A Sustainable Electrical Energy Consumption and Production Development Pathway for Nigeria: A Case Study of Energy Recovery from Agro-forestry Wastes

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ABSTRACT

Nigeria is endowed with various conventional and non-conventional energy resources essential for a robust and rapid economic growth and development. However, there is a high degree of infrastructural deficiency in the economy particularly in the electricity sector. This study is an effort to carry out a quantification assessment of the sawdust and rice husk generated in the sawmills and ricemills respectively and their corresponding electrical energy potential in each of the identified clusters. Based on these potentials, the capacity of the power plant was determined. In addition, a load survey in the beneficiary area and the agro-forestry clusters themselves were conducted so as to identify potential site which is not far away from the fuel source for the location of the power plant. Finally, the study also carried out quantification of CO_2 emission minimization capacity and economic gains from fuel displacement based on the usage of sawdust and rice husk to generate electricity. Based on an estimated total volume of wood waste in excess of 212,220 m^3 (about 66,000 tons) per annum and at about 30% efficiency, about 8.0 MW of electric power will be generated with an annual electricity output of about 79,089.3 MWh. Similarly, based on the estimated 55,000 tonnes of annually generated rice husk, and at an overall plant efficiency of 20-24%, a 5 MW rice husk fired power plant is being proposed for ricemill clusters. In monetary term, diesel displaced by the sawdust based power plant is about N177 million (about US$1.3 million) while that of rice husk fired plant is in excess of N236 million (US$2 million) per annum for each of the clusters studied. In addition, CO_2 emissions that will be saved through these projects have been estimated to be in excess of 73,000 tons CO_2/year, making them good candidates for Clean Development Mechanism (CDM) projects.

Keywords: Sawmill, Ricemill, Wood Wastes, Rice Husk, Wood Waste-Power Generating System, Rice Husk fired Power Plant, Socio-economic Benefits, Environmental Benefits, CO_2 Emissions, Clean Development Mechanism

1.0 INTRODUCTION

The provision of adequate, affordable, accessible and sustainable electricity supply is critical to the attainment of the broad goals of high and sustainable human development. Electricity interacts with human development at different levels and, facilitates economic development and poverty reduction by underpinning industrial growth and enhancing productivity [1]. A careful study of the pattern of electricity consumption vis-à-vis economic growth across different countries shows oscillation around an initial cluster characterized by low energy consumption, economic stagnation and energy infrastructural decay. Most countries experienced this cluster very early in their developmental stages. However, with the right strategy, many countries have broken through the cluster to achieve an increasingly sustained path of energy consumption and economic growth. Examples of these countries include, Iran, Malaysia and Chile

Economic history clearly shows that power has served as catalyst for economic growth and development. The level of electricity consumption closely mirrors the level of economic development of a nation. Figure 1 gives the graphical illustration of the interrelationship between electricity consumption and economic growth. The cross country data shows Nigeria at the bottom of the ladder with relatively low per capita income and low per capita electricity consumption, while Singapore occupies the top right position with high per capita income and high per capita electricity consumption. The close correlation between power consumption and economic growth has also been demonstrated in the Nigerian case. The peak of Nigeria economic growth 1970-79 and 2002-2004 are also associated with the highest growth in electricity generation in Nigeria. However, the low investment, and inefficient institutional structure have been the bane of the sector and kept the sector from performing its growth-inducing and welfare improving roles.

Power development therefore has a key role to play in Nigeria's economic development process. It has the capacity to serve either as a catalyst or a fetter on the wheels of economic development. With a population in excess of 140 million people and abundant fossil and renewable energy resources, Nigeria's installed power generating capacity is less than 6,000 MW and average available capacity is less than 1700 MW, representing about 28% capacity utilization. Table 1 reveals that in 2001, the national electrical energy produced per capita was 0.16 KWh while the electrical energy consumed per capita was 0.11 KWh. Comparatively with some other countries whether advanced, newly industrialized or developing, Nigeria's figures are incredibly lower. An evidence of the impact of the poor quality, unreliability and limited availability of power supply on Nigeria's economic development is its debilitating effects on the industrialization process. Nigerian manufacturers have consistently identified poor power supply as the most important constraint to their business. Majority of them have to supplement publicly supplied electricity with very expensive auto-generation. For instance, based on a sample of 232 firms in a study by the World Bank [2], 94% of them reported that infrastructure is their biggest problem (which is 2.5 times more worrisome than finance) and 97% of the firms own generators. Removing the constraint of unreliable power generation will therefore enhance the microeconomic response of the real sector to the various incentives embodied in the National Economic Empowerment and Development Strategy (NEEDS). It will also enhance the realization of the objectives of the Millenium Development Goals (MDGs) and the goals of NEEDS which include wealth creation, employment generation and poverty reduction.

2.0 HISTORICAL TREND OF ELECTRICITY PRODUCTION AND CONSUMPTION

The historical electricity generation, including purchases from independent generators (NESCO, Shell (SPDC) and Ajaokuta Steel Co.), as well as electricity sales are given in Figure 2. The total generation showed vigorous double-digit annual growth rate over the 1970s, with an average of 15.3% for the years 1973-1980. The growth slowed down in each of the next two decades to averages of 6.6% over 1981-1990 and 1.3% over 1991-2000. These corresponded generally to the growth of investments in generating capacity. The low generation growth in the 1990s period, with frequent negative annual growths, reflected the poor state of the plants and lack of funding of the electric utility during the period. The growth of grid electricity sales showed similar trends as those for generation, with average annual percentage growths of 13.6%, 6.0% and 0.8% over the decades (1971-1980), (1981-1990) and (1991-2000) respectively. The average of sales growth rates, though slightly lower, closely matched the averages of growth rates in generation. This indicates that sales and consumption of electricity were constrained by generation. Notwithstanding recent developments in the power sector, the imbalance between supply and demand for electricity is still very high and there is the need to explore other power generation options.

3.0 SOCIO-ECONOMIC DEVELOPMENT OF AREAS OF STUDY

The focus of this study is on productive use of sawdust and rice husk. Sawdust, one major byproduct of wood processing, is produced extensively in forested areas of Nigeria in large quantities and mostly burnt as waste. Also, rice husk is generated during the process of milling dried parboiled paddy rice from the fields. The husk is discarded in designated rice husk dumpsites where mounds of the husk quickly develop. To reduce mound size, the mound is openly burnt from time to time. The burning of these wastes has attracted attention and is viewed as a potential means of generating electricity to augment the epileptic national grid supply, and also provide alternative source of energy to hydrocarbons in various communities in Nigeria. On the environmental issue, the use of sawdust and rice husk is also seen as a potential means of achieving CO_2 reduction to the atmosphere from energy usage.

The areas of study are located in Ogun and Ebonyi states. **Ogun State** is a state in South-western Nigeria. The State has a total land area of 16,762 km^2 and borders Lagos State to the south, Oyo and Osun states to the North, Ondo State to the east and the Republic of Benin to the west. Abeokuta is the capital and largest city in the state. The State is made up of 20 local government areas. The study area in the state covers four local government councils of the Ijebu area namely, Ijebu Ode, Ijebu North,, Ijebu North East and Odogbolu.Total population of the study area based on 2006 National Population Commission census exercise is put at 673,125 [3]. This is broken down as follows: Ijebu Ode LGA - 154,032; Ijebu North - 284,336; Ijebu North East - 67,634; and Odogbolu - 127,123 persons respectively. Agriculture is the main occupation engaged in by the people of Ijebu, but in recent times the people have also been involved in trading and manufacturing. Ebonyi state is located in the south eastern region of Nigeria and is bounded to the north by Benue State, to the west by Enugu State, to the east by Cross River State and to the south by Abia State. With a land area of about 5,935 sq. km, the state lies approximately within longitude 7°30' and 8°30'E and latitude 5°40' and 6°45'N. There are thirteen Local Government Areas (LGAs) in the state. The study area in the state is Abakaliki LGA. Ebonyi State has a population size of 2.58 million consisting of about 205,848 households. It is a rural state with about 70% of the people dwelling in the rural areas. A recently concluded State Energy Survey gives a revelation of the economic status of the people of the state. The survey revealed that 70% of the population is in the low income bracket while 25% and 5% are in the middle and high income brackets respectively. Economic activities of the people include subsistence farming, animal husbandry, trading, and civil/public service. The three primary and leading agro-allied industries in the State are processing of paddy rice, wood saw milling/wood product carpentry works and cassava processing to produce garri (a staple food). The development of the agro-based industries in the state will both facilitate its industrial development and enhance the standard of living of its people.

4.0 METHODOLOGY

The goal of this study was to quantify the amount of energy available for electricity generation using sawdust from the over 100 sawmill found in Ijebu area and rice husk generated from the ricemills in Abakaliki LGA, and also assess their CO_2 minimization capacities. Based on this, the study specific objectives were taken to be: assess and quantify the sawdust and rice husk generated and the electrical energy potentials of these wastes in each identified cluster; determine the capacity of the power plant based on energy potential of sawdust and rice husk generated; conduct a load survey of power demand in the beneficiary area and identified clusters; and quantify the CO_2 emission minimization to be achieved using sawdust and rice husk to generate electricity for operating the sawmills and rice mills. To achieve this goal, partially structured questionnaire was adopted as research instrument [4] designed through field survey to elicit relevant information from the various categories of stakeholders. From the quantification exercise, the CO_2 minimization capacity for utilizing sawdust and rice husk powered electricity generation was carried out based on Hagan [5]. To ensure adequate coverage for the data gathering process for the proposed power plant using wood wastes and particularly sawdust in the Ijebu area and rice husk in Abakaliki area, a participatory approach was adopted involving all stakeholders. The stakeholders include Sawmillers' and Rice Millers' Associations, sawmill and rice mill owners and/or operators, local authorities both traditional and modern (that is the traditional rulers and local government Chairmen), the Chambers of Commerce, a Non-Governmental

Organization (NGO)-Justice, Development and Peace Commission (JDPC), National Electric Utility Company-Power Holding Company of Nigeria (PHCN) – Ijebu District, and the National Population Commission (NPC) in the study areas. Specific questions within the questionnaire were designed to meet the research objectives. For the local authorities and the Chambers of Commerce, the questions directed at them were mostly those that relate with interest in the proposed power plant and desire to contribute to its successful implementation. Specific questions related to power demand and supply situation in the study areas were directed at the PHCN while questions relating to raw materials required, wastes generated, grid electrical energy demand, alternative source of electricity generation, quantity of fuels used for self generation, etc were directed to the sawmiller and ricemiller associations and sawmill and ricemill owners and operators. The returned questionnaires were examined for completeness and usability. Usable returned questionnaires were coded and entered into a computer spreadsheet for analysis.

The Ijebu area of Ogun State covering four local government areas with over 200 towns, villages and communities is home to quite a number of sawmills making use of wood from the vast forest resources in the area which in turn produces large quantities of sawdust. Several clusters of sawmills in Ijebu Ode, Ijebu North, Ijebu North East and Odogbolu Local Government Areas (Ijebu Igbo, Obalende, Egirin Road, Oke-Owa and Orilonise clusters) were identified for quantification of sawdust generated from their sawmill industry. Abakaliki Local Government area (LGA) consisting of Abakaliki Township and Ekumenyi were identified for quantification of rice husk generated from the ricemills.

5.0 RESULTS AND ANALYSIS

5.1 QUANTIFICATION OF SAWDUST GENERATED AND ENERGY POTENTIALS

Altogether there are about 100 sawmills operating under the umbrella of Saw-millers' Associations in each of the clusters. Quantification of sawdust generated from each sawmill was done using plant visit, peer conversations, data/information from the questionnaire to owner and/or operator of sawmills and calculations were subsequently based on related literature (from scientific journals, etc) accessed from the Internet [6]. The plant visit gave insight to how the waste produced in each sawmill is disposed of. Equivalent of bags used to package 50 kg rice in the market are usually used by women employed to sweep the sawdust from the mills daily. In each sawmill visited, it was estimated that the bags evacuated are between 100 and 120 bags per day per sawmill. Each sawmill employs an average of 4 workers per day for the purpose of keeping the working area free of wastes. A bag filled with sawdust was weighed and found to be about 20 kg and its volume was calculated to be about $0.082m^3$. It was estimated that each sawmill produces an average of 110 bags/day. This will amount to approximately 2.2 tons of sawdust per day per sawmill. Thus the total amount of sawdust that would be produced by all the clusters of sawmills covered in the study is estimated at about 220 tons per day. Quite a sizeable amount of this sawdust is burnt off by sawmillers in order to avoid the problems of dumping, groundwater as well as air pollution. To estimate the volume of wood produced in each sawmills was challenging as most of the respondents could not give a clear estimate of the volume of logs that come for processing despite the fact that they could readily account for the number of logs. Since the logs are not of the same volume from the forest, a proxy based on total amount of sawn-wood per band saw per working day was then applied to estimate the volume of wood produced per sawmill. It was discovered that operating at optimal level, each band saw is capable of producing about 350 ft^3 or 9.45 m^3 of wood per day. This is estimated to need about 760 ft^3 of wood-log per day. Despite the epileptic electricity supply however, it was revealed through interview with the operators that most sawmills, operating with only a band saw, could still produce at a minimum of 200 ft^3 or 5.4 m^3 of wood per day. Wood-logs processed in all sawmills located in the study area are air-dried. The operations of these mills depend heavily on electricity mostly powered by electricity from diesel-fuelled generators and supply from the national grid. It is estimated that sawmills spend an average of N9,000 ($72.30) for 100 litres of diesel per day (which amounts to about N5.4 million per week for the 100 mills) aside from the average of N22,000.00 ($186.44)/month paid to utility for electricity supply per sawmill. On a monthly basis, electricity/energy related expenses of the saw-millers is estimated at approximately N238, 000.00 ($2,017) (or N23.8 ($0.21) million on energy/electricity related expenses by the 100 sawmills) depending on the number of saws operated by sawmill. Ample experiences abound in other parts of the world especially Asian countries such as India and some African countries (Ghana) on the utilization of sawdust as fuel for electricity and steam generation. It is hoped that the same experience could be replicated in Ijebu area to provide reliable, affordable, sustainable, and adequate electricity supply to the area. This is with the aim that utilizing sawdust for electricity generation will stimulate industrial growth and in turn affect economic development of the area and at the same time create a benign environment for human existence. Table 2 highlights the breakdown of sawmills in each of the clusters, while Table 3 shows breakdown of saws found in these clusters. Table 4 summarizes the average volume of log handled daily in each cluster while Table 5 presents estimated average volume of wastes generated aily in each of these clusters.

5.2 ELECTRICITY DEMAND AND SUPPLY IN IJEBU AREA

The study area falls under the precinct of the Ijebu Ode District of PHCN. The peak electricity demand for the entire district is put at 51 MW. This peak demand is met with 30 MW supply from PHCN which represents 59% with the remaining supply coming from self-generated electricity [7]. Weekly energy supply to the district from the national grid is put at 2,500 GWh. Total number of customers in the district is put at 49,106. This is broken down into 82.7%, 17.1% and 0.2% for residential (low voltage), commercial (medium voltage) and industrial (high voltage) customers respectively. Metered customers are 70.1% while the un-metered customers are put at 29.9%. Number of unplanned outages per year is put at 126 with the duration put at 469 hours per year. Fault and load shedding are the two main reasons given for causes of major power outages in the district. However, there is no record of the total volume of unplanned outages per year and there is no record also for the number of complaints related to deficient services in the district. Based on the amount of energy received from the national grid, the annual revenue expected is put at N45,378,234.54($384,561.30) whereas revenue collected is put at N33, 691,922.68 ($285,524.80). This puts the annual revenue loss for this district at about 26% of expected revenue.Some information regarding electricity supply situation based on field survey are presented in Figure 3 and Table 6 respectively.

5.2.1 Power Demand/Supply Situation in Sawmill industry

As stated earlier, sawmill industry in Ijebu Area is a major industry affecting the income earning capacity of quite a number of its inhabitants. PHCN places the power demand from sawmill industry under commercial (medium voltage) customer category. Also, as highlighted earlier, the typical energy requirements to run the sawing machines of small- and medium-size sawmills are only mechanical as typified in the schematic diagram in Figure 4. Typical prime movers in these sawmills are powered by electricity. The energy requirement for processing in sawmills depend on the type of wood, product type, the equipments used, and the factory size. Average energy consumption by the industry differs based mainly on the units of band and circular saws in each sawmill (Table 7). The survey indicated that Ijebu Igbo cluster with the highest number of band and circular saws has the highest electricity demand amongst the clusters. The survey revealed that out of the four clusters, the least demand for electricity was made by Obalende cluster. Total electricity used in sawmill clusters per day was estimated based on a 10 working hour per day. The result for each cluster is presented in Table 8. From the administered survey questionnaire, the average tariff charged by PHCN for the medium voltage customer is N8.50/kWh ($0.072/kWh). Average daily energy consumption by sawmills in each cluster, split into grid and self-generation is presented in Table 9. Peer conversations with owners/operators in each of the clusters of sawmill during the field survey revealed that hardly does the PHCN supply electricity from the grid to power their saws for operation. 90% of their operations are carried out with electricity supplied from their standby diesel fueled generators. Table 10 presents the estimated cost of daily diesel consumption for each of the clusters with the total cost at almost N600, 000 ($5,084.75) per day. This, they reasoned had added significantly to their cost of production and consequently eroded their profit margin.

5.3 ESTIMATED CAPACITY OF PROPOSED POWER PLANT USING THE SAWDUST GENERATED

From Table 7, the power demand for the clusters of sawmill in Ijebu Area is estimated at a little over 5.5 MW. Out of this, Ijebu Igbo presently has the highest power demand with a little over 2 MW. All the visited sawmills in Ijebu Area operate mainly with band and circular saws which require electricity to run. The electricity supply at the visited sawmill factory is provided from the PHCN grid through a step-down power transformer with capacity of 400 kVA. During all the periods the visits lasted to the clusters of sawmill, most of the transformers were disconnected by PHCN due mostly to load shedding. As highlighted earlier, 90% of power used for each of the saws comes from installed standby generators within each sawmill.Based on discussion with operators of sawmills, it was estimated that the power demand of each sawmill (if all equipments work in parallel) is about 700 kVA. The distribution of saws per cluster of sawmill is presented in Table 11. In order to achieve an equivalent of the present production level of approximately 700 m^3 sawn-timber per-day (see Table 4), the sawmill industry at Ijebu area will require to process approximately 1,500 m^3 wood-log per-day. From this total amount of wood process daily, it was estimated that the total wood waste that would be produced by the clusters of sawmill is 800 m^3/day. If we assume that 20% of the waste is used by local community as firewood for cooking then about 640 m^3/day is left in the clusters of sawmill or about 176 tons of wood-wastes per day. As for diesel consumption, using a daily consumption of 50 litres for the operation of one band-saw and one circular-saw respectively for 10 hours, it is estimated that this is equivalent to approximately 19,650 kWh per month. With about 100 sawmill establishments in Ijebu Area, the total volume of sawn timber production is estimated at about 212,220 m^3/year. The average sawn timber production for each factory would then be about 2,122 m^3/year per-sawmill. Sawmills in this area are powered with electric driven band and circular saws with power capacity of 30 kW and 22.5 kW respectively.Though specific energy consumption for each saw in the study area was not taken, a proxy study [8] was used to estimate this value to be about 65 kWh/m^3-sawn timbers produced. The specific energy production from the waste is estimated at about 80 kWh/m^3-sawn timbers. Thus, the generated waste can fulfill the energy demand of the mill if it is utilized.

5.4 TECHNICAL CHARACTERISTICS OF PROPOSED SAWDUST FUELED POWER PLANT

To estimate electricity capacity to be generated from sawdust, some characteristics have to be considered as these differ in woods and their residues based on species and origin or location. In Table 12 are presented the average characteristics of Ghanaian wood and their residues (close to Nigerian woods), wood processing residue samples including sawdust as determined in laboratory studies. On the average, the thermal value quoted for wood residues (including sawdust) as fuel is 15,000kJ/kg. In sawmill terms this equates to 875.7 kWh/m^3. Plants generating electricity from wood normally operate at thermal efficiencies between 30% and 60% depending on plant composition. With the estimated average volume of sawdust produced annually at 212,220 m^3 and assuming an efficiency of 30%, the equivalent electrical potential from the sawdust generated annually at MOW is 212,220 m^3 x 875.7 kWh/m^3 x 0.30 $\geq$ 55,752,316.2 kWh. All scheduled maintenance is to be carried out only on Sundays and a forced outage rate of 42 hours/month is assumed. For a plant operating at 7008 hours annually (Table 11), the corresponding size of the power plant would be:

Sawdust usually presents disposal problems for wood processing firms and it is assumed that all the quantity needed for the plant would be

$$55{,}752{,}316.2\text{ kWh} \Big/ 7008\text{h} \geq 8.0\text{ MW}$$

fetched and/or purchased at minimal cost from the many wood processing firms in the area to allow this power production. From a similar pre-feasibility assessment on such wood waste power systems done for Indonesian wood products industry, all scheduled maintenance could be conducted on Sundays and a forced outage rate of 6% of the annual hours could be expected for well-maintained plants [9]. According to this Indonesian report, worldwide experience reveals that scheduled maintenance requires about 5% of the annual hours, which amounts to 36.5 hours per month. Thus, the scheduled maintenance on Sundays (104 hours/month) and a forced maintenance period of 6% of the annual hours (42 hours/month) assumed in this pre-feasibility report study for the proposed power plant for Ijebu Area is adequate. Altogether the plant for Ijebu Area would be operating for 7,008 hours annually. For the financial analysis, the factors to be considered under the financial analysis include capital cost of proposed plant, project financing (debt and equity ratio to be determined at feasibility study level), expected revenue from proposed plant and project analysis.

5.5 ESTIMATE OF POTENTIAL GENERATING CAPACITY FROM THE FIELD SURVEY

Field survey to Ijebu Area indicates that the volume of wood wastes presently generated in the clusters of sawmill is enough to attract the location of power plants utilizing sawdust and other wood wastes. Table 12 highlights the electricity generation potential of each cluster and the wood factories based on the volume of wastes they generate and the generator capacity that would be installed for this purpose. For the proposed power plant, a Combined Heat and Power (CHP) plant, that is, a co-generation plant may be better than the conventional power and heat generating options due to some factors which include:

· The relatively lower capital investment of a co-

generation plant.
· Its reduced fuel consumption
· Its reduced environmental pollution.
In addition, energy through co-generation could be used to produce steam for:

· Steaming peeler blocks for plywood manufacture.
· Drying of lumber especially in these saw mills where drying of lumber is solely done by sun drying. This takes longer time and the quality of the end product is not good enough as to attract considerable price.
· Production of electrical power to reduce the mills dependency on the national grid.

5.6 PROJECT BASELINE GREENHOUSE GASES (GHG) EMISSION CALCULATION

The project boundary (see Figure 3) excludes the product of both processes that are out of the physical boundary. This means that anything that happens outside of sawmill is excluded. Landfill or burning by the people in surrounding areas will not be part of the calculations of the potential GHG emission. The boxes with colours are the components of GHG emission/saving calculations. Figure 4 shows three components: electricity from grid, diesel generators and wood wastes that are staying in the factory. The project will replace electricity supply from grid, mechanical energy from diesel generators and avoid wood waste from being dumped. The two aspects regarding baseline emissions are local emissions and distance emissions. The local emissions are due to wood waste dumping and the use of diesel generators. Distance emissions are due to electricity generation in the Power Holding Company of Nigeria System.

5.6.1 Local Emissions

If the project is not implemented in the project area, two things will happen to wood wastes. The first is wood burning and the second is wood dumping. The sawdust/wood chips are usually just dumped. The calculation here is based on the sawdust/wood chips percentage. Burning the wood waste will emit important GHG gasses such as CH_4, N_2O, CO, and NOx, (CO_2 emission is compensated by the sequestered CO_2) while dumping the sawdust could emit CH_4 from the decomposition process. This means keeping the wood waste inside the factory and not dumping it will prevent the emission of GHG gasses outside the project boundary. Keeping the waste inside the factory does not keep the wood waste from decomposing. From the mass balance in Figure 4 and Table 4, we can see that in sawmills from 100% log, 50% of it becomes waste. Out of 100% log, around 10% becomes sawdust and wood chips. Saw dust and wood chips are usually dumped and burnt. 10% of raw material is 21,222 m^3 of wood chips and sawdust. Using 210-kg/m^3 specific weight factors, the volume will weigh around 4,456.62 tons/year. The emission factor of waste dumping is 1.5 tons CO_2/ton waste [10] Using this number it means that the sawmills can emit more about 6,685 **tons CO_2 eq/year**. The cluster break down of CO_2 emissions based on Table 5 is given in Table 14. Table 14 also gives a breakdown of the total avoided CO_2 emissions, 13,076.3 tons CO_2/year according to emission sources.

5.7 QUANTIFICATION OF RICE HUSK GENERATED AND ENERGY POTENTIALS

From all the local government areas, about 218,622 tonnes of paddy rice are processed to yield about 147,570 tonnes of white rice annually. The production of rice husk from the processed paddy rice is estimated to be about 54,656 tonnes on an annual basis in the State. The study further revealed that the installed capacity of rice mills in Ebonyi State in the period April-July 2005 was more than 2.0 million tonnes of paddy rice per year, while the capacity utilization presently is just about 10%. The implication of this is that at least 10 times the quantity of rice husk generated presently can still be obtained at full capacity utilization of the existing rice mills in the state. Analysis of the survey data revealed several interesting characteristics and potential opportunities for rice milling sector in the state. Table 15 gives a summary of information and data on rice milling facilities, direct workforce employed in rice milling, estimates of paddy rice processed, white rice and rice husk produced, by each local government area (LGA) in the State. Cumulatively, about 55,000 tonnes of rice husk is generated annually from the rice mills in Ebonyi State. About 82%of these is generated in Abakaliki LGA where the largest rice milling cluster is located (Figure 6 shows a dump site for rice huk in Abakaliki). Information gathered during the survey indicated that only 5% of rice husk produced is being used as fuel for residential and commercial cooking stoves and as livestock feeds. The rest has been accumulated at open disposal sites, near the large rice mill cluster in Abakaliki. At these disposal sites, people scavenged for remnant of white rice that has been disposed with the husk. During summer, the accumulated husk mountains often catch fire with attendant environmental consequences and risk to scavenging people. Currently the rice processing facilities face the problem of limited availability of paddy rice (current mill capacity utilization is as low as 10% and the mill is run for 5 hour per day). However, information from stakeholders indicates that the paddy rice production in the State can be doubled to about 300,000 tonnes per annum. Medium to large-scale rice milling activities can be found in two locations in Abakaliki LGA, specifically in Abakaliki and Ekumeniyi townships. In Abakaliki, the rice-milling cluster is located on Ogoja Road while in Ekumenyi, the major cluster is at Nwida Market square. The rice processing facility in Abakaliki Township is the largest in Ebonyi State. It is a cluster with about **1000 milling machines and 30 destoning machines**. The rice mill as well as the de-husking area, currently covers a total of about 10 square kilometer. The following assumptions were generated from the data collected during the field survey and utilized in the estimation of rice husk production on an annual basis at the Abakaliki Township cluster:

Each of the milling machine at the cluster has an installed capacity of about 0.8 tonnes of semi-polished rice per hour;

There are 1000 milling machines in the cluster;

Over the past few years, the milling machine has been averaging a capacity utilization of about 10%. Each milling machine currently operates for about 5 hours per day and 300 days per year;

For each tonne of paddy rice, between 0.65-0.70 tonnes of white rice and between 0.22-0.28 tonnes of rice husk are produced.

Rice milling facilities are also located in Ekumenyi in Abakaliki LGA. Ekumenyi is made up of four major communities namely: Edda; Amachi; Ndegukpetumo and Ndebookpetumo. There are a total of about 10 rice-milling machines. Over 99% of rice produced in Abakaliki LGA comes from the rice mill cluster in Abakaliki cluster with the Ekumenyi facilities yielding only marginal additions. Due to poor and inadequate grid electricity supply, these mills which run essentially on diesel drives spend in excess of N236 million (US$2 million) annually on diesel. Given the above estimate of annual paddy rice production in the State, it can be concluded that about 73% of paddy rice produced in the State is milled; It was also concluded from the survey exercise during interactive discussions with knowledgeable stakeholders that if a waste to energy project is sited in Ebonyi State, rice husks produced in other States not far from the facility are likely to be transported to the site to derive value from the otherwise valueless materials.

5.8 ELECTRICITY DEMAND AND SUPPLY IN EBONYI STATE

Presently, electricity from the national grid is transmitted and distributed to towns and some local government areas of the state. The load demand for electricity in Ebonyi State is estimated at 30 MW covering only the areas hooked to the national grid. Electricity supply in the state is obtained from a 132 KV substation situated at Mile 50 Abakaliki. The total supply of electricity to Ebonyi State is 24 MW. In addition to electricity supply from the national grid, the State Government is making some efforts at rural electrification in the State. In this regard, there are various rural electrification projects at various development stages in various local government areas of the State. Some are funded by the Government and some are being executed through African Development Bank (ADB) assistance. Although agro-industries are well established in the State, these are based on old technologies which are characterized by low production and inefficient energy use. These have led to a lot of generated wastes which are not being converted to energy or any economic use. The impact of these on the environment where such facilities are located is substantial.

5.9 ELECTRICAL ENERGY DEMAND OF THE RICE MILLS

Electrical energy required for the milling operations averaged about 35.6 GWh/year. This does not include energy used in the parboiling and drying of the paddy rice prior to being supplied to the mill. The existing rice processing cottage industry set-up is very energy inefficient. For instance, UNIDO study [11], revealed that while the specific energy requirement (including energy for parboiling and drying of the paddy rice) of a modern rice mill ranges between 30-60 kWh per tonne of paddy rice processed, in Ebonyi State this has been estimated to be about 158 kWh per tonne of paddy rice processed. This figure does not even include energy utilized for parboiling and drying of paddy rice and it's between 3-5 times that of the modern mill, revealing the enormous quantity of energy being wasted through inefficient technology. When the rice husk is used as a fuel in a conventional steam cycle power plant, with a fuel throughput rate of 6.63 tonnes/hr, a power rating of the resulting system has been estimated to be about 6.6 MW. A variant of the system above is one where 30% of the steam produced is extracted to be utilized for non-power purposes (e.g. parboiling of paddy rice), the output will include, 4.6 MW power and 92 GWh/yr of heat energy. However, when the rice husk is used as a fuel in a combined heat and power system the rating will depend on the heat to power ratio: for a H:P ration of 3:7, 147 MW of power and 44.32 GWh/yr of steam will be produced; when the H:P ratio is 3:2, power production will be about 8.4 MW and the steam rate will be 88.64 GWh/yr; When the gasification technology is utilized to produce power only, system rating will be about 11MW.

5.10 ETIMATED CAPACITY OF PROPOSED POWER PLANT USING THE RICE HUSK GENERATED

Rice husk powered power plant is a proven technology and more than 100 such plants are already in operation in other parts of the world, though there are limited suppliers of utility boilers. There are successful rice husk power plants in South East Asia countries like Malaysia, Thailand. Based on the estimated 55,000 tonnes of annually generated rice husk, a 5 MW rice husk fired power plant is being proposed for the Abakaliki rice mill cluster [12].

5.11 TECHNICAL CHARACTERISTICS OF PROPOSED RICE HUSK FUELED POWER PLANT

With a plant life of 20 years, a gross power generation of 5 MW and plant consumption of 0.5 MW, the plant's net power generation is 4.5 MW. While the boiler efficiency (LHV %) ranges between 80-85%, the overall plant efficiency (LHV %) ranges between 20-24 % This plant with a total investment cost of US$ 11.26 is expected to run for 8,000 hours requirng between 48,000-56,000 tonnes of rice husk annually. The land required is about 2 hectares.

5.12 SOCIO-ECONOMIC AND ENVIRONMENTAL BENEFITS OF PROPOSED PROJECT

As a low NOx and SOx technology, the avoidable total greenhouse gas emissions accruing from this project is about 60,000 tonnes of CO_2 equivalent annually. Under the Clean Development Mechanism (CDM), this will give 60,000 CER per year. Apart from revenue from sales of generated electricity, at €10 per CER, total revenue from CER is €600,000 per annum. This revenue is possible for the next 21 years [12]. In addition; about 9,600 tons of rice husk ash will be generated from the project. There is a global demand for rice husk ash particularly in Japan, North America, Europe, Korea, Taiwan, Australia and New Zealand. It is being used in the steel, cement, fertilizer, refractory, brick making, die-casting, semiconductor, rubber and oil recycling industries as well as poultry farms. However, the demand for this rice husk is still unknown and its quality is yet to be ascertained. The international price for rice husk ash ranges between US$50-120/ton [13]. Using a modest figure of US$50 per ton, additional revenue of US$480,000 will accrue from rice husk ash sale annually.

6.0 CONCLUSION

Sawmill industry in Ijebu Area and ricemill industries in Abakaliki LGA contribute significantly to the economic well being of their communities. As is with various other industries and business concerns, these industries are suffering from acute shortage of electricity for operations as most of their operations are electricity dependent. Sawdust and rice husks are major by products of these industries and about 80% of these by products are currently being burnt as wastes, since there is no means of utilizing them within the industries and around the study area. In quantifying the amounts of sawdust and rice husk produced per cluster in the study areas, it was estimated that a total volume of wood waste produced is a little over 212,220 m^3 (about 66,000 tons) and about 55,000 tons of rice husk per annum. At 80% gasification efficiency [8], the produced wood wastes have been estimated to be capable of providing fuel to power 8.0 MW generating plant with an annual electricity output of about 79,089.3 MWh. Similarly, based on the estimated 55,000 tonnes of annually generated rice husk, and at an overall plant efficiency of 20-24%, a 5 MW rice husk fired power plant is being proposed for ricemill clusters. This study reveals that there are considerable socio-economic and environmental benefits that these projects will bring to both the immediate communities and direct beneficiaries as well as to Ogun and Ebonyi States and the country, generally. Implementation of these project has the potentials of saving at least 6,550 litres of diesel consumption daily at the sawmills. In monetary terms, this translates to about N600, 000 per day and N177 million per annum. At the ricemills, the cost savings of the diesel displaced is in excess of N236 million. These cost savings, it is believed will increase the profit margin of the sawmill and ricemill operators. The benefits of the project from the environmental perspective include:

· replacement of electricity supply from the national grid to the sawmills,
· replacement of diesel fueled self-generated electricity,
· avoidance of dumping of wood wastes to the earth.

The CO_2 emissions that will be saved through these activities that will be avoided have been estimated to be in excess of 73,000 tons CO_2/year, which make them good candidates for Clean Development Mechanism (CDM) projects. These are just clusters in only one area of the States of areas of study, with clusters of sawmills and ricemills scattered across the country, many of these projects could be established given the enabling environment. Excess electricity after the sawmills and ricemills have been duly satisfied can be wheeled to other small and medium scale enterprises (SMEs) around the mills as well as neighbouring households electricity consumers. However, to maximize the benefits of these projects, the sawmills and ricemills need to adopt energy efficient equipments. In order to attract investors into the electricity sector and particularly these projects, the electricity tariff regimes have to be market driven for the investors to make good returns on their investments. With the ongoing reforms and restructuring in the electricity

Table 1: Electrical Energy Production and Consumption in Selected Countries around the world (2001)

Country	Electrical Energy Produced/Capita (KWh/Cap)	Electrical Energy Consumed/Capita (KWh/Cap)
A. Some G8 Countries		
Canada	**17.4**	**15.5**
USA	**12.7**	**12.3**
France	**8.6**	**6.9**
Japan	**8.1**	**7.6**
Germany	**6.6**	**6.2**
B. Some Australasian Countries		
Australia	**9.95**	**9.26**
Taiwan	**6.60**	**6.20**
South Korea	**6.00**	**5.60**
C. Some Latin American Countries		
Paraguay	**7.25**	**6.43**
Venezuela	**3.50**	**3.30**
Chile	**2.63**	**2.54**
Argentina	**2.50**	**2.40**
D. Some African Countries		
South Africa	**4.60**	**4.20**
Libya	**3.60**	**3.33**
Egypt	**0.99**	**0.92**
Algeria	**0.77**	**0.71**
Ghana	**0.42**	**0.40**
Morocco	**0.45**	**0.41**
Nigeria	**0.16**	**0.11**

Source: Dayo, 2005

Table 2: Number of Sawmill per Cluster

Cluster code[1]	**Cluster name**	**Number of Sawmill**
OdgLGA	Ejirin Road	29
IjNLGA	Ijebu Igbo	42
IjNELGA	Oke Owa	23
IjOLGA	Obalende	2
Others	Wood Factories	4
	Total	**100**

Table 3: Number of Saws in Each Sawmill Cluster

Cluster code	**Cluster name**	**# of Band**	**% of Total**	**# of Circular**	**% of Total**
OdgLGA	Ejirin Road	47	36	47	36
IjNLGA	Ijebu Igbo	50	38	50	38
IjNELGA	Oke Owa	27	21	27	21
IjOLGA	Obalende	4	3	4	3
Others	Orilonise Wood Factory	3	2	3	2
	Total				

OdgLGA ≥ Odogbolu Local Government Area; IjNLGA ≥ Ijebu North Local Government Area; IjNELGA ≥ Ijebu North East Local Government Area; IjOLGA ≥ Ijebu Ode Local Government Area

Table 4: Average Volume of Log Handled Daily Per Cluster

Cluster code	**Cluster name**	**Actual volume of wood processed per day m^3/day)[1]**	**Yearly production capacity (m^3/year)**	**Potential volume of wood that can be processed per day (m^3/day)**	**Yearly production (m^3/year)**
OdgLGA	Ejirin Road	444	133,245	254	76,140
IjNLGA	Ijebu Igbo	473	141,750	270	81,000
IjNELGA	Oke Owa	255	76,545	146	43,740
IjOLGA	Obalende	38	11,340	22	6,480
Others	Orilonise Wood Factory	28	8,505	16	4,860
	Total	**1,237.95**	**371,385**	**707**	**212,220**

Table 5: Estimated Average Volume of Wastes (Chippings, Shavings and Sawdust) Produced Daily Per Cluster (m^3/day)

Cluster code	**Cluster name**	**Quantity of Sawdust Produced per Day (m^3/day)**	**Yearly Production (m^3/year)**
OdgLGA	Ejirin Road	25.4	7,614
IjNLGA	Ijebu Igbo	27.0	8,100
IjNELGA	Oke Owa	14.6	4,374
IjOLGA	Obalende	2.2	648
Others	Orilonise Wood Factory	1.6	486
	Total	**70.7**	**21,222**

Table 6: Customer and Tariff Distribution under Ijebu Ode District of PHCN

Customer Type	# in Group	Tariff Amount (N/kWh)
Residential (LV)	40,579	From 1.2 to 8.5
Commercial (MV)	8,415	8.5
Industrial (HV)	94	From 6.5 to 8.5
Total	**49,088**	-

Table 7: Estimated Power Demand in Each Cluster of Sawmill

Cluster code	Cluster name	Power demand from saws (kW)	Other ancillary equipment (kW)	Total Power Demand (kW)
OdgLGA	Ejirin Road	1,513.8	37.7	1,551.5
IjNLGA	Ijebu Igbo	2,088.0	52.0	2,140.0
IjNELGA	Oke Owa	1,409.4	35.1	1,444.5
IjOLGA	Obalende	208.8	5.2	214.0
Others	Orilonise Wood Factory	156.6	3.9	160.5
	Total	**5,376.6**	**133.9**	**5,510.5**

Table 8: Estimated Energy Demand Based on Total Power Demand in Table 7 in Each Cluster of Sawmill

Cluster code	**Cluster name**	**Electricity Demand (kWh/day)**
OdgLGA	Ejirin Road	15,515
IjNLGA	Ijebu Igbo	21,400
IjNELGA	Oke Owa	14,445
IjOLGA	Obalende	2,140
Others	Orilonise Wood Factory	1,605
	Total	**55,105**

Table 9: Source of Electricity Supply to Each Sawmill in Each Cluster

Cluster code	**Cluster name**	**Electricity Demand met from Grid (kWh/day)**	**Electricity Demand met through Standby Generators (kWh/day)**
OdgLGA	Ejirin Road	1,551.5	13,963.5
IjNLGA	Ijebu Igbo	2,140.0	19,260.0
IjNELGA	Oke Owa	1,444.5	13,000.5
IjOLGA	Obalende	214.0	1,926.0
IjNELGA	Orilonise Wood	160.5	1,444.5
	Total	**5,510.5**	**49,594.5**

Table 10: Estimated Daily Diesel Consumption per Cluster

Cluster code	Cluster name	# of Band	Diesel Consumption	Daily Amount	Annual Amount N
OdgLGA	Ejirin Road	47	2,350	211,500.00	63,450,000.00
IjNLGA	Ijebu Igbo	50	2,500	225,000.00	67,500,000.00
IjNELGA	Oke Owa	27	1,350	121,500.00	36,450,000.00
IjOLGA	Obalende	4	200	18,000.00	5,400,000.00
Others	Orilonise Wood	3	150	13,500.00	4,050,000.00
	Total		**6,550**	**589,500.00**	**176,850,000.00**

Table 11: Distribution of Saws Operated in Each Cluster of Sawmill

Cluster code	Cluster name	1 Unit of Saws	% of Total	2 Units of Saws	% of Total	3+ Units of Saws	% of Total
OdgLGA	Ejirin Road	15	51	10	34	4	14
IjNLGA	Ijebu Igbo[1]	25	52	15	31	8	17
IjNELGA	Oke Owa	18	67	7	26	2	7
IjOLGA	Obalende	0	-	2	100	0	0
IjNELGA	Orilonise Wood Factory	0	0	0	0	3	100
	Total	58		34		17	

Table 12: Nominal Characteristics of Some Wood Processing Industry Residues

Green Moisture Content (Wet basis)	36%
Green density	210 kg/m^3
Volatiles	8.3%
Ash Content	1.6%
Higher Heating Value (HHV) (Oven dry)	20.0 MJ/kg
Lower Heating Value (LHV)	11.9 MJ/kg

Table 13: Estimated Electricity Generation Potential and Generator Capacity for Each Cluster

Cluster code	**Cluster name**	**Quantity of Sawdust Produced per Day (m^3/day)**	**Electricity Generation Potential (kWh)**	**Required Generator Capacity**
OdgLGA	Ejirin Road	254	68,719.7	2.9
IjNLGA	Ijebu Igbo	270	99,525.1	3.0
IjNELGA	Oke Owa	146	54,501.8	1.6
IjOLGA	Obalende	22	9,478.6	0.2
Others	Orilonise Wood Factory	16	4,739.3	0.2
	Total	**707**		**8.0**

Table 14: Estimated Total Avoided CO_2 Emissions (tons/year) from the Three Identified Sources per Cluster

Cluster code	**Cluster name**	**Avoided CO_2 Emissions from Waste Dump to the Earth (tons/year)**	**Avoided CO_2 Emissions from Diesel fuelled Self Generating**	**Avoided CO_2 Emissions from the National Grid Supply (tons/year)**	**Total tons CO_2/year**
OdgLGA	Ejirin Road	2,398.4	1,854.2	344.4	**4,597.0**
IjNLGA	Ijebu Igbo	2,551.5	1,972.5	475.1	**4,999.1**
IjNELGA	Oke Owa	1,377.8	1,065.2	320.7	**2,763.7**
IjOLGA	Obalende	204.1	157.8	47.5	**409.4**
Others	Orilonise Wood Factory	153.1	118.4	35.6	**307.1**
	Total	**6,684.9**	**5,168.1**	**1,223.3**	**13,076.3**

Table 15: Rice Milling Facilities and Rice Processing in Ebonyi State by LGA

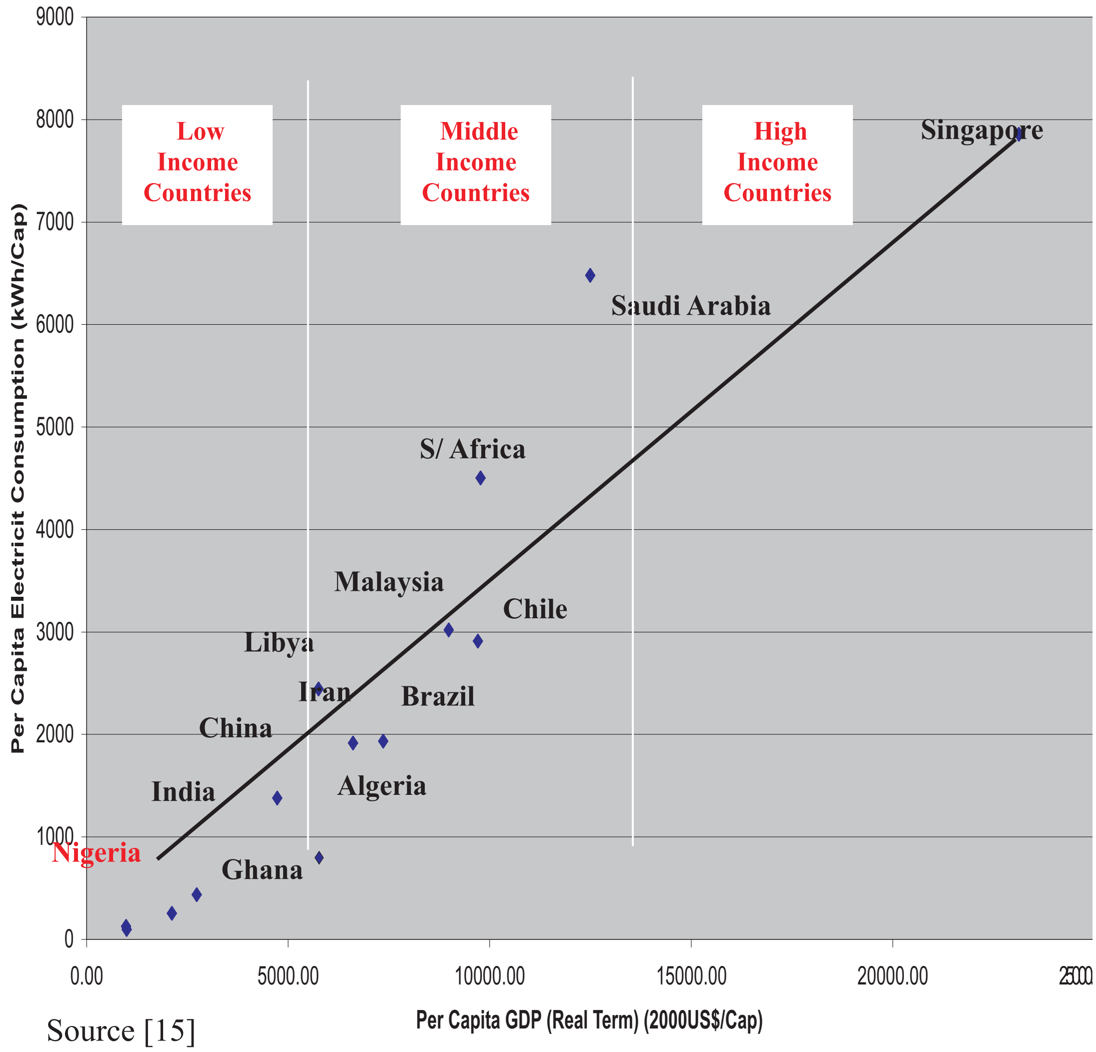
No.	Name of LGA	No. of Mills	No. of De-stoning Machines	No. of Direct Milling Personnel	Paddy Rice Input (Tonnes per annum)	White Rice Rice Produced (Tonnes per annum)	Rice Husk Produced (Tonnes per annum)
1.	Abakaliki*	1010	30	5050	179,555.56	121,200.00	44,888.89
2.	Afikpo North*	27	0	135	3,600.00	2,430.00	900.00
3.	Afikpo South	3	0	15	400.00	270.00	100.00
4.	Ebonyi	13	0	65	1,733.33	1,170.00	433.33
5.	Izzi*	15	0	75	2,000.00	1,350.00	500.00
6.	Ezza South*	24	0	120	3,200.00	2,160.00	800.00
7.	Ezza North*	40	0	200	5,333.33	3,600.00	1,333.33
8.	Ikwo	56	0	280	7,466.67	5,040.00	1,866.67
9.	Ivo*	38	0	190	5,066.67	3,420.00	1,266.67
10.	Ohazara	7	0	35	933.33	630.00	233.33
11.	Ohaukwu*	38	0	190	5,066.67	3,420.00	1,266.67
12.	Onicha*	21	0	105	2,800.00	1,890.00	700.00
13.	Ishielu	11	0	55	1,466.67	990.00	366.67
	TOTAL	**1,303.00**	**30**	**6,515**	**218,622.22**	**147,570.00**	**54,655.56**

· **Sites with Mill Clusters**

Table 16: Present Rice and Husk Production in Abakaliki LGA

Location	**Paddy Rice Input** (Tonnes/year)	**Rice Husk Produced** (Tonnes/year)	**White Rice Production** (Tonnes/year)
Abakaliki Township	172,900.8	43,245.2	116,800.0
Ekumenyi	1,297.0	324.3	876.0
Total	**174,197.8**	**43,569.5**	**117,676.0**

Source [11]



Source [15]

Figure 1: Per Capita Electricity Consumption versus Per CapitaGDP Real Term 2003 for Some Selected Countries

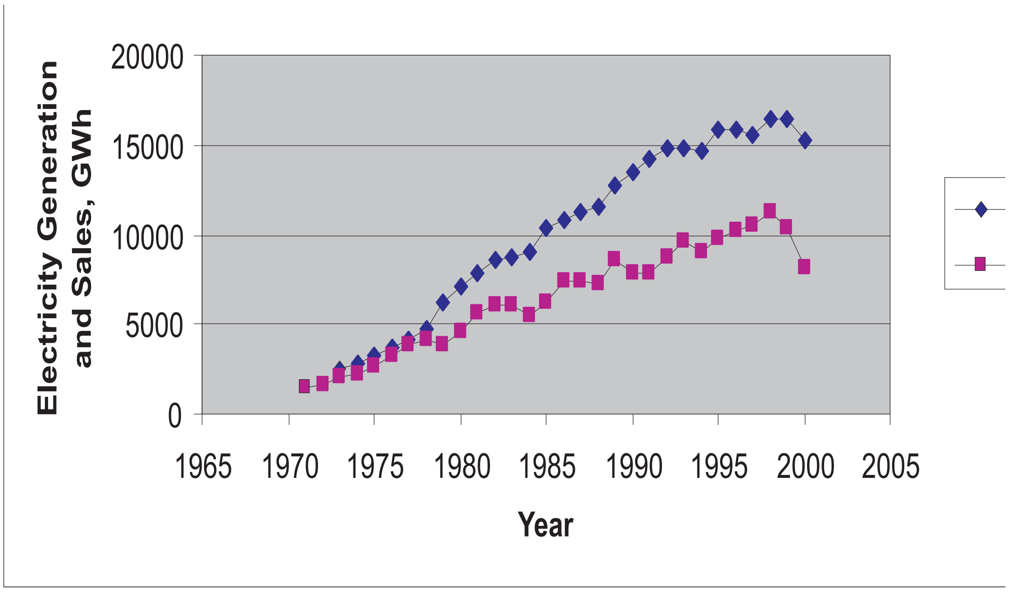


Figure 2: Electricity Generation and Sales

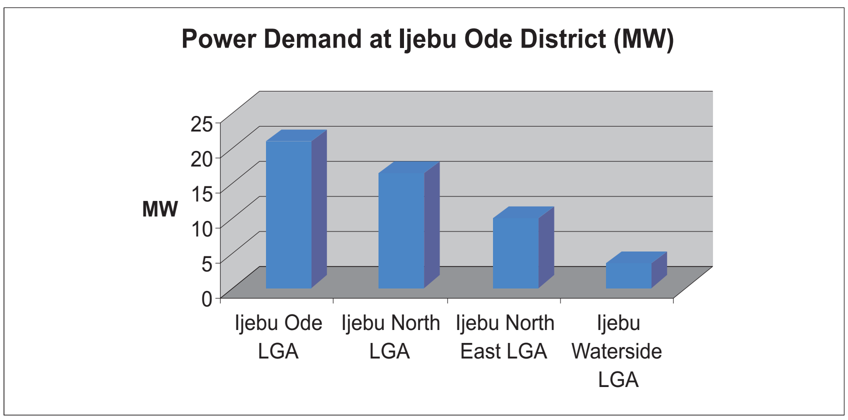


Figure 3: Power Demand in Ijebu Ode District of PHCN [24]

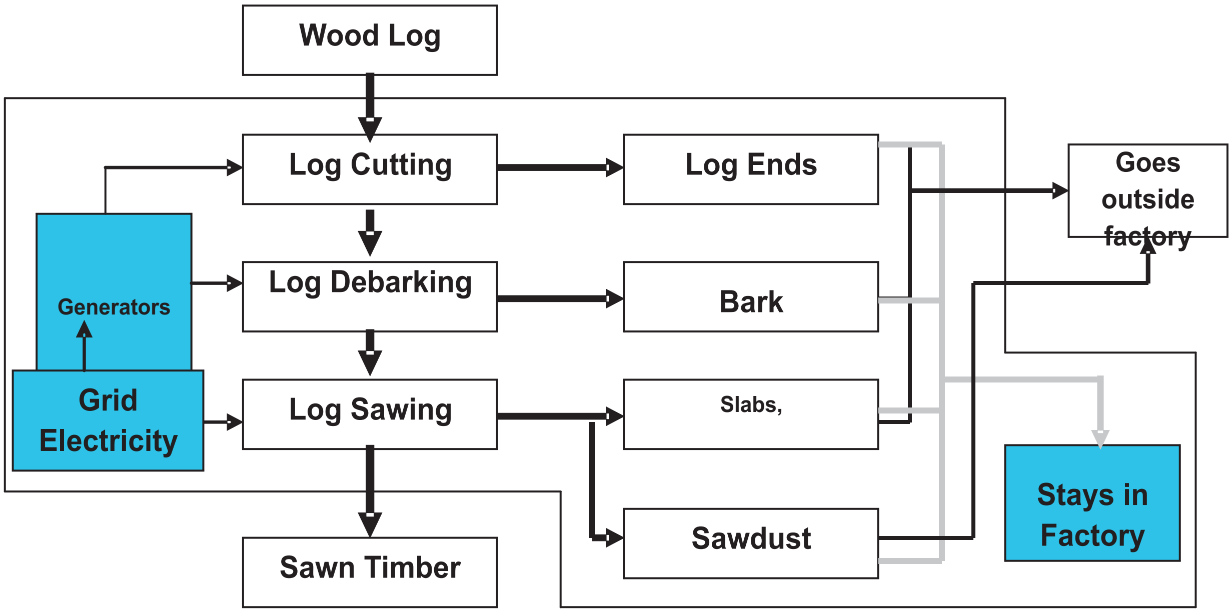


Figure 4: Power Demand in Ijebu Ode District of PHCN[24]

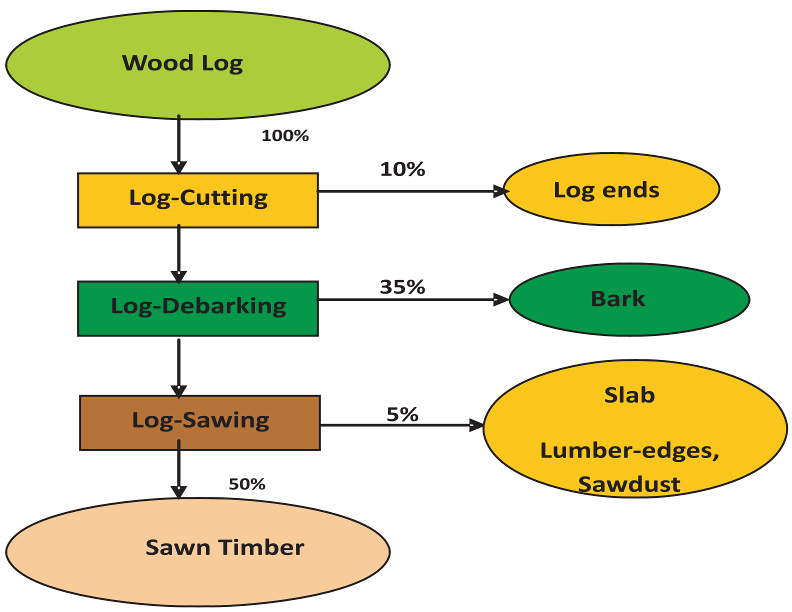


Figure 5: Mass balance of wood processing at Sawmill [27]

Figure 6: Rice Husk Dump Site at the Abakaliki Rice Mill Cluster

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Engaging Renewable Energy in Nigeria: The low Hanging Fruits – Part 1 Solar Water Heaters (SWHs) and Solar PV

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ABSTRACT

Renewable Energy (RE) has been in the consciousness of some segments of the Nigeria public in the past decade at least, while it has been in the academic and research institutes fora since the 1970s. It is well enunciated in the National Energy Policy of August 2003 and in the Draft National Energy Master Plan of June 2007, while it is the main focus of the Draft Renewable Energy Master Plan of November 2005. Nevertheless, RE is yet to make any noticeable impact on either the life of the ordinary Nigerian or even the national energy mix, save for biomass (mostly fuel wood with little or no value-added save for charcoal) consumption predominantly by the household/domestic sector. This paper considers the barriers to the uptake of RE in Nigeria and offers the experience (some personal) of other countries (some in Africa) who have successfully engaged RE into their energy mix with the three-fold benefits of energy security, low-carbon jobs creation, cleaner environment from reduced GHG emissions through identifying the low hanging fruit RE sources in treading the Low Carbon Development path to sustainable growth. Key R&D areas, issues of Standards and Specifications are highlighted as necessary in each part of the 5-part paper. The 5-part paper is as follows:

- Part I – Solar Water Heating Technologies;
- Part II – Other Solar Thermal Technologies and Energy Efficiency & Management;
- Part III – Solar PV Technologies;
- Part IV – Biomass and Biofuel Technologies;
- Part V – Small Hydro and Wind Power Technologies;
- Part VI – Policies – those which may, and those which cannot work in Nigeria.

1.0 INTRODUCTION

That solar thermal energy is the lowest hanging fruit any nation should readily engage is not in any doubt from Figs. 1a and 1b from the 2010 Edition of IEA Solar Heat Worldwide – Markets and Contribution to Energy Supply 2008*[13]*. Fig. 1a depicts the phenomenal growth in installed capacity of flat-plate and evacuated tube collectors worldwide from 2000 to 2008 with an average annual growth rate of 20.1%, and China consistently having the lion shares throughout the period. Between 2007 and 2008, considerably high worldwide growth rate of 37.1% was achieved, with the following regions contributing the indicated growth rates: Europe (+62.5%), USA and Canada (+41.8%), Australia and New Zealand (+39.7%), China (+38.4%) and Japan (+21.9%). The total solar water collector installed capacity in 2008 has been reported to be 132 GWth by IEA *[12]* and 142 GWth by REN21 – Renewable Energy Policy Networks for the 21st Century *[9]*.

The annually installed capacity of flat-plate and evacuated tube collectors in kW_{th} per 1000 inhabitants in 2000-2008 appears in Fig 1b where the dominance of the Middle East (Israel and Jordan) in 2005-2008 and China throughout the period is apparent. The modest but consistent growth rates recorded by Australia and New Zealand and by Europe is noteworthy. The African continent's insignificant growth rate is noteworthy, with only Namibia, South Africa, Zimbabwe and Tunisia being the four major countries on the continent striving to keep abreast of SWH worldwide market trend.

In terms of the contribution to the energy supply and CO_2 reduction, in 2008, both flat-plate and evacuated tube collectors had a total capacity of 131.8 GW_{th} while the installed capacity unglazed plastic collectors used mainly for heating swimming pools was 18.9 Gw_{th}.

Table 1 gives details on solar thermal collectors in four African countries and eight other countries from the list of 53 countries in the list of the IEA book *[13]*. The four African countries are the only African countries in the list of 53 countries worldwide in the IEA study. The tables tabulate the following in each of the countries in 2008: total collector area, m^2; total installed capacity, MW_{th}; calculated number of systems; annual collector yield in GWh/a & TJ/a; annual fossil energy savings displaced by the use of solar thermal energy, toe/a; and the annual reduction in tonnes of CO_2 emission from the fossil energy saved. Table 1 relates to all solar thermal systems for hot water heating, space heating and swimming pool heating installed worldwide at end of 2008 while Table 2 is for solar thermal systems using flat-plate and evaluated tube collectors (e.g. for hot water and space heating and low temperature industrial process heat).

In Table 1, the annual total collector yield globally from the 53 countries in 2008 was calculated by IEA at 109,713 GWh (394,968 TJ), corresponding to 12.4 mtoe energy savings and a carbon emission avoidance of 39.4 $mtCO_2$ out of which China's share was 57.3% and 57.4% respectively. For collector surface area installed in 2008, 16 countries in the IEA report had more than 1million m^2; nine had more than 2million m^2; nine had more than 3million m^2; four had more than 5million m^2; only China, Germany and Turkey had more than 10illion m^2; while China was the only country with more than 100million m^2 collector surface area installed.

On the other hand, Table 2 excludes unglazed solar thermal collectors used primarily in swimming pool heating and focuses more on hot water and space heating as well as industrial process heating applications. Comparing Tables 1 and 2, it is seen that solar thermal heaters of most of the countries listed in the tables are of the flat-plate type and/or evacuated tube collector type as the two entries are the same in such cases. However, for Brazil, Germany, USA, India, Israel and South Africa, the differences in the entries in the two tables result from the exclusion of solar hot water heaters of the unglazed flat plate type mainly used in swimming pools in Table 2 and which are significantly used in these countries.

Table 2. Calculated annual collector yield and corresponding oil equivalent as well as CO_2 reduction of solar thermal systems using flat-plate and evacuated tube collectors (e.g. hot water heating and space heating, low temperature industrial process heat) installed by the end of 2008 in twelve selected countries. *[13]*.

The share of solar water heater capacity among the top 10 countries/regions of the world in 2007 appears in Fig. 2a and 2b. China had 66.7% of the world market in 2007 which had been slightly reduced to 66.4% by 2008. The remarkable 80.2% addition of solar water heating capacity in China between 2007 and 2008 shown in Fig 2b is outstandingly phenomenal, where other countries and regions of the world are in single digit percentages.

Investment flows in 2008 invested in renewable energy worldwide was an estimated US$120 billion, including new capacity and biofuels refineries. Solar hot water collector investment share of this was 6% (i.e. US$7.2 billion) *[9]*. The US$120 billion amount in 2008 was up from about one-quarter of this amount four years earlier in 2004. Solar hot water collectors grew 15% worldwide in this period. *[13]*. Development assistance for renewable energy in developing countries also reached about US$2 billion in 2008.

2.0 INVESTMENT FLOWS IN SOLAR THERMAL ENERGY, JOB CREATION, ENVIRONMENT AND ENERGY SECURITY.

The direct connection between the above investment flows and jobs and employment creation is relatively obvious. The IEA estimates that the solar heating and cooling sector employs more than 200,000 people worldwide *[6]*. Other sources give much higher estimates of solar heating and cooling jobs.

Nigeria with most of Africa is left out of this investment flow with its resultant positive effects on jobs and employment creation, environment and energy security. Yet there is much sunnier climate in Nigeria and all of Africa than in Europe which is at the forefront of solar water collectors for domestic, commercial and industrial applications. The energy savings as well as the CO_2 emission reduction in Tables 1 and 2 amount to cleaner environment, laudable global warming mitigation effort while also moving in the desirable direction of low carbon and sustainable growth.

It might not be so obvious to the casual reader that considerable fossil energy savings can accrue to Nigeria if we are ready to apply some of the regulatory and fiscal measures that have been successfully engaged in the success stories in Tables 1 and 2. Such fossil energy might be from our thermal power stations which contribute about 70% of the total grid electrical power which constantly fluctuate between 1,500 and 3,500 MW as we all know well. On the other hand it could be from the kerosene or the fuel wood and charcoal used in cooking in the average Nigerian home; or it could be from the cooking gas in the more affluent home kitchens; in hotels, government institutions such as teaching hospitals, armed forces barracks, etc. In the private sector, it could be from low temperature (< 90^oC) industrial process heat in such operations requiring drying, malting, etc.

A small desk study was conducted recently to estimate the amount of fossil energy (electricity, kerosene, LPG, fuel oil, etc) used to produce hot water in hotels, teaching hospitals, institutions, some homes, etc., *[3]*. The study is based on an electric water heater (geyser) of 1 kW power rating, say in a hotel bathroom operating for 5 hours a day. We remember that even our electric pressing iron is normally rated a bit more than this, thus the above heater rating is modest. We also know most of them are left on all day, 24/7, thus our 5 hours daily is another modest assumption. Let us now base our calculation on 1 million of such water heaters nationwide, and we will obtain 5000 MWh/day energy consumed daily by the heaters. In a year this will be 1,825,000 MWh/yr. This is about the energy production of a 425 MW power plant (could be a 5 X 85 MW or a 10 X 42.5 MW steam or gas turbine power station) working at 75% plant factor with 65% overall efficiency at rated power full blast throughout the year!

The above 425 MW power plant will produce about 2 million tonnes of CO_2 annually (1.92 to be exact), which would be saved our environment if solar water heaters had been used to achieve the purpose. From the thermodynamic point of view, using such a power plant to produce heat from resistive heating is using a high grade electrical energy to produce a lower grade thermal energy, much like Nigeria has been doing for decades using high grade chemical energy in natural gas to produce unwanted heat energy in the Niger Delta environment!

Before leaving this subject, using solar water heating will also qualify for registration consideration of 1,825,000 Certified Emission Reduction (CERs) units annually under the Clean Development Mechanism of the UNFCCC which could be traded at the prevailing rate on the international carbon market. A CER now sells for about Euro 20 to 25. A CER is equivalent to 1000 tonnes of CO_2 and CER emission certificates are issued upon laid down verification procedures of the UNFCCC.

3.0 WHY NIGERIA HAS NOT MADE MUCH PROGRESS ON ENGAGING SOLAR THERMAL ENERGY

Chapter 3 of the Renewable Energy Master Plan (REMP) of 2005 *[11]* funded by the UNDP for the Nigerian government is on Targets [Short (2007), Medium (2015) and Long Term (2025)] deemed critical to the achievement of the vision of the REMP. Section 3.3 is devoted to Renewable Non-Electricity Targets for energy production from solar thermal, biomass and biogas. Solar thermal share of total thermal energy are 10%, 20% and 40% in the S, M and L terms, made up of solar water and (industrial) air heating of 14,534.2 GWh, 28,297.9 GWh, and 59,728.6 GWh respectively. Furthermore, the implications of these amounts of solar thermal energy are spelt out in Table 3.4.1 where 4000, 57,100 and 146,600 solar water heating collectors are envisaged for the S, M and L terms. In Table 3.4.7, the number of solar water heating collectors with a 2m^2 surface area in the long term is indicated as 1,146,600.

Chapter 4 of REMP on Planned Activities and Milestones details six national programmes on renewable energy including one specifically for its promotion nationwide. Project Concept Notes are included in the Annex among which is the National Solar Heating Programme (NASHP) slated for 2005 – 2025, and with the following stated objective: "*To replace a significant fraction of low temperature (< 80°C) heating applications in the domestic, commercial, institutional and industrial sectors with solar energy, thereby resulting in thousands of tonnes of avoided CO_2 into the environment while releasing fossil fuels and biomass that would otherwise have been used for more useful work*".

Planned activities to achieve the outcomes are given on page 187 of REMP as follows:

- 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, & 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 Programme (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 and air heaters, solar dryers, solar cookers, solar stills, etc.;
- 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 sanctions;
- Product standardization methodology for the Nigerian solar thermal energy industry; and
- Training and certification programmes for artisans, technicians, engineers, business community, banking community, public sector officials, etc. on solar thermal technologies through national energy centres and other higher institutions and NGOs as soon as possible within the year 2005.

In the 2007 National Energy Databank, a Compendium of Renewable Energy Systems in Nigeria by the Energy Commission of Nigeria *[6]*, there is only one project listed on solar water heating, the Solar Water Heating Project at UDU Teaching Hospital in Sokoto. Most probably, just this one still exists today in the whole of Nigeria! This is a 1000-litre capacity system which at best would be of no more than 10 m^2 surface area. This would work out at 0.0000714 m^2 installed capacity per 1000 Nigerians. Compare this with Egypt with population of 81.5 million (2008 World Bank, WDI) which by 2000 had about 200,000 households using DSWH systems with an estimated 400,000 m^2 collector surface area! This works out at 4.9 m^2 per 1000 Egyptians.

With all above, why have we not seen any desired visible movement on solar thermal energy uptake? The answer lies mainly with the legislative branch which needs to be sufficiently educated on the desirability of enacting the relevant Bills/Acts/Laws to encourage the private sector to enter the turf and spur market development. Government on its part will need to show concern for national economic development through well-funded, properly conceived national programmes as expounded above with attractive incentives aimed at the various sectors. None of these has happened so far, six years down REMP. Other successful nations in renewable energy engagement have taken this last but very critical step seriously and they are reaping the benefit today as we have seen in Tables 1 and 2. We will presently look at a number of case studies from successful countries in Tables 1 and 2 to see what we can learn from their experiences, after considering some typical SWH collector system costs worldwide.

4.0 TYPICAL SYSTEM COMPARATIVE COSTS

Table 3 is indicative of typical costs of domestic solar water heaters (DSWH) in selected localities worldwide. Among determinants of cost of solar water heater (SWH) systems are system and installation complexity or simplicity, labour costs, amount of locally manufactured parts in the system, competitiveness of the local market, etc. Domestic SWH systems are basically of three types: (i) Flat-plate collector, consisting of an insulated box housing the blackened absorber plate made of metal or polymer and covered on top with one or more glass plates; (ii) the integral collector-storage system (ICS) consisting of one or more black tanks or tubes in an insulated, glazed box; and (iii) evacuated tube solar collectors featuring rows of glass tubes with metal absorber finned tubes.

Notes: *The thermosyphon systems are one family systems with 2.4 m^2 collector and 150 litre storage tank. The pumped system has a 4-6 m^2 collector and 300-litre storage tank. DSWH systems in Europe cost EUR50-160/MWh of heat energy which is competitive with retail electricity prices but more expensive than heat from natural gas. The Combi-systems for combined space and water heating cost about EUR160-500/MWh. These costs are projected to significantly decline in the long term.[Ref. 10]*

Active solar water heater systems may either be the direct circulation systems which use a pump to move the water through the collector into the end-use point or the indirect circulation system having a closed circuit anti-freeze dozed water exchanging heat inside a heat exchanger with the water required in the end-use point. Passive solar water heater systems on the other hand are much simpler hence less expensive and likely to be more durable systems than the active systems. Passive systems are also of two types: the ICS and the thermosyphon systems. Solar water heaters normally available with an electrical or gas heating element as a backup for cloudy days or for when demand exceeds design conditions.

It should therefore be no surprise to find widely varying solar water heater cost structure as in Table 3. Even then, the installed cost shown above tends to indicate that indeed, solar water heating is one of the lowest hanging fruit technologies any serious nation blessed by nature with reasonable solar energy resource would readily exploit. This is why it has been ranked highest in the order of presentation of the subsequent range of renewable energy technologies.

5.0 LESSONS FROM ISRAEL, GREECE AND BARCELONA, SPAIN ON SOLAR WATER HEATERS

The two main promotion mechanisms adopted by countries worldwide for renewable energy are economic promotion mechanisms and regulatory promotion mechanisms. The latter was pioneered by Israel when in 1980 the Israeli Knesset passed a law requiring the installation of SWHs in all new homes (except high towers with insufficient roof area) applicable throughout Israel. Israel today is reputed to be the world leader in per capita solar energy utilization, and 85% of Israel's 1,650,000 households are reputed to use SWHs. This annually saves Israel 1.6 billion kWh of electricity and represents 21% of her domestic electricity consumption *[1]*.

Greece began her own SWH encounter in the 1970s when the first DSWH collectors were imported from Israel and the first industrial units for the production of 2.5 m^2 DSWH systems were established. Thirty years later, by 2001, Greece had become the leader in Europe in m^2 DSWH installed per capita and the second place (after Israel) globally *[2]*. Reasons for such success adduced in the REACT Case Study *[2]* are:

- Economic/Fiscal Incentive through a tax exemption scheme introduced in the 1980s for DSWH systems;
- Reliable technology and lack of bad examples in the installation of the first systems. To prove the product reliability, it is necessary to define the minimum standards to be attained by such products; and
- Marketing strategy which aimed mainly at the convenience of having "free" hot water on demand, which was possible most of the year given Greece's large solar energy potential.

The study noted that the low price of electricity which was, and still is, the main alternative for domestic hot water production in Greece, was a major barrier. It also stressed the fact that the "reputation" of the product was of great importance in developing the industry as bad examples to kill the market were lacking. The systems, which had an electric heating element backup, were covered by a 5-year guarantee, which is about the payback period.

Furthermore, the tax incentive policy implementation was kept simple and straightforward, not requiring any special management overheads. The buyer simply had to submit his receipt with their tax form and the amount would be deducted from the total family income, representing tax deductible with a cap of 40% of the cost. Thus, this was an indirect subsidy without creating any complex bureaucratic schemes as would be required for the management of a direct subsidy programme.

The public power corporation (PPC), participated actively in the promotion by distributing a small information leaflet along with the utility bills of their customers on behalf of the Greek Solar Industry Association (EBHE). The steady growth pattern of number of DSWH systems installed in Greece between 1980 and 2001 is shown below in Fig. X. By 2001, the DSWH collector surface area was 3 million m^2 in this graph, and from Table 1 had further increased to 3,870,000 m^2 by 2008.

BARCELONA, SPAIN

GTZ did a recent study on the promotion of Renewable Energies, within which was a section on International Experiences with the Promotion of Solar Water Heaters at Household Level *[12]*. Two contrasting examples in this study will be considered in this section, namely, Barcelona, Spain and Tunisia. The City Council of Barcelona, the capital city of Catalonia region of Spain in July 1999 approved the Barcelona-Ordinance (or law) (Ordenanza Solar Termica de Barcelona) which came into force in August 2000, and it requires all new buildings with a daily average energy consumption of hot water supply exceeding 292 MJ (approximately 2000 litres heater capacity) to generate at least 60% of the required heating energy from solar water heaters. This would be equivalent to any of the present day 774 Nigerian Local Government Councils coming out with a law seeking to benefit Nigeria in 2025!.

At that time in 1999, this was only the second such law coming after that of Israel in 1980, but it was the first such Ordinance in Europe. Also, at the time, Barcelona's energy mix was predominantly nuclear, with 4% from hydro power and only 1% from renewable energy sources, hence it would have eminently qualified as a green city. Nevertheless, the forward looking city energy agency at the time forecast about 30% increase in both the city energy consumption and CO_2 emission by 2010, leading the City Council to action on the law, convinced of the extremely favourable solar energy potential of Catalonia, with average of 2,477 hours of sunshine per year and annual solar radiation of 1,502 kWh/m^2, compared with Nigeria's average annual 2,400

sunshine hours and 1,825 kWh/m^2 solar radiation, a bit lower at the coastal zones and much higher at the northern Sahelian zones).
The Barcelona-Ordinance aimed to install 90,000 m^2 new (relative to 1990) solar water heater collector surface area by 2010 (i.e. by the end of this year, a goal set in 1990 by progressive, result-oriented local politicians!!!). Between January 1st 2000 when it came into effect and March 2004, Barcelona had achieved an increase of installed SWH collector area from 1,650 m2 to 24,531 m2 representing 3,415 tonnes per year of CO_2 emission saved the environment.

The Ordinance is a legal mechanism, without any economic or financial incentive involved, just as was the case of Israel in 1980. The Ordinance further required all swimming pools to be heating to be sources 100% from solar energy. The Ordinance installation obligation covers all residential buildings, hospitals, gymnasiums, and commercial buildings, and was thus deliberatively selective to limit massive resistance of the general public. With the 292 MJ daily threshold energy consumption for water heating in the Ordinance, most small residential homes were excluded since such energy consumption would apply only to residential apartment complexes of about 20 units with 4 to 5 person-occupancy in each unit. The procedure was basically simple; the owner or builder would only need to prove when applying for the building permit how the water heating energy demand of the proposed building is to be met in regard to the Ordinance. Further, he would be required to ensure and undertake that the solar heating system is actually used and properly maintained and repaired as necessary before the building permit is issued.

The City Council ensured mass participation and buy-in, as many stakeholders from professional bodies and builders, renewable energy associations, municipal representatives, etc. participated in the design and dissemination of the Information dissemination strategies which also included a Guidebook explaining the Ordinance and how it affects the people.

Quality assurance was also carefully planned. A number of qualified institutions were authorized to certify the SWH collectors to be used in each building design while the installers and technicians must be registered with their relevant professional bodies and additionally posses a certificate on the vocational training required to qualify as an installer of SWHs.

The results of the Barcelona-Ordinance have been spectacular and copied by municipalities not only in Spain but all over Europe. As at 2005, about 40% of all new buildings possessed a SWH. About 65% of the systems were used in the residential sector, 12% in gymnasiums, and 11% in hotels according to a survey by the Barcelona city energy agency.

TUNISIA, NORTH AFRICA

According to the GTZ report *[12]*, participating banks grant loans to the SWH manufacturers who in turn transfer these loans to households in the SWH scheme by selling their systems directly to such households, offering them the financing facility. Monthly repayment is effected through the monthly electricity bill of STEG over a period of 5 years, reducing the risk of default. The energy savings ideally cover the monthly rates fully so that the household would not pay a higher invoice amount than what they were paying before the loan. STEG collects the monthly payments which it lodges with the participating bank which in turn shares it among the credit-allocating banks. The interest rate is slightly below the going market rate, fixed at 7% at the beginning of the programme in March 2005. This interest rate is gradually reduced over time to zero at which point the interest subsidy would have been totally eliminated from the programme, making it a subsidy-free loan market.

The promotion programme is limited to private households only, and only a limited number of producers are allowed to participate. The total funding for the programme is US$ 2 million provided by the Italian Ministry of

Environment and Territory, half of which is used by UNEP for interest subsidy and the remaining half by the public sector energy department ANME as capital cost subsidy.

Publicity and information dissemination on TV and radio as well as the print media was well coordinated, including promotional posters and leaflets located strategically at banking halls, government buildings, etc. and coordinated by both UNEP/DTIE and ANME.

ANME is responsible for quality assurance, quality verification, technical standards, installation and installer certification as well as technical training of the SWH installers.

UNEP/DTIE expectation is that up to 30,000 households would benefit from PROSOL financing by the end of the programme. By 2011, a total SWH collector area of 220,000 m^2 is expected to be installed and financially supported by the promotion programme. Furthermore, it is assumed that each US$ subsidy would be able to generate about US$ 5 to 6 of additional credit volume.

SPAIN (ESPANA)

In 2006, Spain became the second country in the world after Israel to mandate the installation of solar water heating systems, at which time the share of RES heating and cooling in the gross electricity production was 3.6%. The solar thermal installed capacity had reached 1,199,745 MW in 2007. On 17th March 2006, the Spanish government approved the new Technical Buildings Code (CTE, Codigo Tecnico de la Edificacion), the most significant reform of the Spanish building sector for decades. The CET built on the success of the previous municipal solar ordinances, such as those of Barcelona, Madrid, etc. The CET includes the following main areas: security of the buildings structure, other safety and health issues, sustainability and energy efficiency of the buildings. The latter part"Documento Basico HE – Ahorro de Energia") goes far beyond the minimal level of implementation of the EC Directive on Energy Performance of Buildings and includes an obligation to cover 30-70% of the Domestic Hot Water (DHW) demand with solar thermal energy. The solar thermal part applies to all new buildings and to those undergoing a renovation. It applies to any kind of buildings, regardless of their use.

Spanish municipalities have been adopting such measures since 2006 in order to foster the implementation of RES technologies in new as well as old refurbished buildings. More than 60 bylaws exist in Spain, affecting more than 20% of the population.

6.0 RENEWABLE ENERGY PROJECT LOAN PROGRAMME

This national programme entered into force in 2008 and is aimed at giving 100% finance contribution on the investment costs of, among others, applications of solar thermal facilities with a capacity equal to, or higher than 20 kW, and it covers many legal entities excepting private companies.

7.0 RENEWABLE ENERGY PROJECT DEPOSIT PROGRAMME

This is targeted at individuals, SME and micro-companies. The investment in a project on renewable can be paid through a bank deposit ranging from Euro10, 000 to Euro300, 000. The beneficiary has a 2-year period to refund the deposit, with a 7% per year interest rate.

Investment subsidies under the REP 2005-2010 As from 2008, the Renewable Energy Plan (REP) 2005-2010 allocates financial incentives for solar thermal projects. Targeted at individuals, private or public companies, organizations and communities of neighbours, the subsidy covers 37% of the total costs of the project.

8.0 CALIFORNIA, USA REBATE PROGRAM, CSI-THERMAL

The California Rebate Program, CSI-Thermal *[8]* is funded by utility ratepayers of four private sector utilities serving about 90% of all

Californians. The program funding of $350 million is divided into two, $250 million to replace natural gas water heaters and $100.8 million to replace electric water heaters. Natural gas users in residential dwellings get a rebate of up to $1,875 while commercial and multifamily buildings get up to $500,000. Electricity users on the other hand get up to $1,250 for residential users and $250,000 for commercial and multifamily buildings. These incentives decrease yearly till they are eliminated altogether.

The CSI-Thermal program arose from the experiences gained from the 2007 Solar Water Heating Pilot Program of the California Center for Sustainable Energy (CCSE). Four main barriers were then identified to the public acceptance of solar water heaters, which should be kept in mind by any developer of new programs.

The goal of CSI-Thermal is to offset 585 million therms by 2018 which implies installing DSWH in 200,000 single-family dwellings that use natural gas (i.e. 90% of Californians), and to offset 275 million kWh electrical energy which implies installation of DSWH in 100,000 homes that use electricity to heat water.

9.0 CONCLUSIONS

WHAT IS THE WAY FORWARD FOR NIGERIA FROM THE 10 m^2 SWH COLLECTOR AREA?

From the above case studies, it is clear that Nigeria would need to wake up from the deep slumber of 10 m^2 solar water heater collector surface area for our 140 million population. It would be embarrassing and shameful to have it listed among other countries in Tables 1 and 2.

There is therefore an urgent need for a Solar Water Heating Law to be enacted by the National Assembly which will be applicable to all new buildings in the residential, commercial sector, hotels, public sector institutions, teaching hospitals, and in the industrial sector nationwide. The law should also include the retrofit of old buildings in these sectors.

Government on its part must follow this up with well articulated national pilot and market development programmes on solar thermal energy for low temperature (< 90°C) heating applications in various sectors of the economy, particularly in the residential, commercial, and industrial sectors. Sectoral total energy demand in Nigeria from the National Energy Masterplan of June 2007 *[7]* indicates that the household sector has the largest demand forecast for 2010 at 21.65 Mtoe (42.5%), followed by Transport at 13.62 Mtoe (26.8%), Industry 7.81 Mtoe (15.4%), and Services 7.74 Mtoe (15.3%). Of this large amount of energy consumed in the domestic sector, 40-50% will easily go into heating water, either for bathing or as precursor to cooking, which can conveniently and more desirably be supplied by solar water heaters, instead of the current electricity, LPG, fuel wood, and charcoal.

The suggested initial promotion is for the relatively low-cost DSWH thermosyphon systems costing between the EUR 200 (of China) and the EUR 700-900 (of Europe) at the domestic level and the larger Combi-systems and evacuated tube collectors for commercial and industrial large-scale applications, e.g. hotels, teaching hospitals, institutions, public buildings, armed forces and police barracks, etc.

Economic/financial/fiscal incentive measures are recommended for all the sectors, especially the residential sector. As the market develops, the more expensive pumped systems can be gradually introduced into the household sector market. It must be noted that Nigeria's poor infrastructural woes includes lack of public piped water services and this might restrict such pumped systems to homes with piped running water and grid electricity for pumping water through the system. The good news on SWH collectors is that even in rural areas without piped running water or electricity services, batch-type SWH thermosyphon systems can be used.

The initial promotion of the pumped systems however would be more successful if targeted at the large commercial/industrial/tourism cities of Lagos, Abuja, Port Harcourt, Calabar, and Warri, and the high altitude States, e.g. Plateau, Adamawa, Taraba, Nassarawa, and Benue.

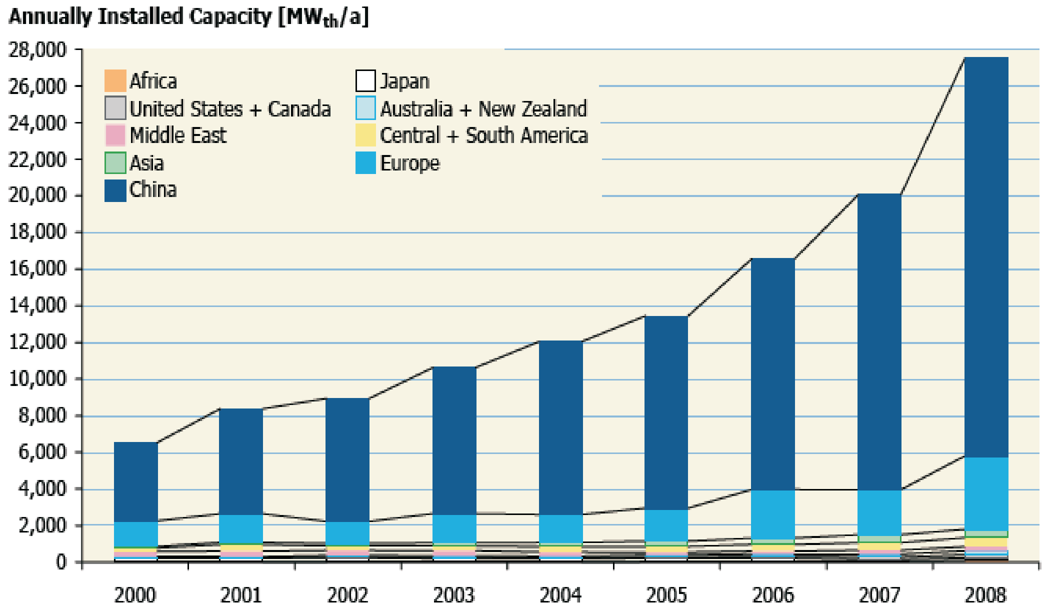
Issues of system reliability, codes and standards, installation as well as installer certification will also need to be well coordinated between the Energy Commission of Nigeria ECN, the Standards Organization of Nigeria (SON), the professional bodies in engineering, architecture, and building, and the SWH manufacturers/vendors to block the influx of sub-standard equipment and unqualified practitioners in the field services. SWH installation requires technical competence of the installers and equipment manufacturers/suppliers. They must be specially trained and certified to be allowed into the profession; otherwise we risk market failure from ruined technology reputation from either substandard systems or ill-prepared installers.

Finally, we recall that Israel and Barcelona are today reaping the fruits of seeds sown by their foresighted lawmakers and leaders 30 and 20 years ago, respectively. We also need to start purposeful development someday, even if it is in only one or two areas of comparative advantage. The Energy Commission of Nigeria must find a way to make the Energy Committee of the National Assembly understand what is at stake here, otherwise, it will be equally culpable when future generations start to ask questions on why this vast clean natural energy potential has continued to be wasted for so long, while lesser endowed countries are using it, and creating jobs for their people from exporting technologies based on it. Responsible political leaders worldwide seek to provide for their future generations, and would not selfishly squander nature's gift in their own generation. This should be the message of the Energy Commission to all tiers of government.

Barrier identified	Remedial Action taken in CSI-
Inadequate consumer education	Large marketing & PR budget for public education
Few highly skilled solar water installers	Devotion of some marketing outreach funds for training; CCSE partnership with community colleges to develop
Solar water heater projects need to satisfy relevant building Codes	CCSE developed educational opportunities for building inspectors to make them understand solar water heater
High upfront solar water heater costs are decidedly a disincentive to its uptake	Floating of the California Rebate Program, CSI-Thermal in response. The $6,000-$7,000 average system cost can be cut in half

As shown in Table 4: Barriers against Solar Water Heating System

Analyzing the market development of glazed water collectors, from 2000 to 2008, it can be seen that the market of flat-plate and evacuated tube collectors grew significantly during this time period (see **Figure 17**).



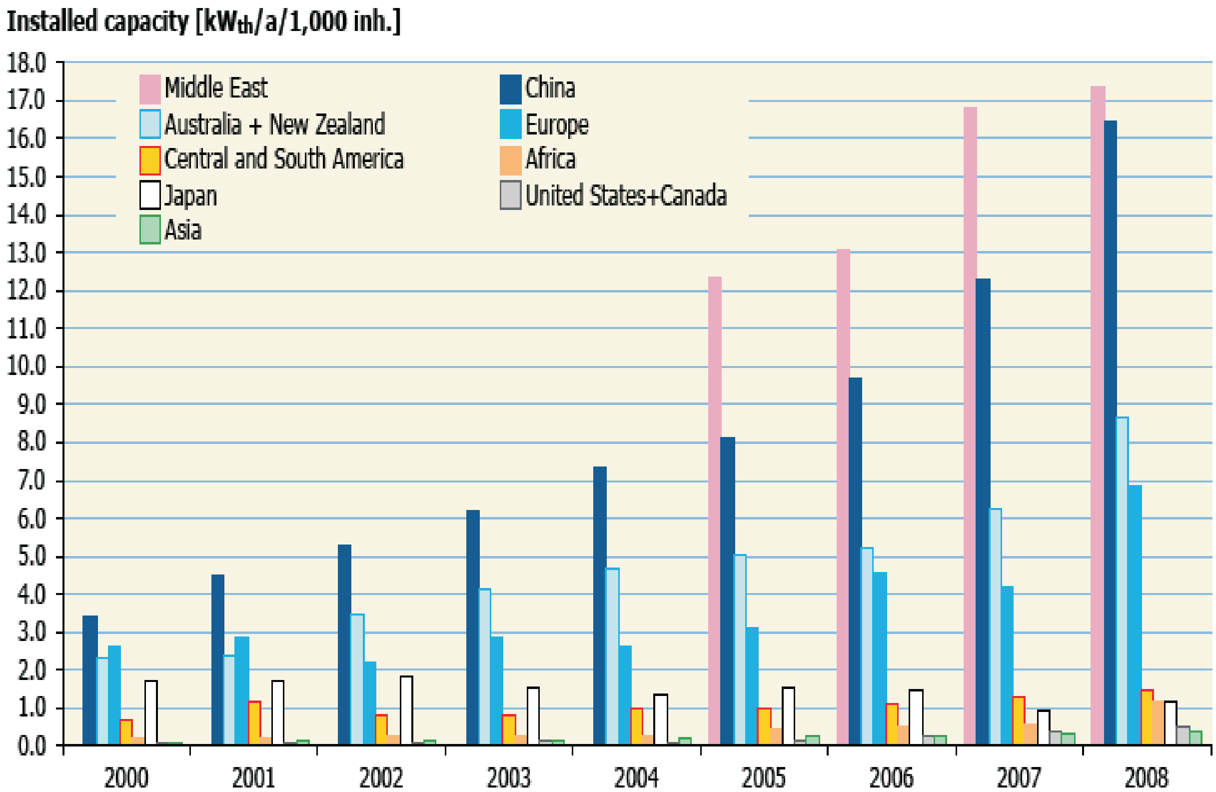
Middle East: Israel, Jordan
Africa: Namibia, South Africa, Tunisia, Zimbabwe
Central & South America: Barbados, Brazil, Chile, Mexico, Uruguay
Asia: India, South Korea, Taiwan, Thailand
Europe: EU 27, Albania, Macedonia, Norway, Overseas Dep. of France, Switzerland, Turkey

Figure 17: Annual installed capacity of flat-plate and evacuated tube collectors from 2000 to 2008

The annually installed glazed water collector area worldwide in 2008 was more than 4 times higher than in the year 2000, and doubled between 2005 and 2008. The worldwide average annual growth rate between 2000 and 2008 was 20.1%.

Compared to the year 2007, the worldwide market for glazed water collectors grew by 37.1%. Especially high growth rates occurred in Europe (+ 62.5%), the United States and Canada (+ 41.8%), Australia and New Zealand

Fig. 1a Annual installed capacity of flat-plate and evacuated tube collectors, 2000-2008. *[13]*.



Middle East:	Israel, Jordan
Africa:	Namibia, South Africa, Tunisia, Zimbabwe
Central & South America:	Barbados, Brazil, Chile, Mexico, Uruguay
Asia:	India, South Korea, Taiwan, Thailand
Europe:	EU 27, Albania, Macedonia, Norway, Overseas Dep. of France, Switzerland, Turkey

Figure 18: Annually installed capacity of flat-plate and evacuated tube collectors in kW_{th} per 1,000 inhabitants from 2000 to 2008 [13]

Besides Israel and Jordan, the Chinese market led in terms of specific collector area installed (capacity/inhabitant), although China loses absolute dominance due to its large population.

Fig.1b. Annually installed capacity of flat-plate and evacuated tube collectors in kW_{th}/1000 inhabitants, 2000-2008. *[13]*.

Table 1. Calculated annual collector yield and corresponding toe as well as CO_2 reduction of all solar thermal systems (systems for hot water, space heating and swimming pool heating) installed at end of 2008 in twelve selected countries. *[13]*.

Country	Total Collector Area, m2	Total Capacity MWth	Calcula-ted No. of systems	Collector yield GWh/a	Collector yield TJ/a	Energy Savings toe/a	tCO2 annual reduction
Brazil	4,293,206	3,005.20	764,218	2,704.40	9,735.70	298,904	946,384
China	125,000,000	87,500	28,493,750	62,893.80	226,417.60	7,145,526	22,616,779
Cyprus	803,520	563	167,614	624.40	2,248.00	69,169	218,698
Germany	11,071,754	7,726.70	1,397,411	3,834.60	13,804.50	470,477	1,489,896
Greece	3,870,000	2,709.00	911,946	2,536.40	9,131.10	272,368	862,879
India	2,547,515	1,771.80	458,146	1,941.10	6,988.00	219,839	697,657
Israel	3,800,000	2,659.70	925,998	3,402.60	12,249.30	355,354	1,125,664
Turkey	10,636,800	7,445.80	2,487,948	7,880.40	28,369.50	879,984	2,786,683
Namibia	6,742	4.70	851	5.30	19.10	658	2,082
South Africa	975,360	682.80	72,419	584.50	2,104.30	59,754	189,154
Tunisia	286,080	200.30	69,546	227.00	817.20	24,135	76,445
USA	20,614,290	14,316.40	542,787	8,024.90	28,889.60	842,893	2,670,575
Zimbabwe	17,316	12.10	4,329	12.10	43.70	1,770	5,628

Table 2. Calculated annual collector yield and corresponding oil equivalent as well as CO_2 reduction of solar thermal systems using flat-plate and evacuated tube collectors (e.g. hot water heating and space heating, low temperature industrial process heat) installed by the end of 2008 in twelve selected countries. *[13]*.

Country	Total Collector Area, m2	Total Capacity MWth	Calcula-ted No. of systems	Collector yield GWh/a	Collector yield TJ/a	Energy Savings toe/a	tCO2 annual reduction
Brazil	3,490,377	2,443.30	760,204	2,443.50	8,796.50	273,278	865,368
China	125,000,000	87,500	28,493,750	62,893.80	226,417.60	7,145,526	22,616,779
Cyprus	803,520	563	167,614	624.40	2,248.00	69,169	218,698
Germany	10,318,154	7,222.70	1,393,811	3,614.20	13,010.90	448,704	1,421,438
Greece	3,870,000	2,709.00	911,946	2,536.40	9,131.10	272,368	862,879
India	2,531,195	1,771.80	458,146	1,941.10	6,988.00	219,839	697,657
Israel	3,772,878	2,641.00	925,864	3,388.40	12,198.40	353,964	1,121,269
Namibia	6,742	4.70	851	5.30	19.10	658	2,082
South Africa	275,682	193.00	68,920	252.20	908.00	27,135	85,954
Tunisia	286,080	200.30	69,546	227.00	817.20	24,135	76,445
USA	2,724,910	1,907.40	454,152	1,491.70	5,370.20	202,589	641,678
Zimbabwe	17,316	12.10	4,329	12.10	43.70	1,770	5,628

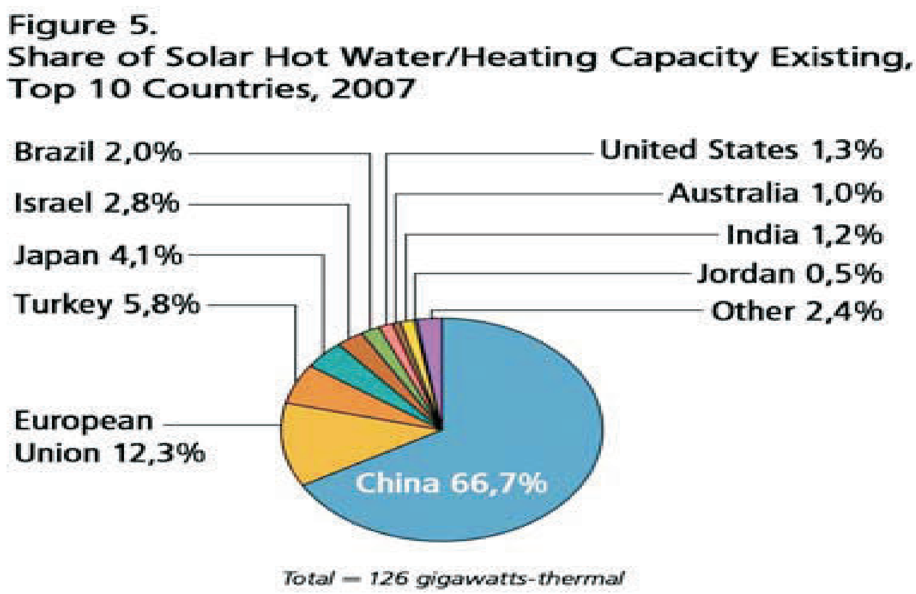


Fig. 2a. Share of 2007 Solar Hot Water/Cooling Capacity for Top 10 Countries/Regions of the World. *[9]*.

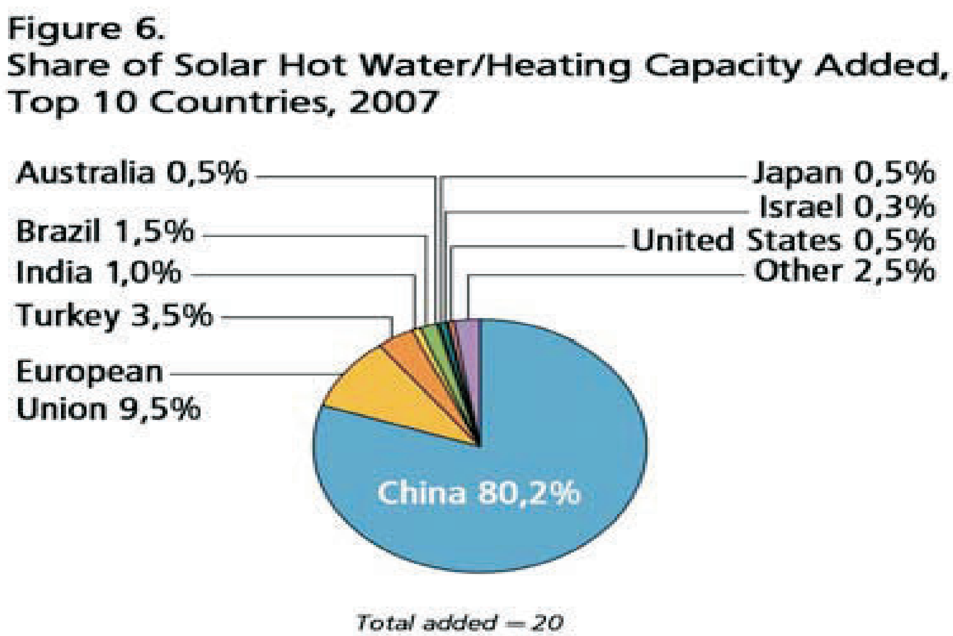


Fig. 2b. Share of Solar Hot Water/Cooling Capacity Added in 2007 for Top 10 Countries/Regions of the World. *[9]*.

Table 3. Typical costs of Domestic Solar Water Heaters (DSWH) in selected localities. *bu - backup*

State/Country	Type	Cost, Euro (E) or US$ ($)	Life, yrs	Payback, yrs	Ref.
Barcelona, Spain	DSWH/TS DSWH/PS	E663/m^2 ≥E1326 ***for 2m^2 system;*** E579/m2 ***for large systems in hotels, apartment bldgs., etc.***			*[12].*
Greece	DSWH/TS	E700-900	**10-15**	4-6	*[2]; [10].*
China	DSWH/TS	E200			*[10].*
Central Europe	DSWH/PS	E4,500			*[10].*
Guangdong, South China	DSWH/PS	$4,000-8,000			www.articlekingpro.com
California, USA	DSWH/PS	$6,000-7,000 ***But cost halved with tax credit & rebate in Rebate Program***		**7-8, EB bu; 13-14, NG bu**	*[8].*
Tunisia	DSWH/TS	E260/m^2 ≥ E520 ***for 2m^2 system in 2005.***			*[12].*
Egypt	DSWH/TS	$324-396 ***for150litr***			*[4].*

Legend: DSWH – Domestic SWH; TS – Thermosyphon system (i.e. no pumps); PS – Pumped system;

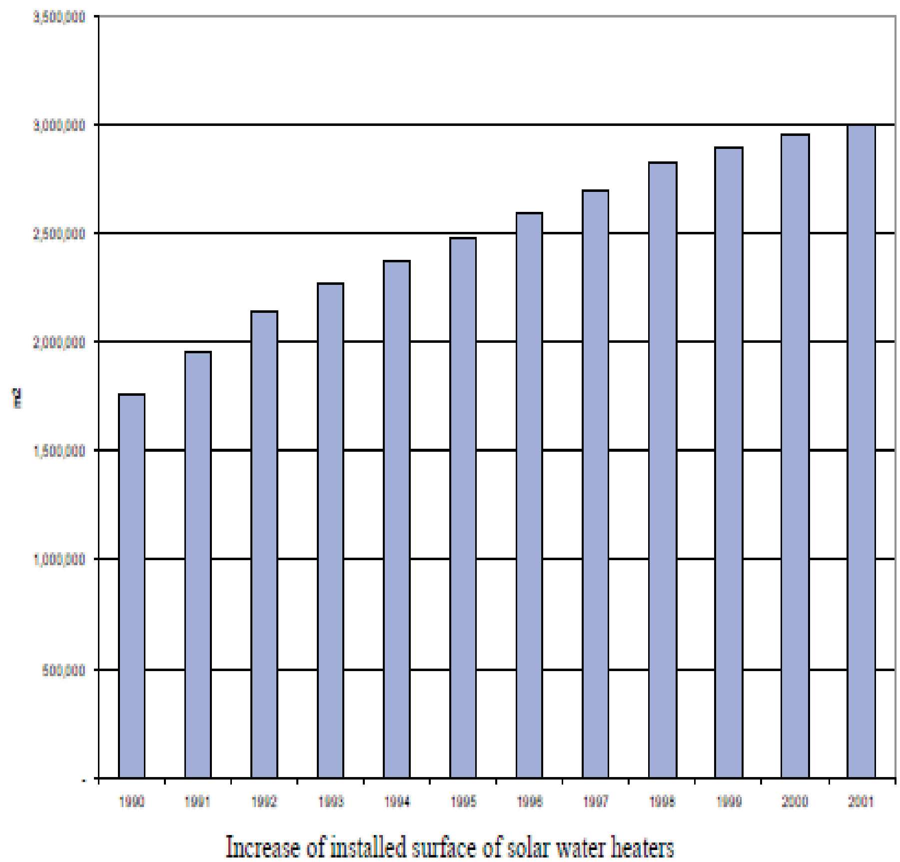


Fig. 4. Growth pattern of DSWH systems installed in Greece between 1980 and 2001. *[2]*.

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