SOLAR ENERGY POTENTIALS AND UTILIZATION IN NIGERIA AGRICULTURE

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ABSTRACT

The major pre-occupation of this review was to assess solar energy potentials and utilization in Nigeria agriculture. Apart from the conventional utilization of solar energy in drying agricultural products such as grains, fish, yam flakes among others; it was revealed from the study that other areas of solar energy utilization in agriculture include: heating and lighting of animal pens, pumping of water and irrigation, food and vaccine preservation and so on. Therefore, to ensure and enhance agricultural productivity in Nigeria, the expansion of solar energy supply schemes to the rural areas was amidst others recommended.

Keywords: *Assessment, solar energy, potentials, utilization, Agriculture and Nigeria*

INTRODUCTION

The sun has been radiating energy for over 500 million years and is expected to continue for at least the next 50 million years (Moon, 1940). Solar energy has an estimated worldwide average powder potential of 24 W/m^2 of earth's surface (Considine, 1997 and Sambo, 1994). Nigeria lies within a high sunshine belt of the world, receiving between 3.5 to 7 kW/m^2/day from the coastal Latitude to the far North (Iwe, 1998). Energy has always been an essential input to all aspects of the modern age.

Rapidly escalating costs of petroleum based products have forced farmers, government officials and scientists to re-evaluate present farming practices and to search for alternatives of petroleum based agriculture. Over 75% of total crop production in Nigeria is growing during rainy season between April and September. Major crops and vegetables grown in Nigeria include yam, rice, maize, millet, sorghum, cowpeas, soya-beans, groundnuts, cassava, tomatoes, onions, okra and pepper which require drying after harvesting for short and long term preservation. Crop drying is essential as it facilitates crop handling by reducing its weight and improves the resistance of the crops to attack by some pests (Itodo, 2007).

Solar energy has for ages been used in crop drying while cooking with solar energy is more recent practice (Yohanna, 2004). Generally, sun drying applies to spreading the crop in the sun on a suitable surface such as roadsides, mats , hanging crops from the eaves on building, trees etc and drying on the stalk by standing in stock or buddle as practiced in many parts of Northern Nigeria. Although sun drying requires capital, it has many limitations and problems including the need to move crops under cover in the event of rain, contamination by dust, sand and stone. Infestation by insects, rodents, theft or damage by birds, animals and high risk of spoilage by micro organisms due to low rate of drying and possible rewetting by the rain during drying process (Arinze, Adefila, Akachukwu and Akanni, 1990; Iloeje, 1992; Yawas and Obi, 2001; Yohanna, 2004)

The essential parts of any solar thermal power generating scheme are a means of collecting solar energy; provision of suitable thermal converter and mechanical converter and a method of strong energy for use in non-solar or low solar periods (Stine and Harrigan, 1985). Solar energy plays a vital role in agriculture. It helps in generation of electricity; reduce human labour on the farm by pumping water for irrigation and domestic consumption. It provides energy without noise because it has no movement in their parts. It provides energy without wastes and do not need waste material for energy production nor produce waste during the course of producing energy.

Solar photovoltaic (PV) technology supplies electricity without combustion. It has less maintenance since nothing is consumed or weared during their operation. It can be converted to other energy (Hasua and Gibs, 1988). Solar energy utilization in drying is totally free from environmental degradation and pollution. The objective of this study is to assess the solar energy potentials and utilization in Nigeria agriculture.

UTILIZATION OF SOLAR ENERGY IN NIGERIA AGRICULTURE

Direct solar energy conversion devices are generally either solar thermal or solar electric while solar thermal system can be extended to produce electricity, both systems can be developed to produce mechanical power. Thus, solar radiation can be applied in agricultural processing which requires heating or cooling such as drying, refrigeration and lighting, water pumping, grinding, threshing and other size reduction processes as well as in conveyance and transportation.

Table 1 gives the renewable energy technology applications in Nigeria. The number of solar application predominate, followed by thermal, Biogas and wind in that order. This application reflects a mixture of resource availability and extent of promotion of the different technologies. Agriculture related applications of the solar technologies were for drying, lighting and wind energy for water pumping and biogas for cooking and over 60% of those for solar PV solar thermal and biogas installations are for drying, cooking and manure production. The existing information on current installations of renewable energy devices particularly for agro-processing in Nigeria is scanty.

CROP DRYING

Crop drying is essential as it facilitates crop handling by reducing its weight and it improves the resistance of the crops to attack by some pests and insects. Cooking is a prerequisite to making most crops edible and palatable. Solar energy has for ages been used in crop drying while cooking with solar energy are more recent practices (Yohanna, 2004). Solar energy utilization in drying and cooking has far advantages and these include its being almost totally free from environmental degradation.

POULTRY PRODUCTION

Egg incubation: Large scale and commercial hatching of eggs away from the chicken is not new. Solar energy has been used since the temperatures required are low and can easily be achieved with indirect natural air circulation (Zibokrere, 2001). Design provision must be made for humidifying the air. For forced air circulation hatcheries, a wick type cloth dropping into a pod of water may be used to increase moisture evaporation into the hatching space. The components consist of a solar air heater, glazed with a single thin PVC corrugated sheet. The exit of the heater is directed to the egg chamber containing a natural circulation tubular exchanger, egg trays, water trough and humidifying cloth wick.

For heating at night a rock filled drum painted black in the outside is provided as a heat storage medium. The full ducting allows for the warm air to flow through the drum on sunny days before entering the egg chamber. The black painted drum surface also acts as a solar collector plate. The heat stored in the rocks is then utilized in the night. On overcast days, the air flows directly into the chamber (Okonkwo and Akubuo, 2001; Singh 1990)

Chick brooding: Young poultry are unable to survive under their self-generated body heat for the first few weeks of life i.e. during the brooding period, which is normally 0 - 4 weeks. Subsequently, the birds can survive on their own body heat in most climates. The brooding principles are the same for all poultry except for pigeons which feed and warm their young ones (Zibokrere, 2000). For large scale poultry production, the brooding is done outside the hen while the latter is applied more usefully to producing more eggs.

Solar energy may be used to provide the required heat through air or water solar heaters or by direct heating of the brooder space. The temperatures required are low and so can be handled with non concentrating flat plate collectors. Due to intermittency of solar radiation heat storage either in rocks pebbles, appropriate liquids such as water or even in phase change materials such as sodium sulphate decahydrate and pentahydrate ($Na_2So_4.10H_2O$ and $Na_2So_4.5$) Barium hydrate octohydrate ($Ba_2(OH.8H_2O)$ sodium hydrate and paraffin ($C1_4$ - $C1_6$) is necessary. Forced or natural air convection solar heaters may be used.

Chicken Growing: Chicken value is optionised by controlling the poultry house temperature during the growing period with an optional temperature of 18^0C (Okonkwo et al; 1993). Power is required to warm and circulate ventilation air for the removal of odors, toxic gases, dust and moisture from the house. Ammonia is produced from the decomposition of waste and may be harmful to the birds. Excess dust from dry droppings feed and floor covering leads to respiratory diseases. A dust concentration of 20mg/lit (ppm) for 6 weeks exposure for chicken leads to gross pathological damages to respiratory tracts and decreased resistance to new castle disease. Exposures at 105 ppm causes eye injury and lowered egg production. Recommended air circulation rates are 0.03 - 0.06 and 0.12m3/m in 1kg bird weight for cold and warm weather respectively. The power for heating the ventilation air if necessary can be supplied by solar heaters while the power for driving the ventilation fans can be sourced from solar photovoltaic generators.

MANURE DRYING

With large scale production of domestic animals concentrated in a single farm, the handling of the waste therefore becomes a problem. For instance a chicken layer will produce about 160g/day of wet droppings from 115g/day of feed consumed, while a dairy low produces 45 liters/day of wet facecal waste (Kut and Hare, 1983). Sawdust, rice husk or straw would often be spread on the poultry house floor and would be discharged with the droppings, thereby increasing the poultry waste load considerably. Poultry and other animal wastes contain a large amount of nitrogen which is basic to their value as good natural manure.

However, if left for long in the wet state, the raw manure will loose the nitrogen content. For wet poultry manure 85% of the wet will be lost within 5 days (Sainsbury, 1986). It is therefore necessary to dry the manure quickly in order to conserve its nitrogen content and hence its usefulness as manure. Manure is more easily handled in the dry state so it needs drying. Any proposal to commercialize the supply of animal manure must therefore consider systems for drying the waste. Comparatively, sun drying is a cheap but slow and hazardous method. It may promote the spread of bad odor and disease through insect and air vectors and is unreliable during the rainy season. Engineered solar dryers offer improvements in the form of faster drying rates, protection from flies and other insects since the dryer chamber is normally too warm for the insects; reduced hygienic problems, protection from rain and possibility of year round usage when compared to the open sun drying.

SWINE PRODUCTION

Young pigs require moderately elevated temperature during the first few days of life. Schuttle et al., (1989) reported a temperature of 23^0C - 21^0C over the first ten days. The sow is however more comfortable at lower temperatures with 15^0C. Separation of baby pigs and sow locations is essential with each space being differentially conditioned space heating as for chick brooding will be required for swine production. For optimum baby pig performance both locating and cooling of their spaces will have to be considered. Solar radiation may be used to heat the air, in a forced circulation air heater which is fed into the baby pig house. The hot water may be circulated through pipes buried in the concrete flooring for localized heating or through radiators located in the pig house. The circulation pumps and fans may be powered by solar Photovoltaic generator.

DAIRY PRODUCTION

Dairy production needs energy for several activities. Hot water at about 40^0C is required to clear and stimulate the adders and to clear equipment in the milking centre. Power is required for ventilation and for lighting, milking, milk cooling, waste disposal etc. Solar photovoltaic generators are used for the above operations.

IRRIGATION AND WATER PUMPING

The use of photovoltaic solar individual solar modules has been demonstrated for pumping water from wells and bore holes especially in rural areas for providing the water requirements of entire communities for irrigation and for drinking by animals. Photovoltaic powered pumps are employed for irrigation purpose (Fig. 1). Table 1, 6, 7 and 8 were obtained by Adeoti et al. (2001) on the analysis of photovoltaic powered rural water pumping project in south western Nigeria. Table 6 presents the summary of the rural house holds survey and the average daily domestic in- house water consumption, which serves as input data in the design process that represents 354.8 litres for average house hold size of 8.6 persons or 41.26 litres per capital day. Table 8 is result of economic assessment. The net present value (NPV) in the economic analysis is 97, 744.79 Naira, which shows that the project has a good economic profitability at 100% capacity utilities.

LIGHTING OF POULTRY HOUSES/STREETS LIGHT

Power is required for lighting the poultry houses. Optimal light intensity varies over 0.1 - 1 for candle, with hours of light varying over 6- 20 hours per day. The actual combination of light intensity and hours of light per day depends on age of poultry and the purpose for the rearing chicken. Broilers require continuous light or additional light at night to extend the day time. For optimal performance solar photovoltaic generators are good sources for powering the electric light sources. Photovoltaic modules have been used to provide uninterrupted electricity during the day and night for traffic controllers in city centres. With the use of storage batteries, they have also been used to power street lights continuously without the power outages commonly associated with the mains supply (ECN, 1996).

Tables 3, 4 and 5 were obtained from research investigation of inhabitants of a village in Sokoto state carried out to examine the impact of Photovoltaic power pilot project of Sokoto energy research centre. The result showed that heads of households benefiting from the project, 48% belong to the age group of 35 - 45 years with those in the age group of 65 -75 years having the least proportion. From table 5, 48% of the users were observed to save between N31 - N40 each month about N360 - N480 per annum for not using kerosene in lighting their room in the night.

REFRIGERATED FOOD, VACCINE AND DRUGS STORAGE

Some foods such as fruits vegetables, meat and fish are best consumed in their fresh form/state. The shelf lives of the above crops in their fresh state are short when harvested due to temperature changes in ambient temperature and humidity. Vaccines and drugs may loss their potencies if poorly stored under light temperature. Refrigerated storage is required to reduce the crop losses, achieve wider distribution and availability both within and out of season. Photovoltaic power components have also been shown + to adequately provide the electricity for refrigerators and deep freezers in which crops, fruits, vaccines and drugs can be safely stored without loosing their potencies. Yahaya and Sambo (1991) stated that the conventional alternating current (AC) powered refrigerator is more available and reliable than the direct current (DC) refrigerators because it can be easily operated with solar cell in rural clinics where irregular or non-availability of main supply results to wastage of very useful and expensive drugs and vaccines.

WATER TREATMENT

Solar cells are designed to produce distilled water from blackish water and are useful for hospitals, industries and laboratories. When sized appropriately, they can provide for the needs of comprehensive health centres of semi-urban areas.

CONCLUSION

Traditionally, solar energy requirement in agricultural processing in Nigeria has been mostly for drying of agricultural products such as grains, cassava (tubers or marsh), yam flakes, meat, fish, fruits, kernels, drying of manure, hides and skins, for cooking and frying of agricultural products which are not preserved or sold raw. Other areas of solar energy utilization include heating and lighting of animal pens, pumping of water and irrigation, food and vaccine storage. Wind installation and solar photovoltaic have over 60% for water pumping, over 30% of solar PV are for lighting and refrigeration, 3% of solar thermal installation are for drying while 1% of biogas installations are for cooking and manure drying. Irrigation and water management are considered to have low level of usage; poultry production is fairly used while crop drying has very high level of utilization in Nigeria. Beneficiaries of PV power saved some money since they do not buy kerosene for their bush lanterns.

Solar energy technology has good social and economic potential base which ensured agricultural productivity and improved high standard of living so it needs encouragement.The expansion of solar energy supply schemes to rural areas should be encouraged and undertaken in order to ensure and enhanced agricultural productivity. This will improve the standard of living by creating opportunities for higher income generation. The level of development and application in Nigeria today is such that tremendous benefits are obtained in the way of agricultural output if solar energy is effectively harnessed for on farm utilization. Since Nigeria lies within a high sunshine belt of the world, it should use this as a turning point in the quest for solution in energy utilization problems, which will create more efficient, more hygienic environmental friendly technology.

Table 1: Renewable Energy Technology Application in Nigeria

Energy Source	Application	No. Installed	Capacity	Date
Solar Thermal	Drying	3	5.5 tone	1992-94
Biogas	Cooking/Manure	1	$18000M^3$	1996
Solar PV	Water Pumping	61		1982-95
PV	Lighting	31^+		1985-95
PV	Refrigeration/Health	27^+		1988-95
PV	Telecom and TV	7		1987-93
Wind	Water Pumping	NA	-	-

Source: ECN (1996). Potentials for renewable energy application in Nigeria.

Table 2: Demographic Characteristics of Beneficiaries of PV Light Project

Variables	Categories	Frequencies	Percentage
Age (years)	35-45	12	48
	46-55	6	14
	56-65	5	20
	66-75	2	8
Occupation	Farming	25	100
	Trading	11	44
	Fishing	16	64
Family Size	1-5	6	24
	6-10	13	52
	11-15	3	12
	16-20	2	8
	Above 20	1	4

Source: Umaru, Yahaya and Atiku (1998).

Table 3: Number of Rooms Connected to PV Power per Household

Number of Rooms	Frequency	Percentage
Two	11	41
Three	9	36
Four	5	20
Total	25	100

Source: Umaru, Yahaya and Atiku (1998)

Table 4: Amount of Money Saved Per Month for Not Using Kerosine Lanterns

Number of Rooms	Frequency	Percentage
20-30	7	28
31-40	12	48
41-50	4	16
51-60	2	8
Total	25	100

Source: Umaru, Yahaya and Atiku (1998).

Table 5: Summary of Household Survey on Domestic Water Consumption in Rural Houses

Description	Amount N
Number of persons/household/day	8.6
Toilet Flushing	0
Drinking	34.6
Cooking or Food preparation	25.7
Dish washing	23.7
Baths	106.2
Clothe washing	143.1
Floor washing/wetting, cleaning of windows/walls	1.3
Water for laundering	9.7
Water for animals	3.4
Others including cottage industry use	7.1
Average consumption/household/day	354.8

Table 6: Costs Benefit Analysis of the Solar PV-Powered Water Pumping Project

Item	Cost (Naira)	Total Cost (Naira)
(a) Initial Investment		
PV Panel		393,000
Submersible pump		110,000
Pump controller	20,000	
Cables	12,500	
Other Installation accessories		
installation cost	25,000	
(b) Annual operating cost		565,500
Operation and maintenance cost	4,800	4,800
(c) Annual benefit	109,800	153,720
generator hiring cost/fueling	43,920	

N/B: 120 Naira = 1 US$ in year 2001 (Adeoti et al 2001).

Table 7: Results of Economic Assessment of Solar PV-Powered Water Pumping Project

Profitability Index	Economic Assessment
(1 = 2.4%, N = 50 years)	
Net present value NPV (Naira)	97,774.79
Internal Rate of Return (IRR) (%)	27.28
Payback period (years)	9.42

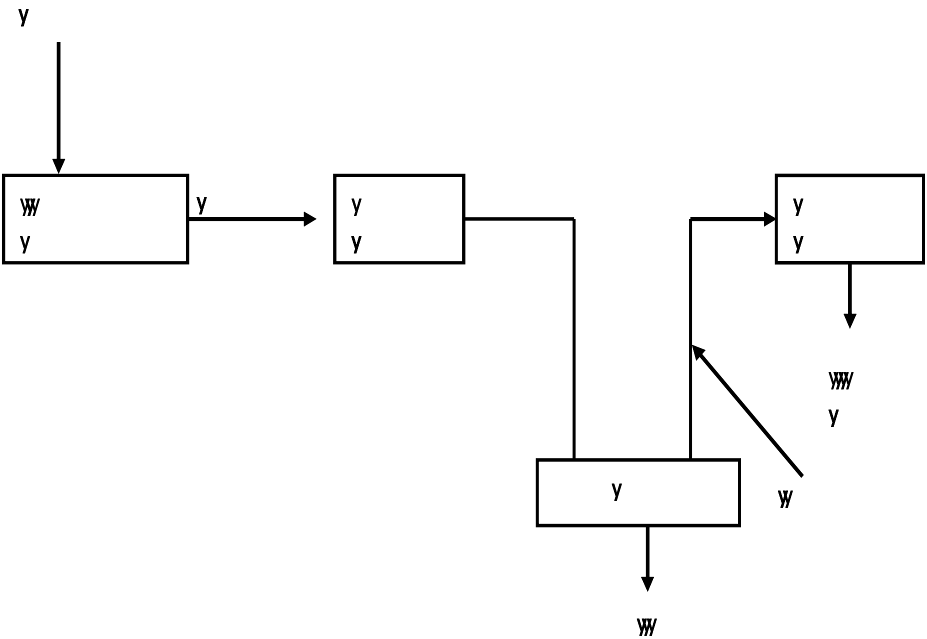

Figure 1: Schematic diagram of PV cell water pump layout

REFERENCES

Adeoti O., Agun B. J. and **Falegan T.** (2001). *Economic Analysis of Photvoltaic Powered Rural Water Pumping Project in South Western Nigeria.* The Nigerian Institution of Agricultural Engineers. Pp 449 - 456.

Arinze E. A., Adefila S. S., Akachukwu C. A. and **Akanni A.** (1990). Experimental Evaluation of various Designs of Free Convective Solar Crop Dryers with and without Thermal Storage. Paper presented at the National Conference of the Nigerian Society of Agricultural Engineers, University of Agriculture, Makurdi, Nigeria.

Considine, D. M. (1997). *Energy Technology Handbook.* New York.McGraw-Hill Book Company.

Energy Commission of Nigeria (1996). *Potentials for renewable energy application in Nigeria.* Lagos: Energy Commission of Nigeria.

Hasua, S. M. and **Gibs, B. M.** (1988). Project for Harnessing Renewable Source. *Pakistan Journal of Energy,* 4, 40.

Iloeje, O. C (1992). Economics of Solar Drying. Proceeding of Training Workshop on Solar Drying Technology for Agricultural and Industry. National Centre for Energy Research and Development, University of Nigeria, Nsukka.

Itodo, I. N. (2007). *Agricultural Energy Technology.* Makurdi: Aboki Publishing Company, Nigeria.

Iwe, G. O. (1998). Energy Options in the Industrialization and Development Process of the Nation. What Role for Coal. Bulletin of the Central Bank of Nigeria.

Kut, D. and **Hare, G.** (1983). Applied Solar Energy (2nd Edition). London: Butherworths Publishers.

Moon, P. J. (1940): Proposed Standard Solar Radiation Curves for Engineering Use. *Journal of Franklin Institute,*230, 83.

Okonkwo W. I., Iloeje O.C., Echiegu E. A. and **Akubuo C. O.** (1993). Performance Evaluatiion of a Medium Scale Passive Solar Energy Poultry Chick Brooder. *Nigeria Journal of Solar Energy*, 12, 14 - 19

Okonkwo, W. I and Akubuo, C. O. (2001). Thermal Analysis and Evaluation of Heat Requirement of a Passive Solar Poultry Chick Brooder. Proceedings of 2nd International Conference of the Nigerian Institution of Agricultural Engineers, Vol. 23: 374 - 385

Sainsbury, D. (1986). *Poultry Health and Management.* Granada: Granada Publishing Ltd.

Sambo, A. S. (1994). Renewable Energy Technology in Nigerian Resource Availability and Potential for Application to Agriculture. *Journal of Agricultural Technology,* 3 (1), 1-25.

Schuttle D. D., Deshazer J. A. and **Milanuk M. J.** (1989). Performance Comparisons of Naturally and Mechanically Ventilated Solar Assisted Swine Nurseries: *Trans. ASEA*, 32 (1), 216 - 220

Singh R. A. (1990). *Poultry Production.* New Delhi: Kalyani Publishers.

Stine, W. C. and **Harrigan, R. W.** (1985). *Solar Energy Fundamentals and Design with Computer Applications.* New York: John Wiley and Sons.

Umaru B. I., Yahaya H. N. and **Atiku A. T.** (1998). Socio-Economic Impact of Solar Photovoltaic Power on Inhabitants of Kwalkwalawa Village of Sokoto State. *Nigerian Journal of Renewable Energy,*6 (1&2), 27 - 30.

Yahaya, H. N. and **Sambo, A. S.** (1991). A Study of the Performance of Solar Powered Refrigerator under loaded Condition. *Nigerian Journal of Renewable Energy,* 2 (2), 36 - 41.

Yawas, D. and **Obi; A. I.** (2001). Development and Performance Evaluation of a Family sized Solar Dryer for Fruits and Vegetables. *Nigeria Journal of Renewable Energy,*9 (1 & 2), 67 - 70.

Yohanna, J. K. (2004). Effective Use of Solar Dryers in Nigerian Agriculture for Reducing Post-harvest Losses on the Farm. Proceeding of 38th Conference of Agricultural society of Nigeria at Lafia, Nigeria. Pp 3 - 9.

Zibokrere, D. S. (2000). Potential of Solar Energy Utilization for Chick Brooding in the Port-Harcourt Metropolis. Unpublished Ph.D Thesis, Department of Agricultural Engineering, Rivers State University of Science and Technology, Nkpolu, Port-Harcourt.

Zibokrere, D. S. (2001). Poultry-Egg Incubation with Solar Energy - A Pilot Study for Port-Harcourt. *Nigerian Journal of Agricultural Engineering and Technology,* 9, 32 - 28.