mini and micro hydro schemes hereafter referred to as small scale are of specific interest for the task of meeting part of the energy requirements of some rural communities.

Table 3: Classification of various Hydro Schemes (Aliyu and Elegba, 1990)

| Scale of Hydo Scheme | Capacity Range (MW)* |
|---|---|
| Large | > 100 |
| Medium | 50-100 |
| Intermediate | 10-50 |
| Small | 1-10 |
| Mini | 0.5-1 |
| Micro | < 0.5 |

*Largely Applicable to Nigeria and other Developing counties

Table 4 illustrates the distribution of overall small scale hydro potentials among seven Nigerian River Basin Authorities. Table 5 further presents the same hydro potential distributions among the corresponding Nigerian States.

**Table 4 : Overall Distribution of Small-Scaled Hydropower Potential among Seven River Basins**

| S/N | Rivers Basin | Status | Type Capacity | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Micro | | Mini | | Small | |
| | | | No. | Cap.(MW) | No. | Cap.(MW) | No. | Cap(MW) |
| 1. | Sokoto-Rima | D | - | - | - | - | 1 | 3.0 |
| | | U | 10 | 3.2 | 11 | 8.4 | 10 | 29.6 |
| 2 | H-J | D | - | - | - | - | 1 | 6.0 |
| | | U | 8 | 2.8 | 20 | 11.4 | 7 | 31.6 |
| 3 | Chad | D | - | - | - | - | - | - |
| | | U | 10 | 2.8 | 8 | 6.8 | 2 | 5.6 |
| 4 | Niger | D | - | - | - | - | - | - |
| | | U | 16 | 6.4 | 23 | 18.2 | 22 | 191.0 |
| 5 | UB | D | - | - | - | - | - | - |
| | | U | 8 | 3.2 | 36 | 27.0 | 25 | 185.1 |
| 6 | LB | D | - | - | - | - | 5 | 19.0 |
| | | U | 11 | 4.4 | 23 | 19.2 | 17 | 138.0 |
| 7 | CR | D | - | - | - | - | - | - |
| | | U | 7 | 1.7 | 6 | 4.6 | 5 | 21.8 |
| | Total | D | - | - | - | - | 7 | 28.0 |
| | | U | 70 | 24.5 | 126 | 95.6 | 86 | 704.1 |

Source: Aliyu and Elegba, 1990

H-J= Hadejia-Jama'are; UB= Upper Benue; LB= Lower Benue; CR= Cross River; D= Developed U= Undeveloped

**Table 5: Summary of Small Hydropower Potential Distribution According to States**

| **States**** | **River Basin*** | | **Hydropower Potential** | | |
|---|---|---|---|---|---|
| | | **Total Sites** | **Developed (MW)** | **Undeveloped (MW)** | **Total Capacity (MW)** |
| Sokoto | Sokoto-Rima | 22 | 8.0 | 22. 6 | 30. 6 |
| Katsina | Sokoto-Rima | 11 | | 8.0 | 8.0 |
| Niger+ | Niger | 30 | | 117. 6 | 117. 6 |
| Kaduna | Niger | 19 | | 9.2 | 59.2 |
| Kwara+ | Niger | 12 | | 38.8 | 38.8 |
| Kano | Hadejia-Jama'are | 28 | 6.0 | 40.2 | 46.2 |
| Bornoi | Chad | 28 | | 20.8 | 20.8 |
| Bauchi | Upper Benue | 20 | | 42. 6 | 42. 6 |
| Gogola+ | Upper Benue | 38 | | 12.7 | 162.7 |
| Plateau | Lower Benue | 32 | 18.0 | 92.4 | 110.4 |
| Benue+ | Lower Benue | 19 | | 9.2 | 69.2 |
| Cross River+ | Cross River | 18 | | 28.1 | 28.1 |
| Total | | 277 | 32 | 702.2 | 734.2(MW) |

*Large overlapping River Basin only

**Information Available for only 12 states

+States with either developed or technically exploitable, intermediate, medium and large hydro scheme

Source: Aliyu and Elegba, 1990

**Wind Energy Potentials**

Globally, Nigeria is located within low to moderate wind energy zone (fig. 6). Ojosu and Salawu (1989) carried out the most comprehensive nationwide study on wind energy availability and potential in Nigeria. The study uses Data on Wind speeds and directions for 22 meteorlogical Stations from the Nigerian Meteorological office, Oshodi near Lagos. The meteorological data are based on the 3-hourly records of wind for periods ranging from 12 to 33 years (1951 – 1983)

The isovents at 10m heights are drawn and four different wind zones/regimes are identified as shown in figure 7. The wind energy potential for wind energy utilization in Nigeria is broadly appraised as shown in Appendix 1 (Ojosu and Salawu, 1990).

Ojosu and Salawu estimated the maximum energy obtainable from a 25m diameter wind turbine with an efficiency of 30% at 25m height to be about 97 MWh $year^{-1}$ for Sokoto, a site in the high wind speed regions, 50 MWh $year^{-1}$ for Kano, 25.7 MWh $year^{-1}$ for Lagos and 24.5 MWh $year^{-1}$ from Port Harcourt. Appendix 2 shows the wind energy densities for other sites. (Ojosu and Salawu, 1990).

**Solar Energy Resources in Nigeria**

According to Bala et al (2000), Nigeria is endowed with an annual Average daily sunshine of 6.25 hours, ranging between about 3.5 hours at the coastal areas and 9.0 hours at the far northern boundary (Figure 8). Similarly, it has an annual average daily solar radiation of about 5.25 $KW/m^2/day$, varying between about 3.5 $kWm^2/day$ at the coastal Area and 7.0kW/m2/day at the northern boundary (8). Nigeria receives about $4.851x\ 10^{12}$ KWh of energy per day from the sun. This is equivalent to about 1.082 million tones of oil Equivalent (mtoe) per day, and is about 4 thousand times the current daily crude oil reduction, and about 13 thousand times that of natural gas daily production based on energy unit. This huge energy resource from the sun is available for about 26% only of the day. The country is also characterized with some cold and dusty atmosphere during the harmattan, in its northern part, for a period of about four months (November-February) annually (13). The dust has an attenuating effect on the solar radiation intensity (Bala, et al, 2001)

Based on the land area of $924 \times 10^3\ km^2$ for the country and an average of 5.535 $kWh/m^2/day$, Nigeria has an average of $1.804 \times 10^{15}$ kWh of incident solar energy annually. This annual solar energy insolation value is about 27 times the nation total conventional energy resources in energy units and is over 117,000 times the amount of electric power generated in the county in 1998 as depicted in Table 6 (Chendo, 2002.)

In other words, about 3.7% only of the national land area is needed to be utilized in order to annual collect from the sun an amount of energy equal to the nation's conventional energy reserve.

**Table 6: Solar energy resources in comparison to others in Nigeria**

| | Annual solar Energy Insolation | Conventional Energy Reserve (1999) | Electricity Generated (1988) |
|---|---|---|---|
| Energy (kWh) | $1.804x10^{15}$ | $6.663x10^{13}$ | $15.11x10^{9}$ |
| Ratio | 27.1:1 | 1:1 | 0.00023:1 |
| | 117826:1 | 4347.8:1 | 1:1 |

Source: Chendo, 2002

**Biomass**

The biomass resources of Nigeria can be identified as wood, forage grasses and shrubs, animal as waste arising from forestry, agricultural, municipal and industrial activities, as well as, Aquatic biomass. The biomass resources of the nation have been estimated to be about 8 x $10^2$ M.J. Plant biomass can be utilised as fuel for small-scale industries. It could also be fermented by anaerobic bacteria to produce a very versatile and cheap Fuel Gas i.e biogass (Garba and Bashir, 2002).

**Biogas Energy Resources**

Akinbami et al (2001)'s assessment indicated that in Nigeria, identified feedstock substrate for an economically feasible biogas programme includes water lettuee, water hyacinth, dung, cassava leave, urban refuse, solid (including industrial) waste, agricultural residues and sewage. Tables 7 and 8 present the various agricultural and livestock resources and their associated residues as the potential substrates for biogas production in the country. Akinbami et al (2001)'s views include the following; Nigeria produces about 227,500 tons of fresh animal wastes daily. Since 1 kilogram (kg) of fresh animal wastes produces about 0.03 $m^3$ gas, then Nigeria can produce about 6.8 million $m^3$ of biogas every day. In addition to all these, 20kg of municipal solid wastes (MSW) per capital has been estimated to be generated I the country annually. By the 1991 census figure of 88.5 million inhabitants, the total generated MSW will be at least 1.77 million tones every year. With increasing urbanization and industrialization, the annual MSW generated will continue to increase. Biogas production may therefore be a profitable means of reducing or even eliminating the menace and nuisance of urban wastes in many cities by recycling them.

**Table 7: Agricultural Resources and residues in Nigeria for 1992 (Akinbami et al, 2001**)

| **Resources** | **Production ($10^3$ ton)** | **Residue ($10^3$ ton)** | **GJ** |
|---|---|---|---|
| Industrial wood+fuel | 214250 | 85700 | 80.5580 |
| Wood+charcoal | - | - | - |
| Cereals | 12403 | 16124 | 207540 |
| Roots and tubers | 41602 | 16641 | 106502 |
| Sugarcane | - | - | 3.097 |
| Cotton | 276 | 358.8 | 6.387 |
| Coconuts | 135 | 175.5 | 2246 |
| coffee (Green) | 3 | 3.9 | 50 |

**Table 8 Livestock resources and residues in Nigeria in 1992** (Akinbami et al, 2001)

| Resources | Stock ($10^3$ head) | Residue (GJ) |
|---|---|---|
| Cattle | 15,700 | 32342 |
| Sheep and Goats | 37,500 | 15375 |

Presently, biogas is not in the national energy equation. However this not to say that already a few units of biogas digesters are not in use both in the urban and rural segments of the country for various activities.

Based on a study that a 6.0 $m^3$ family sized biogas digester will generate 2.7 $m^3$ of biogas (about 79.11 MJ) and a probable suitable enabling environment, the likely trend of energy that can be obtained from family-sized biogas digester in the country is depicted by Akinbami et al (2001) as in Figure 9.

**Other Resources**

Presently, the potentials of some the resources like geothermal, waves, tidal and ocean thermal gradients still remain unqualified (Garba and Bashir, 2002).

## 3.0 ENERGY/ RENEWABLE ENERGY POLICIES/PROGRAMMES

**Institutional arrangements in the Renewable Energy Sub-Sector**

The primary governmental agency for the development and promotion of Renewable energy technologies in the country is the Energy Commission of Nigeria, which is under the Presidency. Its mandate includes strategic energy planning; policy co-ordination and performance monitoring for the entire energy sector, laying down guidelines on the utilization of energy types for specific purposes; developing recommendations on the exploitation of new sources of energy. Renewable Energy is therefore a component of its mandate (Iloeje, 2002).

**National Policy Position on RE Development**

The key elements in the national policy position on the development and application of renewable energy and its technologies are as follows (Iloeje, 2002):

- to develop, promote and hardness the Renewable Energy (RE) resources of the country and incorporate all viable ones the national energy mix
- To promote decentralized energy supply, especially in rural areas, based on RE resources
- To de-emphasize and discourage the use of wood as fuel
- To promote efficient methods in the use biomass energy resources
- To keep abreast of international developments in RE technologies and applications

**Relevant Statutes and Documents**

The current Electric Power Sector Reform Bill derives from the National Electrical Power Policy. The Central thrust of the policy is a three-stage legal and regulatory reform of the power sector as follows:

Transitional Stage – Private power generation through Independent Power Producers (IPPs) and Emergency Power Producers (EPPs); corporate restructuring and unbundling of NEPA through sale or license of all thermal plants to private operators and the subsequent privatization through the transfer of management, ownership and control of distribution companies; establishment of transition market rules based on bilateral contracts between generators and distributors; establishment of a Special Purpose Entity (SPE) to take over NEPA's legacy debt, pension fund, unpaid taxes and PPA liabilities; establishment of a multi-year tariff order containing comprehensive tariff charging principles and formular; establishment of the Nigerian Electricity Regulatory Commission.

Medium Term (3 to 5 years after the unbundling and privatization is completed) – Competition among generating companies; energy trading between generation and distribution companies; sale of energy by companies generating power in excess of their needs to distribution companies.

Long-run Competition Structure (Beyond 5 years) – power generation, transmission and distribution companies will be operation optimally; economic pricing of electricity to cover the full costs of supply; opportunity for large industrial consumers to choose their suppliers.

The main objectives of the current reforms in the Nigerian power sub-sector are as follows (Edjekumhene, 2003):

1. Promote competition to facilitate more rapid provision of service throughout the country;
2. Create a new legal and regulatory environment for the sector that establishes a level playing field, encourage private investment and expertise, and meet social goals;
3. Unbundle the National Electric Power Authority (NEPA); and,
4. Privatise the successors to NEPA and encourage them to undertake an ambitious investment programme.

The Energy Commission of Nigeria Act, which established the Energy Commission of Nigeria (ECN) was enacted in 1979. The ECN was charged with responsibility for co-ordinating and general surveillance over the systematic development of the various energy resources of Nigeria.

A National Stakeholders Forum on Rural Industrialisation and Development through RETs was held in December 2002. The forum was organised by the UNIDO and the Energy Commission of Nigeria (ECN).

At the end of the forum an 18-point recommendation, on how Nigeria can access clean, affordable and efficient energy services were made (See section 8 of this report).

**Renewable Energy Programmes**

Some RE programmes of government (through its agencies) are identified by Iloeje (2002) as follows:

- **RE-Training**

Training in RE Science and Technology takes pace at the NCERD and SERC through seminars, workshops, conferences and R&D projects. Some of the R&D work are done in cooperation with academic departments in the Universities that host the Centres. While regular postgraduate work in universities have RE specializations, the National Board for Technical Education(NBTE) is considering the introduction of RE courses in the curricula of the polytechnics. The Solar Energy Society of Nigeria holds an annual conference on RE while some other environmental NGOs occasionally run workshops on RE related environmental issues. Finally, the ECN runs an annual training workshop for Youth Corpers on the fabrication and operation of selected RE devices

- **RE Information Dissemination**

The ECN publishes and distributes booklets and manuels on Re in general and selected technologies in particular, such as on RE Potentials in Nigeria, Solar PV Technology, Biodigesters, Solar Dryers, Improved Woodstoves, etc. The Energy Commission also sponsors TV programmes aimed at popularizing RE technologies. Other existing means of information dissemination are proceedings of workshops and conferences, the journal of the Solar Energy Society of Nigeria and the Renewable Energy Journal published by the SERC.

- **Pilot & Demonstration Projects**

A very important part of the Energy Commission's RE promotional activities is the establishment of pilot and demonstration projects, which are summarized in Table 9 below

**Table 9: RE Pilot and Demonstration Projects of the ECN**

| Technology | Applications | Capacity Range | No |
|---|---|---|---|
| Solar-PV | Village Electrification<br>Village TV<br>Health Center Power<br>Water Pumping<br>Telecommunications | 0.88 – 7.2kWp | 11 |
| Wind Generator | Village Lighting | 5kW | 1 |
| Solar Dryer | Rice and Forage Dry | 1.5 – 2 tonnes | 4 |
| Biodigester | Production of Biogas using cowdung, pig waste, chicken droppings, cassava peelings, human waste | 10 – 30$m^3$ | 6 |
| Hot Water Heater | Hospital Hot Water | 800 liters | 1 |
| Improved Woodstoves | Community Promotion Projects for Cooking | 80 – 200 persons per day | |
| Chick Brooder | Chick Brooding | 100 – 200 Birds | 7 |

- **World Solar Programme**

Nigeria participates in the UNESCO World Solar Programme (UNESCO – WSP) aimed at the promotion of market penetration of RE technologies worldwide. It is an initiatve of UNESCO, approved by the UN General Assembly, and is to be funded from donor and counterpart sources. Nigeria has 8 high priority projects approved for the programme, namely:

i. Integrated rural village energy supply (solar village)
ii. Development and dissemination of efficient biomass stoves and ovens, and briquetting technology
iii. Popularization of biogas and biofertilizer technology
iv. Upgrading the facilities and personnel of renewable energy R&D establishments, and development of RE curricula
v. Training workshops and colleges in RE technologies (Solar-PV and Solar-thermal)
vi. Rural health delivery and potable water supply using solar-PV
vii. Establishment and operation of fuel woodlots
viii. International Solar Energy Institute

The projects are threatened by inadequate funding. As a result, only projects (i) and (vi) have made significant progress

## 4.0 CAPACITY DEVELOPMENT IN NIGERIA

**Institutions**

The ECN has two renewable energy centers under it, namely, National Centre for Energy R&D (NCERD) at Nsukka and the Sokoto Energy Research Centre (SERC) whose mandates are to carryout R&D, manpower Development dissemination and promotion of renewable and alternative energy technologies. There are other agencies that have significant renewable energy components in their programmes, as shown below (Iloeje, 2002):

Federal Department of Meteorological Services (FDMS)
National Electrical Power Authority (NEPA)
Nigerian Building and Road Research Institute (NBRRI)
Project Development Institute (PRODA)
Universities and Polytechnics (UAP)
Federal Institute of Industrial Research, Oshodi (FIIRO)
National Centre for Energy Research and Development (NCERD)
Centre for Energy Research and Training, ABU, Zaria (CERT)
Centre for Energy Research and Development, OAU, Ile-Ife (CERD)

**Some Renewable Energy Technology Developments**

As a consequence of R&D work in renewable energy technologies at the energy research Centres, some other research institutes, Universities and Polytechnics, a number of RE conversion devices have been developed. Some of these include (Iloeje, 2002):

- **Solar Crop Dryers**

These have ranged from small experimental cabinet dryers, through demonstration small size forced circulation dryers, to large scale natural circulation dryers. The latter include a 2-tonne capacity rice dryer developed at the NCERD and a 2-tonne capacity forage dryer constructed by the SERC

- **Solar Manure Dryer**

A natural circulation solar manure Dryer for the drying of poultry waste and similar materials was developed at the NCERD. The existing model has a capacity of over 71kg of Wet manure. On a test day with peak solar intensity of 600 $W/m^2$ it reduced the moisture content of the manure from 71% to 35% (wb) in 22 hours

- **Solar Cookers**

Both the flat plate and concentrating versions have been constructed and tested at the NCERD and SERC. The flat plate version could cook rice and beans in 4.5 minutes at solar intensities of about 850W/m2. A major shortcoming of the technology is the need for outdoor cooking during high solar intensity periods of the day.

- **Solar Water Heater**

Horizontal and vertical tank, natural circulation solar water heaters have been construced. A family size model with a tank capacity 70 litres can generate water at 50 – 70$^oC$ on an

averagely sunny day. An 800 liter capacity model is available at the Usman Danfodiyo University Teaching Hospital, Sokoto

- **Sola Chick Brooders**

In place of electricity, kerosene or gas heated chick brooders for the conditioning of brooder space temperatures (at 35 – 25°C) over the first four weeks of life, the NCERD has developed a natural circulation solar-heated chick brooder. 100 and 200 bird capacity models have been constructed and extensively tested. Chick weight Gain and mortality rates were better than those reported for kerosene heated brooders

- **Biodigesters**

An efficient environmentall clean way of utilizing biological wastes is through their use as feedstock for bio-digesters for the production of biogas and biofertilizer, through an anaerobic process. The biogas is composed roughly of 65% $NH_3$ and 35% CO2 and has a hi calorific value, while the solid effluent is a nitrogen rich, pathogen deficient, manure. Biodigesters of the fixed and floating dome types have been constructed in the country, especially by the SERC and NCERD. Capacities range from small laboratory prototypes to 30 m3 plants, while cow dung, chicken waste, cassava peelings, pig waste and human waste have been used as feedstock

- **Improved Wood and Other Solid Fuel Stoves**

Fuelwood and other biomas fuels are estimated to constitute over 50% of the total
National energy consumption. The prevalent stove is the stone type or versions of it, with thermal efficiencies of 5-10%. These facts have created multiple environmental problems through contributing to increased deforestation, combustion related health hazards and global warming

Improved wood anD solid fuel stoves of Various Designs have been constructed at the SERC and NCERD. They include 1, 2, 3, and 4 metal frame, or sheet metal cladding lined internally with burnt clay insulation. Some designs are fitted with chimneys. Some of the stoves are appropriate fr the combustion of charcoal and coal bridquettes. With thermal efficiencies in the range of 19-25%, their use will greatly reduce fuelwood consumption

- **Solar-PV Equipment and Systems**

Apart from some limited work on materials for solar cell production at Obafemi Awolowo University IIe-Ife, and thin film Growth at the NCERD, Nsukka, most of the studies on Solar-PV in the country have been on components and systems testing, economic viability studies, pilot plant and other application projects. The largest single pilot plant is 7.2kW village electrification project at KwalkwalaWa in Sokoto State, put up by the Energy Commission are for Water pumping, health center power supply and village lighting and TV viewing.

- **Wind Power**

A number of wind powered water pumps have been installed in some northern states, notably at Goronyo in Katsina State, Kedada in Bauchi States and in Sokoto State. Presently, a 5KW pilot wind turbine/generator is under tests at Sayya Gidan-Gada village in Sokoto State. The performance so far is satisfactory.

- **Other Developments**

Other developments include solar air heaters, solar absorption and absorption refrigerators, solar stills for water purification, sawdust stoves, etc.

- **Renewable Energy Data**

Considerable work has been done in the area of Atmospheric physics and in the collection of renewable energy related data. These include solar radiation intensities (global, direct and diffuse) wind speeds and directions, relative humidities, precipitation and ambient temperatures. The Department of Meteorological Services is the agency charged with responsibility for the collection, storage and dissemination of meteorological data in the country. It collects data for 64 towns,-one third of whose stations have been in existence for over 50 years. The Physics Department University of IIorin, runs a Centre for the Study of Atmospheric Physics. Also at least 12 other Research Institutes/Centres and Universities in the country are significantly involved in the collection and analysis of solar and other meteorological data. Finally, the Energy Data Bank being developed by the Energy Commission of Nigeria has provisions for Renewable Energy Data

## 5.0 CURRENT INDUSTRY CAPACITY

A Sample List of RE Industry Actors in Nigeria is Provided in appendix 3

**Commercial Activities in RE**

At present, significant commercial activities in RE technology is limited to solar PV. A national survey by the Energy Commission reveal a total of 33 companies that Were active in Solar PV by 1999. Most of them were established within the last ten years. All of them Were vendors or contractors for the supply and/or installation of solar-PV equipment and systems, with some of them Representing foreign manufacturers. There Was, and still is, no local manufacture of the major solar-PV system compoents including modules controllers, inerters and solar batteries. The only key system components that are locally produced are such Standard electrical components as cables, switchgear, overlaod protectors and consumers units. The slow growth in the demand for solar PV systems is largely responsible for the absence of manufacturing activity (Iloeje, 2002)

**Solar PV industry in Nigeria**

There are over 200 solar PV installations, in the country as At 1998, with capacities ranging from 3.5 to 7.2 kWp. A survey of one hundred and nine solar PV installation conducted, in 1995 over the ten Northern states, revealed the distribution in application, by type, as follow (Bala et al, 2000):

| | |
|---|---|
| Water pumping (domestic) | 57% |
| Rural clinic (refrigeration and lighting) | 24% |
| CommunicaTions (Tele and radio) | 10% |
| Village and Domestic Lighting/TV Viewing | 8% |
| Experimental Room Air conditioning | 1% |

According to Bala et al (2002), the basic solar cell is not yet produced within Nigeria. Modules and panels are, therefore, imported from abroad. Similarly, other components like Regulators, inverters, etc are also imported from offshore. However, electrical cables, supporting frames and fasteners are locally sourced, providing good opportunity for linkages between the relevant industries.

## 6.0 RE PROJECT INITIATIVES

Some striking examples of RE project initiatives in Nigeria are provided in this section.

**Village Electrification in Jigawa State**
In 2001, Solar Electric Light Fund SELF), an NGO based in USA, and Jigawa State Government initiated a proposal to bring solar-generated electricity (PV) to power essential services in 3 villages of Jigawa State. The project information brief are as presented below (SELF, 2004). Further information items on the project are provided in Appendix 4.

Funding Support: United States Government through USAID and Department of Energy (60%); Jigawa State Government (40%)

Project Goal: to demonstrate the comprehensive use of solar-generated electricity in a village setting to improve education, water supply, health, agriculture, commerce, security, and women's opportunities

Many projects scattered around the globe feature single or more limited use of PV technology such as in providing home lighting or vaccine refrigerators or water pumping. This project, while including the aforementioned applications, goes further by addressing virtually all of the things that a community needs electrical energy for nine types of PV systems were developed for this project and are described below. Unless noted, one of each type of system was installed in each village.

1. Community Water Pumping. The powerful solar-powered pumps supplied with this project are designed to run maintenance free for eight to ten years or more and are currently supplying the villages with clean, fresh water.

2. Village Health Clinics. Solar lights enable health workers to see patients at night for the first time, vaccine refrigerators allow more effective vaccination programs and fans increase patient comfort.

3. Village Schools. Illuminated classrooms are allowing adult education classes for the first time and a place for children to work on their lessons. The headmasters have received computers and computer training.

4. Streetlights. In a hot climate where people enjoy the cool of the evening, lights provide safe gathering places for socializing and commerce. Ten to twelve lights were installed in each village.

5. Mosque Lighting. Lighting makes nighttime activities possible and a public address system facilitates the call to prayer.

6. Micro-enterprise Centers. The centers have been constructed to provide electricity to 6 very small businesses in each village. The shared PV systems, much less expensive than individual systems for each shop, increase productivity and income for tailors, barbers,

electronic repairmen and other businesses. A micro-credit scheme helped some of the businesses buy electric appliances.

7. Home Lighting Systems. Approximately 20 home lighting systems were installed in each village to demonstrate lighting that is better, safer and no more costly than the kerosene lamps they replace. Better lighting in the homes supports home businesses and education.

8. Mobile Solar Irrigation Pumps. In the one project village that has a year-round source of surface water, efficient solar-powered pumps help the poorest farmers grow crops during the dry season to provide a critical inflow of food and cash into the village.

9. Groundnut Oil Expeller. The making and selling of groundnut oil is one of the few sources of income for village women. A solar-powered expeller installed in one project village saves time and labor while earning more income for women.

SELF was the lead implementing organization and partnered with the Jigawa Alternative Energy Fund (JAEF), a non-governmental organization formed to promote the use of renewable energy in Northern Nigeria. Installation began in June of 2003 and was completed in April of 2004. This project is now fully operational and is demonstrating the transformative effect that a sustainable source of electricity has on village life in the areas of health, education, water supply, security and economic development.

**Existing Small Hydropower Schemes**

There are few small hydropower plants currently operating in Nigeria that have been constructed simply because they constitutes, among other competing alternatives, the most cost-effective means of providing cheap and Reliable electricity for the intended end uses. Table 10 presents such existing small hydropower plants including one yet to be completed (Aliyu and Elegba, 1990).

According to Aliyu and Elegba (1990) the first five hydro plants of Table, built and managed by Nigerian Electric Supply Company (NESCO), essentially harnessed some of the natural falls that abound in the Jos Plateau region of Nigeria. The main purpose remained until early seventies, the provision of cheap power Requirements of the mining companies and other load centers in that Area. With the subsequent extension of the national grid to Jos metropolis and immediate environs, the current services of the hydro stations are now largely restricted to rural electricity supplies. The other existing small hydropower projects of Table 10 are essentially additional secondary benefits derived from large irrigation dams built primarily for dry season agricultural purposes. More specifically, the recently completed hydro electric facility of Bakolori dam project serves part of the electricity needs of Sokoto Rima Basin Authority; most especially for agricultural processing, irrigation schemes and resettled rural dwellers. The other being Tiga Dam in Hadajia Jamaare Basin, for which all the necessary civil works for added benefit of hydropower generation believe completed only required, technically speaking, the installation of suitable turbine generator combination for project maturation

**Table 10: Existing Small Hydropower Plants**

| No. | Location | River | Design | | Installed Capacity (kW) |
|---|---|---|---|---|---|
| | | | Head (m) | Flow ($m^3$/sec) | Installed Capacity (kW) |
| 1 | Ankwil I | Bagel | 60 | 1.7 | 1000 |
| 2 | Ankwil II | " | 60 | 3.4 | 2000 |
| 3 | Kurra | Kurra | 115 | 7.09 | 8000 |
| 4 | Jekko I | Lere | 85 | 4.80 | 4000 |
| 5 | Jekko II | " | 85 | 4.80 | 4000 |
| 6 | Bakalori | Sokoto | 19 | 15.4 | 3000 |
| 7 | Tiga | Kano | 28 | 20 | 6000* |

*Yet to be completed

**Past windmill Projects**

A description of past windmill project was provided by Ojosu and Salawu (1990) as follows: A few windmills were installed in the northern States in the 1960's. What remain of most of them can Still be seen all over the states especially in Dundaye village, Sokoto state, where a piston pump tye windmill, installed in the early 1960's was used for puming Water (11). In Jos, plateau State, a propeller type windmill had been in use for generating electricity on a small scale as for back as 1970 (15). In Garo, kano state , about 54 km from kano city, a climax machine of about 3-4 m rotor diameter was installed for lifting Water from a dug well at about 15m with a masonry storage tank at ground level. This unit supply a school, a dispensary and about twenty houses with piped water. It had been maintained by the water Department in Kano and had provided Satisfactory service until the early 1980's. In Badagry, there is a propeller type windmill employed for pumping water for use of a large portion of the town's population. The Gear type model Were installed in most parts of Katsina State.

In different surveys of the old installations conducted by UAC – T & E, UNDTCD and Sokoto Polytechnic, it is found out that most of the above wind failed because of inadequate maintenance of wind mill

Ojosu and Salawu (1990) also indicated that, in June 1989, Tractor and Equipment (T & E), a division of UAC started making wind pump (the "Unapower") for harnessing wind energy for water pumping. Test units are installed in Goronyo, Sokoto State and at UAC Agro Farms at Kedanda in Zaria, Kaduna State. One unit can produce 5,000 gallons per day. The project has started attracting customers across the country.

**Notable ECN pilot projects include**

Notable ECN pilot projects have been described by Iloeje (2002) as follows:

**Solar-PV:**

7.2kWpKwalkwalawa village Electrification, Sokoto State
1.87kWp Iheakpu-Awka village Electrification/TV viewing, Enugu State
1.5kwp Nangere Water pumping Scheme , Sokoto State

**Wind:**
5kw Sayya Gidan-Gada village Electrification, Sokoto State

**Solar Dryer:**
2-tonne Solar Rice Dryer, Adani, Enugu State
1.5tone Solar Forage Dryer, Yauri, Kebbi State

**Biodigesters:**
$30^3$ plant, NAPRI, Zaria, Kaduna State
$20m^3$ plant (owdung) May flower Secondary School, Ikenne, Ogun State
$10m^3$ plant (chicken droppings/cassava pels) Nsukka, Enugu State

**Improved Woodstoves:**
Danjawa 200 Stove pilot Project, Sokoto State
100 persons/day Community Woodstove project, Zaria, Kaduna State

**Chick Brooder:**
200-Bird chick Brooder, Nsukka, Enugu State

**Solar PV Installations (Iloeje, 2000)**
According to Iloeje (2002), following a survey of activities in solar PV in the country up to 1999 a total of 316 installations amounting to 238.8kWp, were identified nationwide. Based on installed capacity, the percentage distribution of the installations over various applications were as follows:

| S/N | Solar-PV Applications | % by Capacity |
|---|---|---|
| 1 | Residential (mostly lighting) | 6.9 |
| 2 | Village Electrification & TV | 3.9 |
| 3 | Office/Commercial lighting & Equipment | 3.1 |
| 4 | Street, Billboard, etc, lighting | 1.2 |
| | **All Lighting** | **15.1** |
| 5 | Industrial | 0.4 |
| 6 | Health center/clinic | 8.7 |
| 7 | Telecom & Radio | 23.6 |
| 8 | Water pumping | 52.2 |
| | **Total** | **100** |

Of the 316 installations, there was at least one 26 out of the 37 states and the FCT. Lagos (23.6%), Yobe (16.3%), Kano (8/6%) and Akwa Ibom (8.6%) States had the highest number of installations. Financing of the installation came principally from the Federal Governments, (ECN, NITEL, FMWR, DFRRI, PTF, ADP), State and Local Governments, European Union and Mobil. Some installations especially in the Lagos area, were funded by private persons.

More recently, Delta and Lagos States had embarked on projects to use Solar-PV for street light. No other modern RE technology has anywhere near the usage or number and capacity of installations in the country as solar-PV(Iloeje, 2002).

## 7.0 FUTURE-PROSPECTS FOR RE

Iloeje (2002) noted that there are great opportunities for the use of the renewable energy Technologies in applications where electricity, thermal energy or mechanical power is required. Such applications, according to him, include thermal power plants, non-thermal electricity generation, Grid power supply, Stand alone power systems; industrial and domestic cooking and heating of liquids and Gasses; drying and processing of agricultural products; water purification, irrigation and potable Water Supply, lighting, etc. However, in view of certain characteristics of the energy sector in Nigeria and the attributes of renewable energy, in comparison to non Renewable and conventional energy, he was of the view that greater prospects for the use of RE exist in the rural Sector of the economy.

**Integrated Rural Village Energy Supply (IRVES)**

Modern economic activities depend predominantly on petroleum products and electricity. Their extension from the urban to the rural areas suffers serious economic and demand capacity constraints . Rural areas are poor, energy demand levels are low and centers of demand are scattered. Consequently, while 81% of the urban dwellers have access to electricity, only 18% of the rural population are similarly exposed. Furthermore, while kerosene can be bought in some urban centres at the pump price, its retail price in rural areas is often higher (Iloeje, 2002).

Renewable energy resources such as solar radiation, wind small-scale hydropower and biomass are, in general, well distributed over the country, including especially the rural areas. The concept of the IRVES programme is to Study the energy needs of a rural community for various socio-economic activities, the energy resources available to the community, energy related environmental problems, as well as the skills and trainability of its manpower (Iloeje, 2002). An energy supply and consumption system for the village is then developed, according to Iloeje (2002), utilizing the available energy resources, which are mostly renewals, to meet the identified needs in a sustainable way. Capacity building programmes and post project management are provided for to enhance sustainability. Key features of the post-project management arrangements are (Iloeje, 2002):

(1) Provisions for community participation in the management and
(2) Payment, by beneficiaries, for centrally provided energy services, to cover operation and maintenance costs

**Rural Electrification**

Solar-PV, wind and micro-hydro systems have proved more cost-effective on a life-time basis, than grid electricity or diesel generators in situations where loads are low and far from the grid. The dotted nature and low power demand levels of rural load centers suggest the use of decentralized and small-scale power supply system s to which solar PV, wind, micro-hydropower and other renewable energy power generators are adequately suited (Iloeje, 2002).

Deliberate policies and programmes are required to identify and implement the above concept in rural areas that are unlikely to be gride connected in the long term (15-20 years). A sustainable project implementation approach will require the joint participation of government, the private Sector and consumers

**Alternatives to Fuelwood**

According to Iloeje (2002), there is great potential in using modern renewable energy alternatives to traditional fuelwood based technologies. The 1992 Presidential Task force on Alternatives to fuelwood recommended the large scale introduction of biogas technology and solar cookers (as well as the use of coal briquettes, natural gas and kerosene) in order to reduce the share of fuelwood in the energy mix. In this respect, Iloeje (2002) also identified solar water heaters and improved wood stoves.

## 8.0 CONCLUSIONS

**Barriers to RE and**
**Priorities for action**

The key barriers to RE in Nigeria have been identified by Akinbami (2001). Also, the priorities for dissemination of RE were articulated during the UNIDO Abuja forum of 2002 (www.unido.org; the Forum site (www.gfse.at)). These are as follows:

- ***Key Barriers***

1. Technological Incapability – With the exception of solar thermal and biogas technologies, no other RET has been developed in Nigeria. Most of the technologies have to be imported, thereby further escalating the already high investment cost;
2. High cost of Energy Infrastructure – Small scale hydro power, central and residential solar PV technologies, etc have not penetrated the Nigeria's energy supply systems because of their relatively high investment costs. This barrier has also been found to be the major obstacle to widespread adoption of family- sized biogas digesters in the country.
3. Financial Constraints – there is limited public funds available for the deployment of RETs. In the absence of any serious private sector involvement in the development and the dissemination of the technologies, this posed a serious barrier to the RETs;
4. Low Level of Public Awareness – public awareness of renewable energy sources and technologies in Nigeria and their benefits, both economically and environmentally are generally low. Consequently, the public is not well-equipped to influence the government to begin to take more decisive initiatives in enhancing the development, application, dissemination and diffusion of renewable energy resources and technologies in the national energy market; and,
5. General absence of comprehensive national energy policy – Nigeria has never formulated a comprehensive energy policy; only sub-sectoral policies have formulated. Since such a policy is pivotal to using energy efficient and RETs, this has to large extent contributed to the lack of attention for the RETs.

- **Priorities for action**

1. The Forum recommends that an energy policy which emphasis the development of renewable energy resources and technologies should immediately be put in place (note: Nigeria now has a published energy policy. The policy did emphasized the development RE).
2. Since the lack of access to affordable, clean and convenient energy is inextricably linked to poverty, it is recommended that a resource survey and assessment be carried out to determine the total renewable energy potential in the country as well as identify local conditions and local priorities in various ecological zones.

   3. The development of renewable energy services is linked to many other sectors such as agriculture, small scale industrial enterprises and poverty alleviation, it is recommended that, renewable energy related projects have a greater likelihood of success if implemented in tandem with activities in these sectors to ensure sufficient demand for the energy services providers.

4. Recognizing that current flow of information on renewable energy technologies is inadequate, it is recommended that demonstration projects on various energy forms be

established widely so that the performance and efficiency with which services are delivered can be sensitised.

5. In order to ensure an orderly development of renewable energy technologies and to assure quality of products, it is also recommended that a testing and standards laboratory for RETs similar to the one in South Africa be established in Nigeria.
6. As renewable energy technologies are increasingly used to address energy shortages and to expand the range of services in both rural and urban areas, it is recommended that Nigeria take advantage of global partnerships such as the REEEP initiative of UK, to help the country for creative integration of renewable energy systems.
7. As RET applications in the developing countries are attracting increased interest and financial support from the donor community, it is recommended that the Government of Nigeria develop agreements, guarantees and financial instruments that specifically target RETs and stimulate market to attract investments. In this regard, development of market supporting framework will remain the primary conditions for the country's ability to attract foreign capital.
8. In view of the vital importance of RETs to kick start rural industrialization and the need for harnessing and channelling multilateral and bilateral funds to that purpose, it is recommended that a renewable energy funding/financing agency like India's IREDA (Indian Renewable Energy Agency) be established.
9. The Forum also felt that activities such as entrepreneurship and managerial skills development training programmes and technical courses in RETs with a view of developing Energy Service Companies (ESCOs) providing services to rural areas be introduced.

10. The Forum identified definite need for capacity building both at institutional and personnel level for acquiring technical, organizational, and managerial skills required for increased development of renewable energy. The existing Research and Development centres and technology development institutions should be adequately strengthened to support the shift towards increased renewable energy utilization. Human resource development, critical knowledge and know-how transfer should be in focus for projects development, project management, monitoring and evaluation. Preparation of standards and codes of practices, maintenance manuals, life cycle costing and cost- benefit analyses tools to be undertaken on urgent priority.

11. The experience from successful renewable energy promotion projects especially from other developing countries have highlighted the need for participatory approach during project formulation and implementation exercises and public awareness creation programmes aiming at end users, financiers, decision makers, local governments, traders and regulators.
12. The Forum urged the concerned agencies to help commercialise proven indigenous renewable energy technologies and promote local production of RE equipments, devices and components through investment promotion strategies and fiscal incentives.
13. The role of renewable energy in rural industrialization and development by providing access to clean and affordable energy for village industries especially agro-processing industries and introduction of photovoltaic based information-communication technologies (ICTs) for improving the quality of life of the rural poor was emphasized by the forum and called upon UNIDO to take enabling steps towards this direction.

14. Forum requested the Federal Government of Nigeria and the State Governments to consider introducing renewable energy and energy conservation as subject of study in various levels of education beginning with primary school level.
15. National level programmes for immediate introduction of proven technologies such as small hydropower, biomass, solar thermal and photovoltaic may be devised and implemented. In this regard, the Forum urged UNIDO to provide necessary technical assistance and support.
16. Forum recommended the compulsory introduction of solar water heater in hotels, hospitals, hostels and public buildings.
17. Concerned agencies were requested to initiate master plans for the development of renewable energy applications in their respective jurisdiction taking lessons from successful models implemented elsewhere.
18. The Forum recommended holding a National Round Table – comprising of private, public sector, and civil society representatives as a follow-up to WSSD. This group should also form two sub-committees one on renewable energy and another on nonrenewable energy.

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## APPENDICES

**Appendix 1: Potential of Windmill Utilization According to the End Use (Ojosu and Salawu, 1990)**

| S/No. | AREA | Small-scle Irrigaion | Domestic water supply | LiveStock Water Supply | Electric Power Supply |
|---|---|---|---|---|---|
| 1 | Semi-Aride, Hot dry areas: Sokoto, Kano Katsina, and Borno States | GP | GP | GP | GP |
| 2 | Along the shores of Lake chad | GP | GP | GP | GP |
| 3 | TemperAte Areas: Plateau, Nigeria, Bauchi and Gongola (parts of ) States. | GP | GP | GP | GP |
| 4 | Savannah, warm Humid areas: Kwara, Benue and Gongola States | LP | MP | MP | LP |
| 5 | Alog the shores Rivers NiGer and Benue | MP | MP | MP | LP |
| 6 | Hot humid areas: Oyo, Ogun, Ondo, Bendel, anambra, Imo, Cross River States | LP | MP | LP | LP |
| 7 | Coastal Areas" Lagos, Rivers, Akwa Ibom parts of Bendel and Odo States | LP | MP | LP | LP |
| 8 | All other Areas | LP/MP | LP/MP | LP/MP | LP/GP |
| 9 | Off shore | - | - | - | GP |

GP – Good Potential , MP – Medium Potential,
LP – Limited Potentia, Up– Unknown Potential

**Appendix 2: Wind energy Density Estimates at 25m Height** (Ojosu and Salawu, 1990)

| **Station** | **Mean wind speed at 25m Level (ms)** | **Monthly mean Wind Energy KWh/yr.** | **Annual Wind Energy KWh-2 year** | **Annual Wind energy from a wind Energy turbine in KWh year -1** | |
|---|---|---|---|---|---|
| | | | | **Dia = 10m** | **Dia = 25m** |
| Benin City | 2.135 | 2.32 | 27.86 | 2,187.81 | 13,673.78 |
| Calabar | 1.702 | 1.12 | 13.42 | 1,053.69 | 6,587.53 |
| Enugu | 3.372 | 7.83 | 93.91 | 7,375.75 | 46,097.96 |
| Ibadan | 2.620 | 4.15 | 49.78 | 3,.909.79 | 24,436.19 |
| Ilorin | 2.078 | 1.23 | 14.73 | 1,157.06 | 7,230.57 |
| Jos | 4.430 | 16.05 | 192.64 | 15,129.60 | 94,559.98 |
| Kaduna | 3.605 | 9.91 | 188.88 | 9,36.81 | 58,355.08 |
| Kano | 3.516 | 8.57 | 102.86 | 8,078.61 | 50,491.28 |
| Lagos | 2.671 | 4.36 | 52.32 | 4,099.78 | 25,682.52 |
| (Ikeja) | | | | | |
| Lokoja | 2.235 | 2.60 | 31.21 | ,451.23 | 15,320.17 |
| Maiduguri | 3.486 | 8.42 | 101.01 | 7,933.61 | 49,583.17 |
| Minna | 1.589 | 1.05 | 12.60 | 989.60 | 6,185.01 |
| Makurdi | 2.689 | 4.44 | 53.27 | 4,183.51 | 26,148.85 |
| Nguru | 4.259 | 14.48 | 173.74 | 13,645.19 | 85,284.42 |
| Oshogb | 1.625 | 1.07 | 12.81 | 1,006.60 | 6,288.09 |
| oP.H. | 2.640 | 4.17 | 49.98 | 3,925.48 | 24,533.88 |
| Potiskum | 3.636 | 9.44 | 113.25 | 8,894.35 | 55,591.46 |
| Sokoto | 4.476 | 16.47 | 197.68 | 15,525.75 | 97,035.94 |
| Warri | 2.027 | 2.02 | 24.20 | 1,.900.66 | 11,879.15 |
| Yelwa | 3.360 | 7.76 | 93.13 | 7,314.88 | 45,714.59 |
| Yola | 1.824 | 1.45 | 17.34 | 1,361.88 | 8,511.75 |
| Zaria | 2.891 | 5.32 | 63.88 | 5,017,26 | 31,357.02 |

## Appendix 3: A Sample List of RE Industry Actors in Nigeria

**Solarmate Engineering Limited**
**Business type:** Service, Installations,wholesale supplier, retail sales
**Product types:** Packaged/custom built power systems. Xantrex/Trace Engineering Authorized Service Center.
**Service types:** system installation
**Address:** 435/437 Herbert Macaulay Street, P. O. Box 1654, Yaba, Lagos Nigeria
**Telephone:** 234 1 7740887 OR 2880165
**FAX:** 234 1 4974607

**Renewable Energy Solutions**
**Business type:** importer
**Product types:** energy efficient appliances, refrigerators and freezers, DC to AC power inverters, solar water pumping systems, solar panels, charge controllers, battery chargers, power supply systems(0.1-45Kva modules)Semi-Traction and Deep Cycle Batteries. Brands represented by the company include Sunfrost, ASP, Airtherm, Victron-Energy,

**WAECO, Germanos and Moll..**
**Service types:** consulting, installation, engineering, retail and wholesales
**Address:** 10, Oregun Road, Ikeja, Lagos Nigeria
**Telephone:** +2341-4701020, +2341-4723831, 08033467821, 08033236026
**FAX:** +2341-3205553
Sabadel Solar System (Nig) Ltd
**Business type:** wholesale supplier, importer
**Product types:** photovoltaic systems, solar water pumping systems, energy efficient lighting, renewable energy system batteries.
**Address:** 16, Adegbola Street, Ikeja, Lagos Nigeria P.O.B 4733K
**Telephone:** 01 4930483

**Comfort Zone (Nig.) Limited**
**Business type:** retail sales, importer
**Product types:** solar electric power systems, packaged power systems, energy efficient lighting, energy efficient appliances, photovoltaic systems, renewable energy system batteries, Solar Powered gift items.
**Service types:** consulting, design, education and training services
**Address:** E052 Alade Shopping Complex Allen Avenue, Ikeja-Lagos, Nigeria
**Telephone:** 2341-497-1744
**FAX:** 2341-497-1744

**Naija Solar Products**
**Business type:** retail sales, importer
**Product types:** emergency backup batteries, energy efficient lighting, natural daylighting, photovoltaic systems, nickel metal hydride batteries, water filtering and purification systems, Educational & Gift items.
**Service types:** design, installation, education and training services, maintenance and repair services

**Address:** 56, Adebayo Mokuolu Street, Anthony Village, Lagos Nigeria
**Telephone:** (01) 2341 493-6671
**FAX:** (01) 2341 493-6671

**New World Energy Limited**
**Business type:** retail sales, wholesale supplier
**Product types:** publications, photovoltaic cells, renewable energy system batteries, solar electric power systems, fluorescent light bulbs, photovoltaic module mounting systems, Solar Panels.
**Address:** #12 University Market Road Nsukka P.O. BOX 974, Nsukka, Enugu State Nigeria
**Telephone:** 08037240119

**Solarec Engineering Limited**
**Product types:** solar electric power systems, solar charge controllers, solar water pumping systems, DC lighting, backup power systems, photovoltaic modules, Inverters.
**Service types:** consulting, design, installation, project development services, maintenance and repair services
**Address:** 2nd Floor, 6A Ahmadu Bello Way, Kaduna, Kaduna State Nigeria P. O. Box 9062
**Telephone:** 234 62 241437
**FAX:** 234 62 241079

**Dahiru Solar Technical Services**
**Business type:** retail sales, importer
**Product types:** deep cycle batteries, air cooling systems, biomass energy systems, DC to AC power inverters, photovoltaic systems.
**Address:** 8/9 Kundila Market/Zaria Road, Kano, Kano Nigeria Box 10867
**Telephone:** 234 64 661408

**Honey - Fiks Solar**
**Business type:** wholesale supplier, exporter, importer
**Product types:** photovoltaic systems, solar outdoor lighting systems, solar water pumping systems, solar garden lights.
**Address:** Suite 23, Gwarimpa Plaza, Federal Capital Territory, Abuja Nigeria
**Telephone:** 234-9-6712478

**Jon Paca Investments Limited**
**Business type:** wholesale supplier, exporter, importer
**Product types:** solar water pumping systems, investment and financial services, photovoltaic module components, air cooling systems, alternative home and building construction materials, packaged power systems, solar streetlighting, solar garden light.
**Address:** Suite 38, Kogi Street, Garki Model Market, Garki, Garki, Abuja Nigeria PMB 5066
**Telephone:** 234-8044115323, 234-8037034906, 234-8033031885, 234-9-6700832 Ext: 108

**Enrel Energy Corp**
Nae Ismail, President
(613) 748-1809
nismail0423@rogers.com

**Details**: Have an agent based in Lagos Nigeria who is currently working on a Nigerian Gov't sponsored project in the Abuja area to electrify schools using PV powered system. Their R&D department has developed a 1Kwatt wind generator that is for sale/distribution.

**Philips Projects Center.**
The center represents **Shell Solar of Holland**. Services: Engineering services, PV consulting, retailing, equipment supplies, installation services. Address: 8 Kofo Abayomi Str. V/I Lagos. Tel: 01-2620811; 01-2620632. Fax: 01-2620631; 01-2615143

## Appendix 4: Further Informationon Village Electrification Initiative in northern Nigeria (SELF, 2004)

### Project Aim, Sustainability, Efficiency

In meeting the project aim of demonstrating PV electrification as a foundation for enabling and catalyzing development in marginalized rural villages, a great deal of attention was paid to sustainability, reliability and efficiency.

Initial feasibility studies showed that PV technology was the most efficient and economical way to electrify villages in this region. It is unlikely that the national electric grid will connect to rural villages any time within the next two decades. Diesel generators have a high failure rate due to the unaffordable expenses of fuel and upkeep, and the region lacks the resources for localized wind or hydro power generators. There is plenty of solar radiation in the project area and there are existing solar pumping applications that have good operational histories.

The design and implementation of this project encompasses technical, financial and organizational components to ensure sustainability. Trained technicians live in each village and are charged with basic upkeep of the systems. Technicians with a higher level of education and training are employed by JAEF to supervise and train the village technicians as well as to handle more complex repairs. JAEF is structured as an "ESCO", or energy service company and as such retains ownership of all the individual systems. Each user is charged a monthly fee that is calculated to supply all the funds needed for operation and maintenance costs. JAEF manages the collected funds and uses them to buy supplies, pay the technicians and cover the ongoing administrative costs of the project. In most cases, the user fees are less than or equal to what families were paying for kerosene. Local government money is used to supplement the upkeep of community service systems such as water pumping, streetlights, clinics, etc.

In this project, individual PV systems are utilized for each application. Each school, home, clinic, streetlight, etc. is a stand-alone, independent system. Distributed systems offer increased reliability to the community as a whole as opposed to a central power plant where the failure of a single major component could cut off power to the entire community. Distributed systems also eliminate the need for installing expensive electrical distribution wires throughout the village. Having an energy source under their own control, empowers the users and encourages individual responsibility for improving the lot of the family.

### Innovative Aspects

The "whole village" approach taken in this project recognizes that a village develops and prospers as a result of parallel improvements in all aspects of village life, including health, education , security., water supply and economic development. By supporting all these areas simultaneously, village conditions can improve at a more rapid rate than by supporting a single area of development. For example, improving education may do little good if people do not have the health to take advantage of it and improved health care can be compromised if the village does not have source of uncontaminated water. Electricity, in this case reliable PV-generated electricity, has the power to support all areas of development in a sustainable and environmentally friendly manner.

This project pays particular attention to economic development as the engine that can most rapidly improve the living conditions of families. The micro-enterprise centers, mobile irrigation pumps and oil expeller are all systems that have not been seen before in Nigeria or

in other areas of West Africa. Given the lack of local employment opportunities and lack of economic growth happening in the region as a whole, the creation and support of village enterprise offers the best hope for bringing more income into the village.
By including women in the installation teams and by supporting a source of income for village women, this project seeks to open up options for a segment of society that traditionally has been limited to tightly defined roles.

**Costs and Benefits**
The cost of PV electrification is much less than the cost of bringing in the national power grid
or the cost of a local diesel power plant. More importantly, PV plants require less maintenance and operational expense and with sustainability measures in place, can be expected to be a much more reliable source of power.
Even though the project was only recently completed, we are already hearing of the benefits. A school principle reports that his solar-illuminated classrooms are being used every night for new adult education classes, regular primary classes and as study centers. A village health officer reports that with the better light, he is able to safely perform procedures such as inserting IV lines and injecting medications. Home businesses are reporting increases in efficiency with better lighting. Several young people have been able to utilize micro-credit to start new businesses that require electricity. New small businesses have cropped up under the streetlights at night.
In addition to the benefits to health, education, security and economic development as outlined above, PV electrification of offers the social value of making these three villages more desirable places to live. PV technology is encouraging village residents to stay and develop their own villages instead of migrating to larger cities and towns that are already short of employment and housing. Residents of one project village are proud that they have lights at night when the power is out in a larger grid-connected town located nearby.

**Replication Potential**
This project is highly replicable in that it works as designed, is well accepted by its users and meets the needs found in many Nigerian and West African villages.
The project has attracted a great deal of attention and has been visited by the Governors of several neighboring states, President Obasanjo of Nigeria, Rick Roberts, the acting U.S. ambassador, and by international media such CNN which broadcast a story on the project. It has also piqued the interest of many people and businesses from outside the villages who are connected to the national power grid but are looking to make their power supply more reliable. Because of the numerous inquiries, it is likely that JAEF will launch a for-profit enterprise to sell PV systems to people outside the project area. It is hoped that a privatized spin-off of this project will help create jobs and supporting micro-industries as the demand for these systems grow.
Replication is likely to be a reality as Governor Turaki reports that he is working on funding for the next phase of at least 30 more villages. In addition, SELF has been approached by another Government that provides aid to Nigeria about replication of the project in other Nigerian states.

**Figure 1: Location and Political Maps of Nigeria**

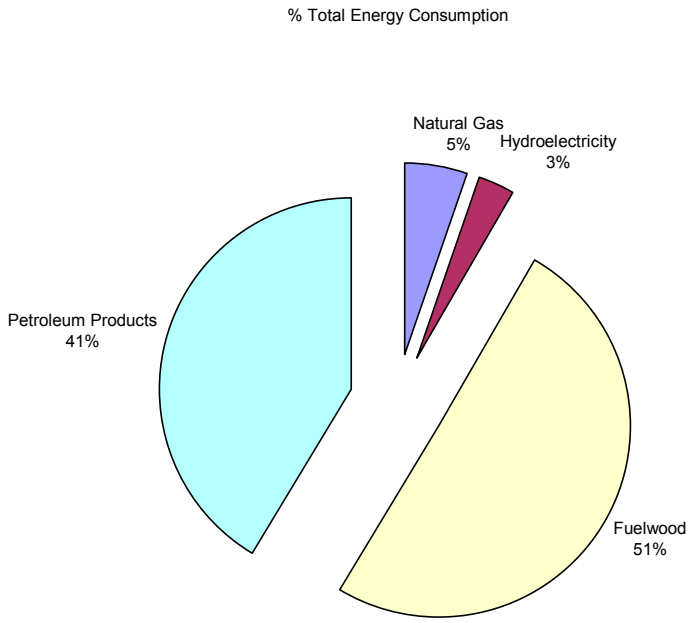


**Figure 2: Typical Energy Supply Mix in Nigeria (1995) (Akinbami, 2001)**

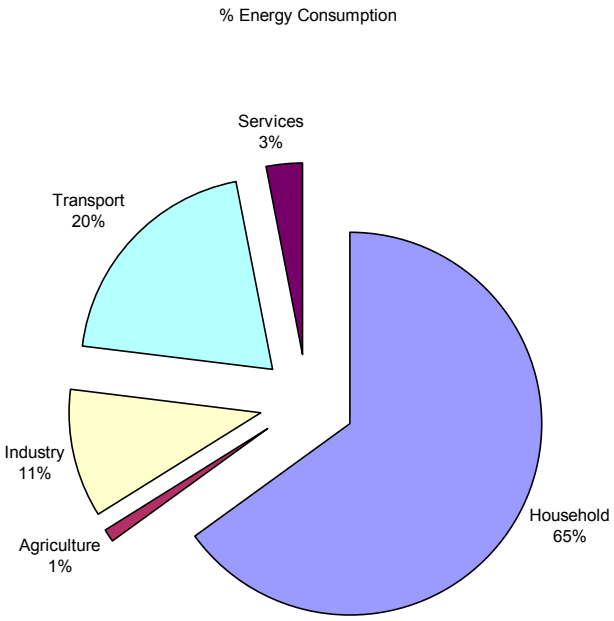


**Figure 3: Sectoral Distribution of National Final Energy Consumption (PJ) in 1989 (Oladosu and Adegbulugbe, 1994)**

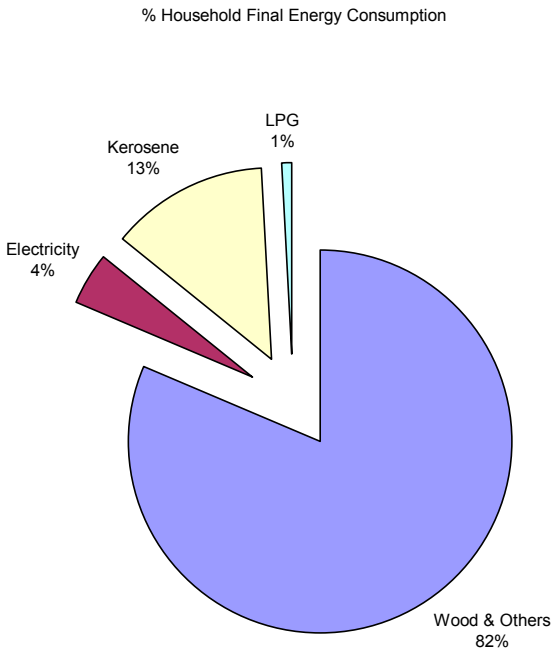


**Figure 4: Distribution of Household Final Energy Consumption among Energy Carriers in 1989 (%) (Oladosu and Adegbulugbe, 1994)**

**Figure 5: Nigerian River System and Basins (after Aliyu and Elegba, 1990)**

**Figure 6: Global Annual Average Wind Speed (atefact, 2004)**

**Figure 7: Isovents at 10m Heights and Wind Zones/Regimes in Nigeria (Ojosu and Salawu, 1990)**

**Figure 8: Annual Average of Daily Global Solar Radiation ($kWh/m^2/day \times 10^{-1}$) (Iloeje, 2000)**

**Fig. 9: Energy Consumption trend from projected Family-Sized Biogas Digesters in Nigeria for the Period 2000-2030 (Akinbami et al, 2001)**

Low Biogas Growth Scenario = 0.1% of the households per annum adopt biogas digesters

Moderate Biogas Growth Scenario = 0.5% of the households per annum adopt biogas digesters

High Biogas Growth Scenario = 1.5% of the households per annum adopt biogas digesters