SOLAR PV DEMAND FOR LIGHTING IN NIGERIAN REMOTE VILLAGES

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The paper analyzed the current status of Solar Photovoltaics (PV) and other energy sources for lighting in Danjiwa and Dahuwa remote villages that are pilot sites for rural electrification projects in Nigeria. A total of 190 questionnaires were administered to Solar PV users in the households and public institutions (schools, palaces, markets and halls), in these villages to elicit information on solar PV use. Model for Analysis of Energy Demand (MADE-II) was used to analyze the primary and other secondary data obtained for the study. The results showed that the current contribution of solar PV in the lighting demand split for the villages was still very low in spite of various government interventions. Its usage level constituted an insignificant share of 16.4% and 5.5% of the total lighting requirement for Danjiwa and Dahuwa villages respectively. For each village, lighting with incandescent bulbs was about 10% of this total requirement, while that of fluorescent lambs stood at 7% and 6.5 respectively. The research results also revealed that kerosene maintained a domineering share of 66% and 77% of the total demand in the two villages respectively. This connotes that further investigations into policy intervention to move rural dwellers away from domineering use of kerosene for lighting to solar bulbs usage should be carried out.

I. INTRODUCTION

In spite of Nigeria's very rich energy resource endowment, the country is still suffering from acute energy crisis which permeates all facet of the economy. Close to 100 million Nigerian rural dwellers lack access to electricity (NBS, 2006). The country has deteriorating installed capacity of 6000 MW, but her current output is less than 3000MW, much of which is not put to use due to poor power transmission and distribution infrastructure. This available power output is far less than her present demand of over 10,000 MW. This explains why her 2004 per capita electricity consumption of 140 KWh is not comparable to 1337 KWh in Egypt and far lower than that of South African which is 4546.4 KWh (EIA, 2004).

Most remote rural settlements like Danjiwa and Dahuwa in the north-western region of Nigeria are placed at a very serious disadvantaged and may not get connected to the national grid in the next ten years due to relatively high grid (generation, transmission and distribution) expansion cost. Thus, leveraging on the oobvious potentials of solar PV technology as readily deployable stand-alone facilities for provision of electricity in Nigerian remote villages promises to be a step in the right direction (Jesuleye 2010). For this reason, government support for applications of solar PV technologies such as mini-grid systems; solar home systems; solar water pumping; street and traffic lightings; solar vaccine refrigeration and solar PV power back-up for communication gadgets, now exist in skeletal rural demonstrated pilot projects in Nigeria. However, the real impact of solar PV (for instance) for lighting is yet to be felt as good substitute for kerosene (Siyanbola et al., 2004) and palm oil in the rural areas. (NBS, 2006). Therefore, assessing solar PV contribution to the rural energy mix becomes imperative as the necessary first step in the overall rural electrification program for Nigeria.

II. THE NEED FOR IMPROVED SOLAR PV ACCESS FOR LIGHTING IN NIGERIAN REMOTE VILLAGES

It is noteworthy, that the final draft of the Renewable Energy Master Plan released by Energy Commission of Nigerian in 2005, estimated 5 MW Solar PV installation share out of the total planned 10,000 MW electricity generations for Nigeria by 2010 (ECN, 2005). Consequent upon this, increase in the solar PV pilot installations across the country by both federal and state governments, supported by various international organizations, was also noticed from 2005 to June 2010 to give impetus to the initial sole effort of the federal government on this since 1999. However, a survey of the total Solar PV installations in the county and detailed analysis of their utilization in the each community is yet to be conducted. Although, ECN in 2007 sponsored a publication titled National Energy Databank: Compendium of Renewable Energy Systems Developed in Nigeria edited by Azare and Ayuba, it only catalogued some federal government sponsored renewable projects without detailed analysis of their utilization in the villages.Thus, it becomes very essential to fill this gap to provide comprehensive database of the share of PVs in the rural energy mix and determine appropriate policy framework for increasing solar PV access to lighting, by the rural dwellers. Information obtained from such effort will serve as useful tools for attracting investment into the PV industry development in Nigeria. It will also serve as useful data for optimal energy demand and supply balance

for overall efficient national energy system. Baseline data for projection of the future solar PV use and guide for monitoring future rural energy requirements could also obtained from the study. Quantified analysis of CO_2 emissions saved as a result of Solar PV intervention to energy mix in these rural areas could also be made available.

III. GENERAL INFORMATION AND PROFILES OF SOLAR PV INSTALLATIONS IN THE STUDY AREAS.

3.1. Danjiwa Village

It is a remote rural Fulani village not connected to the national grid, with about 810 villagers whose major occupations are cattle rearing and peasant farming. It is located at about 10 kilometers away from Sokoto Solar Energy Research Centre (SERC), Utman Dan Fodio University (UDU), Sokoto State. Figure 4.1 which shows the geographical location of the villages in the study areas gives more information its location. It was purposively selected for the study, along with five others, because of its closeness to SERC as one of its solar energy research sites. The peculiarity of its solar PV installation profiles also justifies the reason for its selection. It inherited the federal government sponsored 7.2 KW solar PV electrification project formerly installed at KWakWalawa village in 1994, but later relocated to Danjiwa village when KWakWalawa village got connected to the national grid. The summary the solar PV installation profile presented in Table 1 categorizes it as a mini-grid that generate and distributes power to the villagers in their households through cables to provide them with street lighting and two light points in their homes.

Table 1: The Profile of Solar PV Installation in Danjiwa Villages, Sokoto State

SN	ITEMS	REMARK
1	Estimated Population of the Village	810
2	Average Number of Households in the village	90
3	Average Number of Persons Per Household	9
4	Number of Households Connected	35
5	Type of Solar PV Installation	Mini grid: generated power is transmitted and distributed via cables to the households mainly for lighting.
6	Year of Installation of PV System	2002
7	Capacity of the PV (panels) Installed	7.2 KW
8	Major Components of the PV Installation	206 solar panels and accessories, 28 storage batteries (12 volt. & 200 AmH), 4 inverters, 12 battery controllers and 8 ELCB breakers.
9	Objective of the PV Installation	Generate Electricity for the village
10	Sponsors of the PV Installation	SERC/UDU
11	Status of the Installation	Working very well
12	Monitoring & Evaluation	SERC/UDU
13	Sustainability	Continuous training of village technicians who work with experts at SERC for daily maintenance of the installation

3.2. Duhuwa Village is remote rural villages not connected to the national grid, with estimated village population of 900. The major occupations of people living in the village are cattle rearing and peasant farming. It is located in the central district local government area of Jigawa State. The village is about 10 kilometers away from the main city about 15 km far away from next closest village called Garko-Ali.

Duhuwa Village is among the nineteen rural communities in Jigawa State now enjoying a unique source of electrical power generated by solar energy. The solar PV Installations in this village is funded by Jigawa State Government in conjunction with the United States Agency for International Development (USAID), the Japan International Cooperation Agency (JICA) and the Millennium Development Goals (MDG). The Alternative Energy Fund of Jigawa State is the implementing organ for these installations. Table 2 The Profile of Solar PV Installation in Danjiwa Villages, Jigawa State

Table 2: The Profile of Solar PV Installation in Dahuwa Village, Jigawa State

1	Estimated Population of the Village	900
2	Average Number of Households in the village	100
3	Average Number of Persons Per Household	9
4	Number of Households Connected	60 Households (i) 40 stand alone 55W panel per household with battery, (ii) 20 batteries only System powering 2 bulbs in each home.
5	Type of Solar PV Installation	Solar Home System and Solar Battery Charging Stations with DC connection mainly for lighting.
6	Year of Installation of PV System	2005
7	Capacity of the PV (panels) Installed	5.5 KW
8	Major Components of the PV Installation	70 80W solar panels and accessories, 14 storage batteries (12 volt. & 150 AmH), battery controllers and ELCB breakers.
9	Objective of the PV Installation	Generate Electricity for the village.
10	Sponsors of the PV Installation	Jigawa State, USAID, JICA & MDG
11	Status of the Installation	Working well but not enough to village demand.
12	Monitoring & Evaluation	Alternate Energy Fund, Ministry of Women Affairs, Jigawa State.
13	Sustainability	Continuous training of village technicians who work with experts at AEF for maintenance of the installation

IV. RESEARCH QUESTIONS AND THE STUDY OBJECTIVES

Consequence upon the challenges posed by the various energy problems plaguing Nigeria, certain pertinent research questions constantly agitate the minds of policy makers, energy planners, researchers and energy analysts in their search for optimal solutions to the Nigerian Energy problems. Some of these are:

- To what extent can solar electricity contribute to improved access, improving energy efficiency lighting and environmental protection of the country?
- Does the country's present and future solar electricity utilization pattern correspond with the world trends, considering the current worldwide increasing demand for solar electricity due to downward trend in the investment cost and improved technical efficiency?

Thus, as an input into the policy framework for widespread and accelerated use of solar PV in the rural areas, this paper quest to analyze the current status of Solar PV and other energy sources for lighting in Danjiwa and Dahuwa remote villages that are pilot sites for rural electrification projects in Nigeria.

V. ADAPTATION OF MODEL FOR ANALYSIS OF DEMAND FOR ENERGY (MADE-II) FOR DATA ANALYSIS

Model for Analysis of Demand Energy (with the acronyms MADE-II), developed at the Institute for

Energy Economics and Rational use of Energy, University of Stuttgart, Germany in 1989, is the adapted energy demand analysis model for this paper. The Model combines the application of statistical, econometric and engineering process techniques as appropriate for the various sectors of the economy. As presented in Figure. 1.

MADE-II is made up of 7 blocks of data in flow for demand analysis. Block 1 deals with general information about energy levels, base year and future time periods while information on development of population is presented in Block 2. Data analysis for useful energy demand in the households sector is treated in Block 3, while block 4 and 5 deal with the Households, Cottage Industries and Community Services sectors. The transport sector is not included in the analysis while block 7 deals with efficiencies, penetration factors and sectoral demand for Solar Electricity Lighting. Other Energy Services such as: Water Pumping for Drinking and Irrigation Purposes, Powering of TV, Video, Radio, Refrigeration, Ventilation, Cooking and Process Heat are not considered in the analysis due to dearth of data.The basic analytical approach employed in **MADE-II** which makes it suitable for demand analysis of solar electricity in Nigeria is its flexibility and applicability for demand projection over short or long period. So also, analytical techniques adopted in MADE-II rest on the idea that energy is a means to an end and it is used together with other production factors to provide products (in form of goods and services) to the society (Saboohi, 1989).

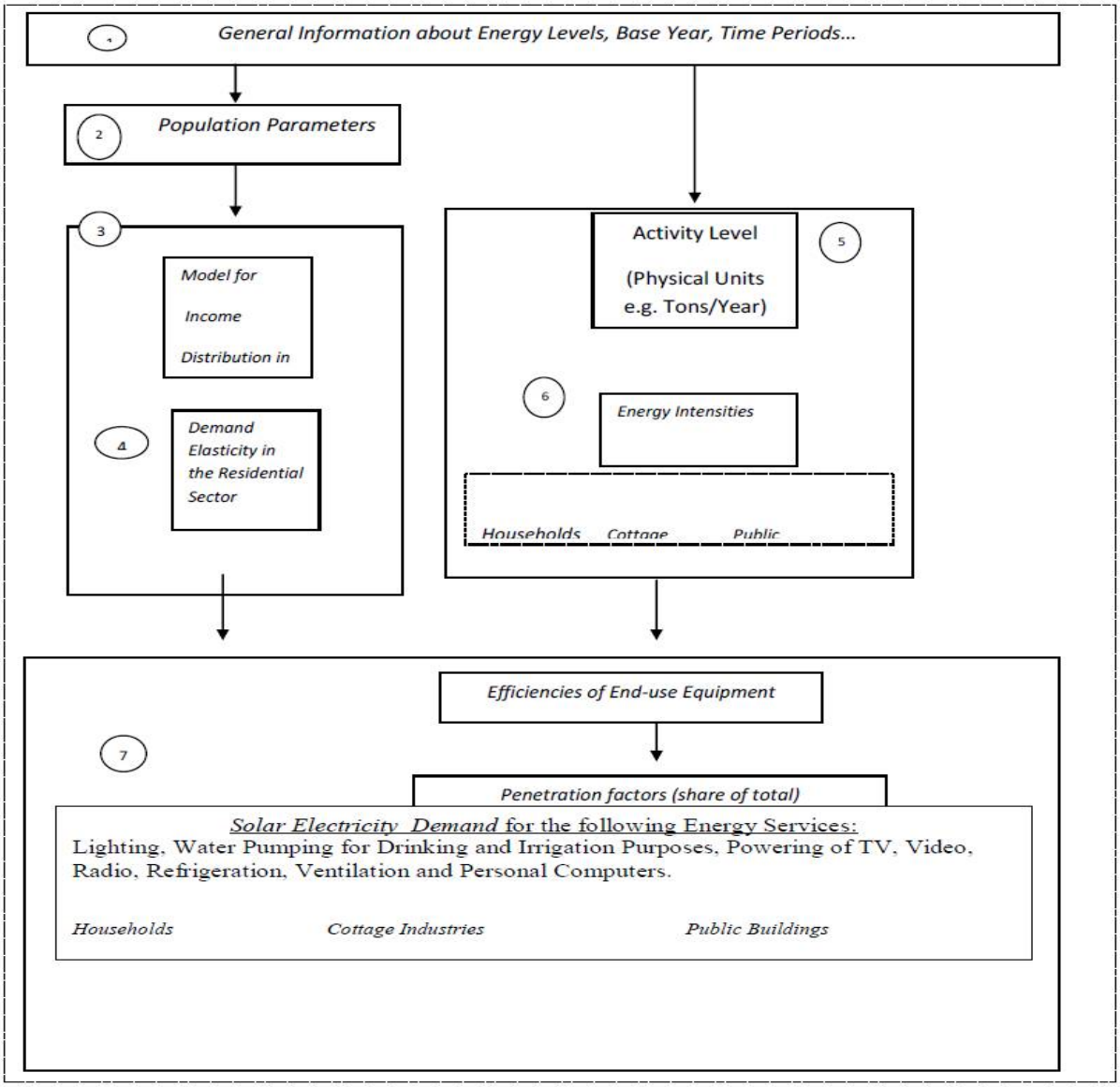

Figure. 1: Adapted Data Flow in MADE –II (Model for Analysis of Demand for Energy)

Village Survey for Data on Socio-Economic Variables for Energy Demand Analysis.

Two remote villages that are pilot sites for national and foreign assisted solar electrification programs in the northern, ecological regions of the country were

purposively selected for the study. They are: Danjiwa in Sokoto State, and Duhuwa in Jigawa State. Questionnaire techniques together with computer modeling were employed as research instruments for the study. Three sets of questionnaire were administered on the Solar PV users, suppliers and government agencies. A total of 190 questionnaires were administered to Solar PV users in the two villages that constitute the study areas as shown in Table 33. The table also shows the number of villagers per household and the number of households per village population. The questionnaire elicited information on alternative energy sources (kerosene, diesel, gasoline, solar panels, etc.) for provision of energy services (lighting, space cooling, refrigeration, water pumping etc.). It also elicited information on technical, socio-economic and demographic issues.

Energy Intensity Calculation Variables

Calculation of energy intensity is also essential to determine demand for various energy services in the study areas. Variables such as technical efficiency of various end-use appliances (usually referred to as the end-use appliances power ratings in kilowatts), stock and duration of use of these appliances and sources of fuel for powering them were identified and obtained from the survey as shown in Table 3.. The table also reveals the total daily per household energy use of 0.72 Kwh for incandescent bulbs, 0.48 Kwh for florescent lambs, 0.24 Kwh for solar bulbs and 1.98 Kwh for kerosene lantern for lighting. For entertainment it stood at 0.48 Kwh, 0.9Kwh, 0.78 Kwh for radio, TV and video appliances respectively. Kerosene and firewood appliances for cooking services have the highest daily per household energy use of 7.9 Kwh and 25.6 Kwh respectively.

VI. MEASUREMENT OF VARIABLES FOR LIGHTING BY SOLAR PV IN EACH VILLAGE

Energy consumption data of each village in the study areas were used to quantify total demand for energy services. This involves the calculation of energy intensities as represented in equation 5 as follows:

$$Energy\ Intesity\left(EI_{j,t}\right) = \frac{(HDL_{j,t})\ Energy\ Input\ (Wp)}{(AL_{j,t})\ Population\ Share\ (Million)}$$

Where,

$$HDL_{j,t} = AL_{j,t} * EI_{j,t} \ldots\ldots\ldots\ldots Equation\ 1$$

and,

$HDL_{j,t}$: Per Household's Demand D for Lighting j in time period t.

$AL_{j,t}$: Per Household's Activity Level (AL) (Population Share) for Lighting j in time period t.

$EI_{j,u,r,t}$: Per Household's Energy Intensity (EI) for Lighting j in time period t.

Wp : Watt

VI. GENERAL SOCIO-ECONOMIC AND TECHNICAL DATA USED AS INPUT FOR MODEL RUNS.

The survey results providing socio-economic and technical information of the two villages under study are presented in Tables 3 and 4. Table 3 shows percentage of households using specified energy sources and end-use appliances for various lighting for the two villages. For instance in Danjiwa village, it could be observed that 38% of the household's population use solar panels as a source of energy generation with solar bulbs as the end-use appliances to provide lighting as the required energy services. Whereas in Duhuwa village, 16 percent of the household's population used solar panels as a source of energy generation, with solar bulbs as the end-use appliances for lighting provision. Table 4 also reveals the survey data for energy intensity calculation (kWh/Household/Day) per village to be 0.72, 0.48, 0.24 and 1.98 for gasoline powered incandescent bulbs, gasoline powered florescent tubes, solar bulbs and kerosene powered lantern respectively..

Table 3: Households (%) Using Alternative Energy Sources and End-Use Appliances for Lighting in Danjiwa and Dahuwa Villages.

Villages	Energy Generation Sources (%) and Appliances in UsE				
	Gasoline	Battery	Solar Panels	Kerosene	Candle
Danjiwa	8 Inc. Bulbs & Florescent Lambs	1 Touch Lights, Rechargeable Lamps	38 Solar Bulbs	50 Kerosene Lanterns	1 Candle Sticks

Dahuwa	9 Inc. Bulbs & Florescent Lambs	1 Touch Lights, Rechargeable Lamps	16 Solar Bulbs	70 Kerosene Lanterns	1 Candle Sticks

Table 4: Survey Data for Energy Intensity Calculation per Village

End-Use Appliances for Lighting	Gasoline Powered Incandescent. Bulb	Gasoline Powered Florescent Bulb	Solar Bulb	Kerosene
Average Usage Hours per Household per Day	6	6	6	6
Appliance Energy Efficiency (%)	100	100	100	*37
Appliance Wattage	60	40	20	0.25 litre
Average No of Appliances in Use per Household per Day	2	2	2	19.8
Daily Per Household Energy Use in Kilowatt Hours	0.72	0.48	0.24	1.98

Table 5: Total Energy Demand for Lighting in the Danjiwa and Duhuwa Villages in 2010

Energy Source	Danjiwa		Duhuwa	
	kWh/Village/Day	% of Total	kWh/Village/Day	% of Total
Gasoline Powered Incandescent Bulbs	5.2	10.4	6.5	9.9
Gasoline Powered Florescent Bulbs	3.5	7.0	4.3	6.5
Solar Bulbs	8.2	16.4	3.6	5.5
Kerosene Lighting	33	66.1	51.3	78.1
Total Lighting	**49.9**	100	**65.7**	100

VIII. ANALYSIS OF ENERGY DEMAND SPLIT FOR LIGHTING IN THE DANJIWA AND DAHUWA VILLAGES.

As shown in Table 5, gasoline powered incandescent bulbs, gasoline powered florescent lambs, solar bulbs and kerosene lantern are the end-use-appliances for lighting services in all the two villages considered. The total daily lighting demand for Danjiwa, stood at, 49.9 kWh while that of Duhuwa stood at 65.7 kWh. For the these villages kerosene maintained a domineering share of over 66.1 and 78.1 percent of the total demand respectively.. Further analysis shows that, although Dahuwa village had the highest, an

insignificant amount of only 5.5 percent of this total, was powered by solar bulbs, whereas the shares of inefficient gasoline powered florescent lambs (6.5%) and incandescent bulbs (9.9%) were still higher that of solar bulbs for the village. This connotes a level of ignorance on the part of the villagers on financial and energy savings accruable by substituting energy efficient bulbs with florescent and incandescent bulbs. Thus, there is a need to raise the level of awareness of the villagers on this and subsequently enforce the required energy efficient measures for the village. Contrast to this very low solar bulbs usage for the same lighting service in Danjiwa village recorded a better share of about 16.4 percent of her total. The reason for this is attributable to higher level of investment by the government in this village compare to other village. This trend should be encouraged for other remote villages. Policy to move rural dwellers away from domineering use of kerosene for lighting to solar bulbs usage should be adopted. This should be complemented with policy that supports use of kerosene for cooking in replacement for firewood for environmental benefits.

CONCLUSION AND RECOMMENDATIONS

- Government support for solar PV intervention in these villages should be further encouraged.
- Solar PV Usage for lighting by the villages is commendable and increase in intensity of usage essential..
- Solar PV usage for radio, television and video entertainment for improved social well-being of this villagers should be investigated.
- Its usage for food and vaccine preservation through refrigeration; ventilation and water pumping for provision of portable water and farm irrigation should also be researched into.

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