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Illuminating the Nights in Rural Communities

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Abstract:
Electric power supply in many cities in developing countries is erratic and can only be described as non-existent in the rural areas. Kerosene lantern, the main source of illuminating the night is associated with obnoxious fumes production and more especially the kerosene fuel is scarce to find. Rural dwellers who cannot afford the globed kerosene lanterns either use the locally fabricated globeless kerosene lanterns, "atunja" or log fire. Log fire is associated with deforestation and desert encroachment. A solar lantern has been designed and built for illuminating the nights in rural communities. Battery and LED are part of the components used and it is recommended that appropriate safety measures are put in place not only in use but also in their disposal.
***Key Words*:** Diode, LED, deforestation, lumen, ultraviolent, photochemical

I. INTRODUCTION

The sun is abundant in sub Sahara Africa, unfortunately however, this is the region where the use of renewable energy is making the least inroad and yet electric supply in the cities is erratic and can only be described as non-existent in the rural communities. Development plans in this region hardly consider the rural dwellers. The villages are not likely to be connected to the national electric grid and communication facilities are very poor. In some places where the national grid is available, one may find the lines and transformer in utter disrepair or vandalised. As far as the power companies are concerned, maintenance support is usually planned to be concentrated in the big cities. In countries, for example Nigeria, where kerosene is subsidized for those who can afford to use the lantern, scarcity of the product is rampant due to alleged illegal diversion to the aviation industry and the smuggling of the product to neighbouring non oil producing countries. The chronic poverty in rural communities can significantly be reduced by the provision of basic modern infrastructure to empower the people to exploit and benefit from global economic activities. The digital cell phone is readily available but the poor farmer is handicapped by the absence of electricity to charge the phone. Non Government Organisations (NGOs) may have donated and installed some solar energy lights at the village square and mobile phone charging gadgets but the absence of skilled personnel locally means that the lights and phone charging systems are abandoned once a fault, no matter how minor, develops. Therefore, the traditional methods of illuminating the night by many rural dwellers include the use of log fire, locally fabricated open flame globe-less kerosene lantern, "atunja" fig. 1, and for those who can afford it, the real globed kerosene lanterns.

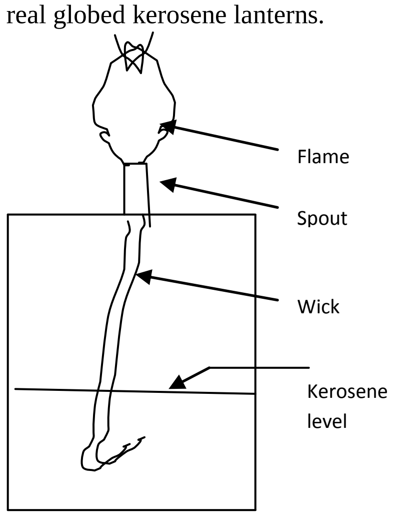

Fig. 1 The Globeless Kerosene Lantern (Schematic)

The log fire not only contributes to greenhouse gases but also to deforestation. When woodland was abundant, dead tree branches were correspondingly plentiful to provide the log needed for both cooking and illuminating the nights. These days however the locals resort to cutting down of live trees and drying the trunks to make fire with no well articulated plan for tree-replacement. The kerosene lanterns with cotton wicks are expensive to run, comparatively provide poor quality illumination and more importantly, lead to the degradation of the surrounding air quality and hence the inhaling of obnoxious gases. On account of the limited financial resources of the rural dweller, what is needed is primarily an inexpensive lighting system.

The system chosen should be environmentally friendly, sustainable and the illumination quality superior to that of the kerosene lantern. Solar lantern will fulfil these basic requirements. Therefore the dual purpose of this project is to develop a cheap solar lantern and for sustainability, train the locals to acquire the skills needed to build and maintain solar energy devices. Experience gleaned from NGO solar energy projects, shows that success is guaranteed only if prompt availability of support service is built in the project plan. Functionally, the lantern should be characterised by: ruggedness, six hours minimum operation between recharge, average life of 5 years, 360^o light spread, ability to charge mobile phone, play the radio and above all easy to maintain. The solar lantern has been designed, built and tested for compliance with the requirements.

The emphasis on training in this project cannot be overstated. With proper training, the main cause of failure of solar energy devices would have been removed because within the community will be available someone trained in solar panel building and fault diagnosis. Projects of this type can help reduce youth unemployment. From this, there will be other spin offs including cell phone chargers and powering the radio. The arrival of the solar lantern should be promoted in the mosques, churches, schools and other social gatherings to encourage maximum take-up and acceptability so that economy of scale will help reduce the price further. There must be a guarantee of supply of the solar lantern at reasonable price and the availability of trained technical support personnel.

Training of personnel to acquire the skill required to build and repair solar energy devices is part of the project. With solar energy phone chargers, the rural dweller is in a position to communicate directly with the farm produce customer instead of dealing through a third party as currently practiced. Achara [1] has indicated that much of the poverty in the rural areas is caused by inability to preserve farm produce for use during the lean periods of the year and/or reach the city fresh for maximum return. With solar lantern, the rural communities can do away with the kerosene lamps and the incident of inhaling kerosene fumes with the attendant fire risk will significantly be reduced.

1.1 The Rural Dweller

They feed the city dwellers, they toil six days a week, they are not organised as a trade union, they never go on strike (perhaps not yet aware of this weapon and the potential impact just a week's stoppage will make). He may have financially contributed to bring the public power line to the village. The lines were energised just before the elections. Since after the elections the transformer has been dismantled and moved to the city for use by "more important", vocal city dwellers. Kerosene for the common man is subsidised but not always available, retails at more than three times the subsidised price. The rural dweller is financially no match to the men from the aviation industry so he resorts to the use of log fire in the light with the ugly consequences of deforestation, soil erosion and desert encroachment.

1.2 The Photovoltaic and Africa

The first use of solar modules was to power satellites and even today, solar power technology is still the primary source of energy in space stations. The widespread use of solar cells in space applications may be attributed to their higher power-to-weight ratio compared with any of the other competing technologies. Although widespread application of solar technology has been very slow in taking off but gradually, solar energy is being used to operate remote stations, supply power in regions where the utility grid is not available. It is certain however that wide spread use can only materialise when grid price parity is achieved. Even with the current price disparity, photovoltaic technology, except in Africa, has been gaining ground steadily as an alternative and sustainable way to produce electricity.

Despite the massive solar resource in Africa, Mark Hankins [2], has noted that only about one and half percent of solar trade in 2012 had Africa as its destination. Furthermore, according to Bloomberg New Energy Finance, of the $268.7 billion invested worldwide in renewable energy in the year 2012, only about $4.3 billion was made in Africa — and most of this went to South and north Africa.

The reason why Africa is on the slow lane of the solar energy revolution may be attributed to cost, ignorance, lack of political will, lobbying by diesel generator set dealers. Although, the cost of solar modules have been falling steadily, comparatively speaking, it is still high for the typical African. The African Governments who are in a position to fund solar energy projects, usually have their energy priorities elsewhere. Some decision makers still see solar energy as a "toy thing", off the grid village square lighting system that has nothing to do with the public grid. The cost of the solar module itself can also partly account for the slow pace of solar energy introduction in Africa

II. BASIC DESIGN REQUIREMENT

In addition to the basic requirements that the solar lantern will have to meet, affordability, considering the financial position of the target user, should be included

2.1 The local lantern

A survey of a typical African rural community reveals that there is a class of the rural dwellers who cannot afford to buy even the locally fabricated globeless kerosene lantern. Therefore, for universal application, price reduction comes to the forefront. The few components where it is possible to reduce cost are: the lantern housing and the circuit board. As far as the batteries and solar panel are concerned cost reduction measures are limited. It is however known that significant cost reduction is possible if the solar cells and batteries are purchased in bulk. Two types of housing are: chosen factory moulded housing and discarded transparent plastic water bottle. The later is targets the “atunja” user. Incidentally, the “atunja” kerosene lantern to be replaced is made from discarded empty metal milk can. For the “atunja” version, it was decided that the charging circuit should be self-regulating therefore there is no need for charge control on the circuit board. This decision calls for very careful choice and matching of the batteries with the solar panel. It was also decided not to incorporate the mobile phone charging port on this design rather to have a mobile phone battery charging adapter as an add-on which the user could, when his/her finances improve, purchase. All this is geared towards cost reduction of the primary unit. The main items on the circuit board are the diode and control switch. The housing cover carries the circuit board, the battery and the LED. The LED is positioned below the circuit board and it looks down the base of the housing. The covering on top of the housing does not have to be transparent but must be made water–tight. A typical example of the lantern is shown in fig. 2. Note the lantern is turned upside down and without reflector to reveal the LED and circuit board.

Fig. 2 The Plastic Water Bottle Housed Lantern

III. SAFETY AND POTENTIAL BENEFITS

3.1 Safety

Batteries contain strong electrolytes and heavy metals. These materials should be handled with care because the electrolytes are most often caustic and corrosive whilst the heavy metals are toxic and hazardous and pose serious health risks [3]. The LED ultraviolent radiation has been noted to pose no serious health problem but not the blue light. LED emits blue light in a wavelength range (400-500 nm) that could harm the eye if viewed at sufficient intensity and duration. Blue light has enough energy to cause chemical changes in the retina and may damage cellular DNA.

The blue light hazard is generally considered the area of most concern for LED lights. There is evidence to suggest that exposure to LED light suppresses the release of melatonin, the hormone responsible to inform the body when to sleep [4]. There is a growing awareness that products should not only subject users to mechanical and electrical hazards but also chemical health risks [5]. It has been noted that the primary danger comes from the blue portion of the spectrum (400-500 nm) that exists in situations where high surface intensities is exhibited [6]. Designers are encouraged to consider the use of diffusers when harsh specular reflections are involved. Diffusers significantly reduce surface intensity and thus increase user comfort and safety when high powers LEDs (> 1 watt) are used.

3.2 Potential Benefits:

Change management is a difficult task and the project team is aware of this – it is not easy to change old habit. Persistence is required in talking and cajoling the people especially since it is not to be freely distributed, a lot of convincing will be needed. The dissemination of relative advantages of the technology is important and these should be carried out in the churches and mosques. Consideration is to be given to the need of different buyer groups and their ability and willingness to pay. Three user groups have been identified and these include: the log fire - those who cannot afford to buy any gadgets at all, the "atunja" users and finally the normal kerosene lantern users.

The promotions of renewable energy sources should be stepped up targeting mostly decision makers. They should be made to understand that solar energy can now supply a whole community with all the energy requirement not only just light.

After break even, running cost, except for occasional battery replacement, would be nearly nil. The solar lantern would transform most family lives in the village. With properly lit surrounding, the children would be happy to read and do their homework. Families can afford to stay up late without worrying about the kerosene lasting till the next market day. With kerosene lantern, families turn off the lamp early and retire to bed so as to preserve the fuel and save money.

The provision of good light in the evenings allows many activities that would otherwise not be possible with the log fire. People can tune and listen to the radio which can provide educative link as well as engaging the people with the political process. The savings that are made from not using kerosene can be ploughed back into children's education and improved family health care. Those who have missed out (they could be many) on formal education would have the opportunity to attain evening classes to learn how to read and write. It will now be possible for economic activities to extend to late evenings. The solar lantern locally made as a replacement of the local kerosene "Atunja" would get the people especially the youth involved in not only the technical support but also in the supply and distribution chain thus helping to reduce unemployment.

The beneficial impact of this development would also rob off on the city dweller. As developing countries struggle to improve power availability, those city dwellers who resort to kerosene lantern during power outages can also use the solar lantern.

IV. DISCUSSION

The lantern housed in a transparent discarded plastic water bottle has been frequently exposed to the sun for over one year but has not suffered from photochemical damage due to ultraviolet (UV) radiation. As well, the daily temperature cycling due to visible and infrared (IR) radiation [7] has not stressed the housing to destruction. There is no need to provide "weeping holes" underneath the lantern as it does not appear foggy in the mornings. Batteries contain toxic materials that can endanger human health and therefore their disposal should be carefully planned. Light output, light colour, lumen maintenance, and LED lifetime are all adversely affected by excessive LED temperatures during operation [8]. Light output increases with increasing drive current, but in addition to emitting visible light, the LED chip also becomes hot. This thermal energy limits the amount of power an LED can ultimately handle and there is the need to conduct the heat away from the LED chip and dissipate it in the surrounding environment. Unlike other light sources, LEDs usually don't "burn out;" instead, they get progressively dimmer over time. LED useful life is based on the number of operating hours until the LED is emitting 70% of its original light output called the L70 lifetime [9]. When the LED has reached its L70 light level, it can be considered to have failed even though is still produces light. Robust engineering can manage lumen depreciation except automatic and irreversible physical depreciations that occur at the chip level.

The LED datasheet is the primary way to initially identify the performance capabilities of the device. LEDs, like all electronic components, have specifications that describe the device performance and these are usually listed on a datasheet that contains enough information to allow a designer or engineer use the component in an electronic assembly [10]. The LED performance can vary widely as it depends on the LED chip quality, the packaging and all of the materials and manufacturing steps used in the process of making the device.

For off-grid lighting products, light output, run times, and solar charging rates are directly dependent on the efficiency of the energy collection and consumption of these systems [11]. There is a limit to the amount of power that an individual LED device can handle. The LED chip may be overheated leading to rapid lumen depreciation or even damaging the device if too much power is input. Table 1 summarises the LED behaviour with drive current and heatsink. The table shows that increasing the power to an LED increases the light output but decreases the efficacy because the LED chip will run at a higher temperature.

Table 1: Relationship of Performance with Variation in Drive Current (Source [11])

	Lumen Output	Junction Temperature	Efficacy	Lifetime
Increasing LED drive current	Increased	Increased	Reduced	Reduced
Decreasing LED drive current	Decreased	Decreased	Increased	Increased
Improved LED heatsink	Increased	Decreased	Increased	Increased

A standardized specification sheet (SSS) that manufacturers are encouraged to use when describing their products' performance has been developed by Lighting Global. This is in order to assist buyers of off-grid lighting products make informed choice. Some of the information presented includes lighting service, charging capability, and battery life in a simple, standardized layout [12].

The LED driver, or ballast, of a modern off-grid lighting product is responsible for regulating power from the battery to the LED and the basic and typical topologies commonly used have been discussed in a Technical Note [13].

The ways that sealed lead-acid batteries fail during storage and shipping have been discussed [14]. Suggestions have also been made on steps that manufacturers can take to prevent damage to the battery products in the supply chain [12]. The maximum storage time for lead-acid batteries depends on temperature. At 20°C, rectangular sealed lead acid batteries take 16 months to discharge to 50% state of charge, the shelf life drops to 8-9 months at 30°C, and 4-5 months at 40°C. Recharging is recommended after the battery has discharged to 50 -70% of its rated capacity. Table 2 gives the maximum allowed storage time at various temperatures for this these batteries.

Table 2. Maximum Storage Time Between Charges At Various Temperatures (Source [14])

Cell Temperature	Cylindrical Cells	Prismatic Cells
25°C	5 months	12 months
30°C	3.5 months	8 months
35°C	2.5 months	6 months

III. CONCLUSION

(a) Despite the fact that most African countries are blessed with the resources of the sun, the continent finds itself on the slow lane to renewable energy adoption.
(b) The solar lantern has been designed with two different housings that target different user groups.
(c) The rural dweller who uses the solar lantern will be financially better off and will enjoy improved social live with its associated beneficial effects
(d) The use of both batteries and LED involve safety issues which should not be ignored

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