

# Positive and Future Prospects of Solar Water Heating in Nigeria

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## ABSTRACT

Nigeria is situated in the equatorial region and receives abundant solar radiation. The first area that is most appropriate for the large-scale application of solar energy is domestic water heating. The hot water demand in public and private sector organizations can also be met with solar hot water systems. This paper examines the principles and technology of solar water heating, the current state of development, and the dissemination of the systems and their future prospects in Nigeria. The place of government policies and programs in the general development of solar energy systems are also highlighted.

(Keywords: renewable energy, energy policy, developing countries, energy technologies)

## INTRODUCTION

The conventional sources of energy are finite in nature and pose severe threats to man's environment. The industrial and economic development which have been made possible through the harnessing of conventional energy technologies have brought about significant environmental degradation and climate change with severe impact on human and aquatic life. The world oil crisis in the 1970's and the climatic shifts noticed by the World Meteorological Organization (WMO) in the 1980's have stimulated a global action to mitigate the impact of conventional sources of energy on the environment. The activities of the United Nation's Intergovernmental Panel on Climate Change (IPCC) highlight these facts.

Energy from the sun is not only infinite (in a practical sense) but also abundant; enough to take care of mankind's energy requirements. The sun radiates a hundred billion megawatts. Out of this, the earth receives about two hundred billion megawatts. It was estimated that by the

year 2000, the energy requirement for the total population of the earth would be 15 million megawatts [1]. Studies relevant to the availability of solar energy resources in Nigeria [2-4] indicate the viability of solar energy for domestic and industrial uses. The annual average solar radiation is between 3.7KWm-2 day-1 along the coastal areas and 7.0KWm-2day-1 in the semi-arid zone of the country. The average figure approximates to 5.4KWm-2day-1. It is estimated [3] that Nigeria receives  $5.08 \times 10^{12}$  KWh of energy per day from the sun and if solar appliances with 5% efficiency are used to cover 1% of the country's surface area,  $2.541 \times 10^6$  MWh of electricity will be produced. This tremendous amount of electrical energy is equivalent to 4.556 million barrels of oil per day.

The Federal Government of Nigeria responded to the global concern on energy diversification by setting up four energy research centres in the 1980s. Two of these centres, the National Centre for Energy Research and Development, (NCERD) University of Nigeria, Nsukka and the Sokoto Energy Research Centre have the mandate to research, develop, disseminate and conduct training on solar and other renewable energy technologies. This mandate is being carried out in several fields under solar/alternative energy namely; photovoltaics, solar thermal, geothermal, and biomass technology. Several solar water heating systems, which fall within the solar thermal field, have been designed and fabricated at NCERD.

Considering the large population of the country, the ever-increasing tariffs on electricity, and the need for hot water for household, institutional, and industrial uses particularly during the harmattan period, there is the need to disseminate solar water heating systems in the rural and urban areas. The principles and technology of solar hot-water systems are presented in this paper. The basic schemes of flat-plate collectors, heat losses, amongst others, are covered. Also included are the

status and the prospects of solar water heating in Nigeria.

## **TECHNOLOGY OF SOLAR WATER HEATERS**

The solar collector is the main component of a solar hot-water system. It transforms radiant energy from the sun in the spectral range 0.3-3 $\mu$ m, into usable heat. Two distinct processes are dealt with by the collector:

- (a) The absorption of radiant energy, which requires the highest possible transmission coefficient,  $\tau$  for the transparent cover and the highest possible absorption coefficient,  $\alpha$  for the absorber plate. The effective parameter will be the product ( $\tau\alpha$ ).
- (b) The loss of energy in the infra-red spectrum due to radiation losses between the absorber plate and the transparent cover; natural convection losses between the absorber plate and the transparent cover, and conduction losses through the back and edges insulation.

### **Generic Types of Solar Water Heating Systems**

Water heating is one of the simplest applications of solar heat and one of the least expensive. A great many types of water heating systems have been conceived of by investors and solar engineers; the different types varying in design configuration and system make up. Generally, solar water heaters can be active or passive, stand-alone or hybrid systems.

### **Active Solar Water Heating System**

According to Daniel [5], an active solar system is one having an assembly of collectors, storage device, and transfer fluid which converts solar energy into thermal energy and in which energy in addition to solar input is used to accomplish the transfer of thermal energy. In active solar water heating systems, electric pumps, valves, and controllers are used to circulate water or other heat-transfer fluids through the collectors. They are usually more expensive than passive systems but are also more efficient [6]. Active systems are usually easier to retrofit than

passive systems because their storage tanks do not need to be installed above or close to the collectors.

### **Passive Solar Water Heating System**

This system transfers heat by means of natural circulation by convection (i.e. they do not require pumps to function). They naturally modulate the circulation flow-rate in phase with the radiation level. Here, the warmer, less dense water rises to the top of system, displacing the colder water to the lowest point. Passive solar water heaters also known as thermosyphon systems are generally more reliable, easier to maintain, and possibly longer lasting than active systems. They can be built with inherent freeze resistance so they can be used in areas that are subject to extended periods of freezing temperatures.

### **Other Classifications of Solar Water Heating**

Solar water heaters can also be classified as open loop (direct) or closed loop (indirect). An open-loop system circulates water through the collector. A closed loop system uses a heat transfer fluid to collect heat and a heat exchanger to transfer the heat to the storage tank. Both direct and indirect water heating can be by either natural circulation or by a forced circulation [7].

In a natural circulation solar water heater, there is a separate collector and storage tank and the storage tank is placed at a certain height (30 – 60cm) relative to the top of the collector to prevent the reverse circulation during off-sunshine hours. As the sun heats the collector, the hot water inside rises by natural convection and the colder storage tank water leaving from its bottom flows into the collectors by gravity. Thus the circulation loop is automatically established whenever there is sufficient insolation, and circulation automatically stops during insufficient insolation when the upward buoyancy force is unable to overcome the fluid friction losses inside the pipes.

Like the name implies, forced circulation systems require a pump to forcefully circulate the heat-transfer fluid. The systems may be either direct type or indirect type. In a direct system, the water is directly circulated between the solar hot water storage tank and the

collector. In an indirect system, a fluid (usually an antifreeze, air, distilled water, or an organic heat-transfer fluid) other than the service water is circulated in the solar collector. Here, heat exchangers are used in or outside the hot water storage tank.

PV modules and batch heaters have been adapted also for water heating. Batch heaters are also known as breadbox or integral collector storage systems. They are simple passive systems consisting of one or more storage tanks placed in an insulated box that has a glazed side facing the sun [6]. PV-SWH system uses PV modules for collecting solar energy as electrical energy and in turn utilizing it for water heating.

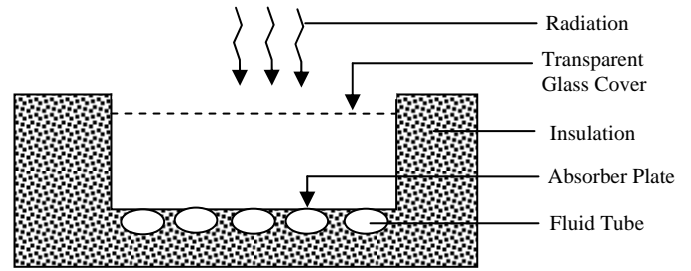
### Basic Components of a Solar Water Heating System

The basic elements of most common solar water heaters are the flat-plate collector, heat transfer fluid, and the storage tank. Other components such as heat exchanger, pumps, pipe network, valves, auxiliary energy source, and control systems can be included depending on the intended design, operation, and application of the system.

As shown in Figure 1, a conventional flat-plate collector is made up of a flat absorbing plate, normally metallic upon which solar radiation falls, and is absorbed, changing to heat energy (properties are shown in Table 1). The absorber plate is usually black in color for optimum collection and its area is the same as the area intercepting the radiation. Attached to the collector absorber plate are tubes, channels, or passages which circulate the heat transfer fluid.

A transparent or translucent cover of glass or plastic is attached on the absorber plate mainly to reduce the upward convection and radiation heat losses from the collector. Insulation is provided at the back and sides of the absorber plate to minimize heat losses by conduction.

Flat-plate collectors are usually mounted in a stationary position with an orientation optimized for a particular location. The absorber plate with the attached riser pipes, back and side insulation, and the cover glass are fitted together and held in their correct relative positions to form the collector unit of the solar water heater.



**Figure 1:** Basic Flat Plate Solar Collector.

**Table 1:** Properties of some Absorber Plate Materials.

Material	Density (kg/m <sup>3</sup> )	Specific Heat Cap. (KJ/kg K)	Thermal Cond. (W/mK)
Aluminium	2707	0.896	204
Iron	7897	0.452	73
Steel	7833	0.465	54
Copper	8954	0.383	386
Brass	8522	0.385	111
Silver	10524	0.234	419
Tin	7304	0.226	64
Zinc (pure)	7144	0.384	112

Thermal energy is stored in the storage tank as sensible heat where the heat capacity of water is used. The amount of sensible heat stored,  $H_s$  in a given volume is expressed as [8]:

$$H_s = V\rho C\Delta T$$

where  $V$  is the storage volume,  $\rho$  is the density of water,  $C$  is its specific heat capacity and  $\Delta T$  is the useful temperature change in the storage tank. This expression shows that the maximum amount of storage per unit volume is

achieved by those materials that have the highest density-specific heat product.

### **POSITIVE PROSPECTS OF SOLAR WATER HEATING IN NIGERIA**

The application of solar energy for water heating in some parts of the world began in the early twentieth century. The thermosyphon solar water heater is the oldest type of water heating system and has been used in many parts of the world. Thousands of these systems were in use in California and Florida in the USA between 1920 and 1950. In Israel, and some other localities, solar water heaters are installed without “back-up” from conventional energy sources.

The hot water tank is heavily insulated and is usually sized to be roughly one day’s usage, and is mounted on the roof of a building where the solar collectors are also located. Water is automatically circulated through the collectors when a sensor determines that the collectors are several degrees hotter than the water in the tank. Solar heated water has been used in the following areas: living apartments, hospitals, health centres and clinics, offices, hostels, dormitories, hotels, and industries.

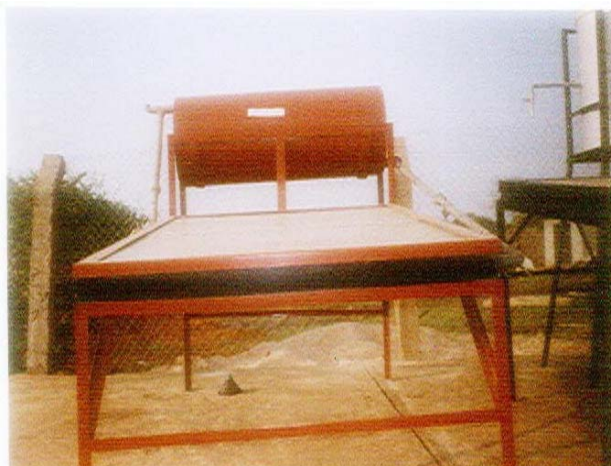
In many developed countries there is strong encouragement to adopt solar water heaters in order to reduce conventional electricity water heating bills and conserve scarce fossil fuel resources. In developing countries like Nigeria, there is even more urgent need for the adoption of solar water heating. This is not only because many of these countries do not have natural reserves of conventional fuel but as a result of the fact that the bulk proportion of the population of these countries live in the rural areas where conventional electricity grids have not been extended. In such circumstances, the hot water requirements of, for example, rural health centres and cottage industries (for processing of agricultural produce) could readily be met by solar water heaters.

At the moment, water heating in Nigeria is done using the conventional electric supply and fuel-wood. These however have not left the nation without their attendant adverse health, economic, and environmental impacts. The demand for energy is consistently increasing as a result of the energy crises of 1970s, population increase, and modernization. Therefore, the

need to embrace a cost-effective and sustainable alternative to our depleting conventional energy sources has become imperative.

### **STATUS OF SOLAR WATER HEATING IN NIGERIA**

Several research projects involving design, modelling, simulation, and testing of solar water heaters have been carried out within the country [9-14]. Many prototypes of these systems have been developed and optimized and are ready to be commercialized. Some systems have been installed in homes and hospital establishments in the country. Thermosyphon solar water heaters were developed at the National Centre for Energy Research and Development, University of Nigeria, Nsukka (Figure 2) in 1994.



**Figure 2:** NCERD Thermosyphon Solar Water Heater.

A prototype of this system installed at the exhibition platform of the Centre has performed satisfactorily for 7 years. Some copies have been ordered by certain individuals for domestic uses. The Sokoto Energy Research Centre has also developed solar water heating systems. A few years ago, the Centre installed one of these facilities at the Usman Danfodio University Teaching Hospital, Sokoto.

Generally, solar water heating systems have not been widely adopted in the country, as is the

case in some other developed and developing nations. Some reasons for this include:

- a) Lack of awareness
- b) Lack of Energy Policy
- c) Low income levels
- d) Lack of subsidy
- e) Short term investment syndrome
- f) Lack of institutional support
- g) Poor funding for research, development, training and dissemination.

### **FUTURE PROSPECTS OF SOLAR WATER HEATING IN NIGERIA**

Given the available solar energy resource, a large landmass and population, the low level of dissemination of solar heated water (SHW) systems and the need to conserve the depleting conventional energy resources (fossil fuel, wood etc.); the prospects for the widespread dissemination of SHW systems are very bright.

Currently, the need for domestic hot water in the country is met through the use of electricity, kerosene, and wood as the major energy sources. Electricity generation in the country is dependent on stations powered by natural gas and water-driven turbines. Irregular supply of natural gas, the fluctuation of water levels in hydropower sites, and obsolete equipment in electric utility network are factors which contribute to the epileptic supply of electricity in the country [15]. Thus, electricity is not readily available particularly in the rural communities, which have a share of about 70% of the country's population [16].

The majority of the population and particularly the rural dwellers therefore resort to fuel-wood for water heating and other energy requirements. A survey conducted in 1991 shows that about 50% of the energy requirements in the country are provided from wood-fuels [17]. There are environmental implications arising from deforestation through the depletion of available fuel-wood in the country.

In the agricultural sector where rural farmers account for more than 90% of the food population, Nigeria is yet to attain self-sufficiency in food production. The reason is partly due to the lack of infrastructure for the generation of heat required for the processing of food

products. The establishment of cottage industries for food processing in the rural areas has been slow. The demand for hot water in the education, healthcare, and other sectors of the Nigerian economy are high. Table 2 gives an indication of the potentials in several sectors of the economy.

**Table 2:** Hot Water Potential in different sectors of the Nigerian Economy.

Sector	Capacity
Household	20 million households
Agriculture [18]	330,000 square km of cropland (only 0.7% has been irrigated)
Health [16]	14,000 (7,210 are operated by Local Government Hospitals Councils)
Education [16]	40,000 (Primary schools); 6,500 (Secondary Schools); 40 (Universities)
Offices	Federal Ministries/Parastatals; State Ministries; Local Government Offices; Private Sector establishments

Harnessing the potentials stipulated above will require that the limitations stipulated in this paper be addressed, through the intervention of the public and private sectors, financial institutions, NGOs, and International Agencies. The federal government has to take the lead to enact policy instruments that will sensitize other sectors of the economy and the entire population on the need to adopt SHW and other solar and renewable energy technologies.

### **GOVERNMENT POLICIES AND PROGRAMS ON THE DEVELOPMENT OF SOLAR ENERGY**

The potential contribution of solar energy to the energy mix of the country has been recognized by the policy makers in the past [17]. However, it cannot be said that policies and programs, specifically drawn up for the development of solar water heating systems had existed in the country. The policies and programs on the ground had been general in sub-sector coverage, with benefits applicable to the solar

thermal sub-sector where applicable. The following policy issues are highlighted:

- **Energy and Environment:** Sustainable energy development must be such that there are minimal or no adverse effects on the environment. Thus, the use of solar energy, and in particular SHW systems, which is known to be environmentally friendly, is encouraged by the government.
- **Research and Development:** The Nigerian government established four Energy Research Centres in 1982. Two of the Centres, located at the Usman Danfodio University, Sokoto and the University of Nigeria, Nsukka, were charged, among others, with the responsibility of conducting research and development (R&D) programs in solar energy. The significance of R & D in the promotion and development of any industry need not be over-emphasized. Original research and development, technology adaptation, and equipment testing are taking place in the Energy Research Centres, other research institutes, universities, and polytechnics. Considerable progress has been made in the development of solar hot water systems.
- **Pilot and Demonstration Projects:** The Government established the Energy Commission of Nigeria in 1989, with the objectives, amongst others, of disseminating information on all forms of energy resources and its corresponding technologies. In particular, demonstration programs to prove the economic and technical feasibility of energy technologies developed for powering developmental projects, forms part of the Commission's programs.
- **Data Bank:** The Energy Commission is establishing a National Energy Data Bank, which will serve as the repository of all information related to energy in the country.
- **Information Dissemination and Publication:** Information dissemination is essential for the development of renewable energy. The Government therefore encourages seminars, workshops, and publications in the area of renewable energy. For example, the Energy Commission of Nigeria (ECN) supports the publication of the Nigerian Journal of Renewable Energy at its

Research Centre in Sokoto. It also supports the ECN-NYSC forum in which some selected Youth Corp members are taught how to fabricate and operate some renewable energy devices. The Corp members would then use the knowledge and pass them on to their contact communities during their primary assignment and even after their service year. The Commission also publishes and distributes booklets and monographs on tested renewable energy technologies for their application in the country.

- **Institutional Framework:** For optimal development of the energy sector, it is necessary to have effective coordination of the various energy sub-sectors because of their interrelatedness. In this respect, the Energy Commission of Nigeria was established as the apex government organ for the coordination of energy sector activities.
- **Investment Promotion and Protection Agreement:** The Government has put in place an investment agreement which guarantees investors' adequate and prompt payments in the event of expropriation, free transfer, of funds as well as provisions for international arbitration in the event of disputes. This agreement is to facilitate the attraction of Foreign Direct Investment (FDI) into the economy and to protect such investments.
- **Incentives:** The Nigerian Government has provided the following package of incentives to encourage industrialists and investors in all facets of the economy.
  - Five years tax holiday for pioneer industries,
  - Tax-free dividends for a period of three years,
  - 95% capital allowance for replacement investment,
  - Elimination of double taxation, and
  - Abolition of excise duties.

Despite these policies, more effort is required in the following areas:

- a) Education-awareness creation
- b) Manpower development and training
- c) Funding of more demonstration projects

- d) Subsidizing the cost of installing SHW systems
- e) Encouragement of commercial production of SHW systems
- f) Soft loans to purchasers of SWH systems.

In this way, the adoption of the SWH technology in various sectors of the economy of Nigeria will be enhanced.

## CONCLUSION

The level of adoption of SHW heating technology in the Nigerian economy is very low at the moment, despite the fact that many prototypes of the systems have been well researched and developed within the country. Enormous potentials exist in the household, health, agricultural, education, and industrial sectors. Widespread dissemination of the systems to meet up the demands in these sectors will depend on the removal of several limitations. Bold initiatives by the public and private sector, the financial institutions, and international agencies are required in order to remove these limitations. The benefits to the citizens, the economy, and the environment thereafter cannot be overemphasized.

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