# KEN DALE TRAVEL BURSARY 2022

# Assessing the impact of using off grid solar powered DC LED lighting systems on improving reliability and access to lighting in Southern Africa’s rural buildings (case study of schools and residential buildings)


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# PREFACE

This document was compiled by Aluwaine Tanaka Manyonga as a report for the 2022 Ken Dale Travel Bursary awarded by the Chartered Institute of Building Services Engineers. The research was carried out in Zimbabwe and Zambia. This document consists of six chapters that provide the details of how the research was carried out. Chapter one covers the introduction of the research and the objectives. In Chapter two the document covers various literature related to lighting with a key focus on Africa. Chapter three and four covers the identification and implementation of the off-grid lighting system in Zimbabwe and Zambia. In chapter five analysis and comparisons of the off-grid lighting system were covered in this section. The last chapter of this document provides a conclusion and recommendations for further study.

# ACKNOWLEDGEMENTS

I would like to extend my gratitude to the Chartered Institute Building Service Engineers (CIBSE) for awarding me the Ken Dale Travel Bursary 2022.

This was really a great opportunity for me to expand my research on off grid solar powered lighting in the Southern African

I am also grateful to the following people who made this research a success:

Derrick Katontoka who was my contact person in Zambia, he assisted in navigating the different places I visited.

Mr Boniface Siame the owner of the residential building in Chililabombwe, Zambia.

Mrs Mwalu the Chililabombe District Education Board Secretary

Mr Mulenga for offering technical advise on how installations are done in Zambia .

Mr Magodoro the headmaster of Gorondondo primary school

Mr and Mrs Venge who allowed me to carry out the installation of the off-grid lighting system at their homestead in Masvingo

Jeffrey and Dorothy who assisted me with the technical work in Zimbabwe

My family also offered me great support throughout the research.

Finally, I thank GOD for giving me the strength to thrive throughout the research.

## ABOUT AUTHOR

Aluwaine Manyonga is an electrical engineering graduate from the University of Zimbabwe. He graduated with a first-class honours and a special recognition as the best researcher and innovator in the faculty of engineering for his study on off grid solar powered lighting and reuse of LED lighting waste to make rechargeable LED lights. Aluwaine did his full year internship at Emmanuel Consultancy Engineers in the year 2020. He is currently employed as junior electrical engineer at Telnet Smart Home Automation which is based in Harare. Aluwaine has strong interest in sustainable building services engineering with a key focus on renewable energy, building automation and lighting design.

Aluwaine has won various awards which include the SLL Young Lighter 2020 award, when he presented his idea titled off grid solar powered lighting and the Chigubhu Lantern Africa's education system game changer. He was featured in the Beacons of Light blog series by DW Windsor in the year 2020. He is also an appointed expert judge for the Build Back Better Awards under the Solar and Lighting category.

Aluwaine work in lighting is aligned to making sure that everyone across Africa has access to high quality and reliable lighting with a key focus on the education sector and this will be achieved by ensuring "A light for every student".

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# CHAPTER ONE

## 1.0 INTRODUCTION

This research was made successful by the Ken Dale Travel Bursary award which is offered by the Chartered Institute of Building Services Engineering. The research was assessing the impact of using off grid solar powered DC LED lighting systems on improving reliability and access to lighting in Southern Africa's rural buildings. The research focused on countries in the Southern Africa Development Community (SADC). SADC is inter-governmental organisation that consist of 16 member states


that are all located in Southern Africa. Among the 16 countries the researcher was only able to carry out assessment and implementation in Zambia and Zimbabwe. The research was divided into three parts, the first one being assessment on how lighting affects night time productivity and identifying buildings that were going to be used for implementing the lighting system. The second part was implementation of the off-grid DC LED lighting system in the buildings selected in stage one. The off-grid DC LED lighting system was used as the basis of improving lighting access to the selected buildings that were used in this research. The implementation of the off-grid lighting system was done in 3 buildings, one of the buildings is in Zambia and two of the buildings are in Zimbabwe. The results from the three installations were used to draw up conclusions for the research. The final stage involved assessing how productivity improved after the implementation of the off-grid lighting system. The results presented in this research were gathered through interviews, observations, and measurements. The researcher further on gave recommendations that might need further research. This paper was guided by the following objectives.

## 1.1 OBJECTIVES

1. Identify rural schools and residential buildings without electricity (lighting) then select one school and a residential building.

2. Assess how performance and productivity is being affected by poor access to lighting in those two buildings.

3. Implement the off-grid DC LED lighting system on the residential building and a school selected in the first objective.

4. Compare costs and time of installing AC LED lighting system powered from the grid with the installed solar powered DC LED lighting system.

5. Compare the reliability, performance, efficiency, and lifespan of the installed DC LED lighting vs. AC LED lighting system.

6. Assess how performance and productivity will improve after the lighting system is implemented.

## 1.2 LIMITATIONS

Although the Ken Dale travel bursary catered for all the expenses incurred during this research, some challenges were faced. The main challenge the researcher faced in Zambia was not being able to get clearance to work and implement the off-grid lighting system on a school so, he was only able to focus on residential buildings. The other limitation was language barrier, as some of the people in Zambia cannot speak English. In Zimbabwe the researcher faced challenges in poor road infrastructure so the researcher had to travel on foot to one of the sites, where he had to cross a river. The other limitation was that in Zimbabwe the building selection process and implementation was done at once, limiting the time for identifying the building first. This led to selection of a school that had been decommissioned classrooms. The research implementation for the school was supposed to be done on a classroom but he ended up installing the off-grid lighting system on the teacher’s accommodation building.

*Figure 1:School building at Gorondondo Primary school*

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

The researcher reviewed literature on lighting and its impact, to build up an understanding of the current lighting situation in Africa. The literature used is from papers, blogs and different organisations dealing with lighting.

## 2.1 LIGHTING IN AFRICA

Buildings in Africa use different sources of light and these are either fixed or mobile depending on location. The fixed lighting sources are mainly provided by electricity that is produced in bulk and distributed in buildings. The mobile lighting solutions range from fuel lamps, solar lanterns, torch and candles these solutions are not fixed in one place. Access to electricity in Sub Saharan is at 41% and this shortage has greatly impacted rural areas which have a deficit of 80% (World Bank, 2014). In rural areas low levels of electrification are being witnessed due to the poor coverage of the grid, while in urban areas electricity supply is not reliable. Africans with access to electricity have been witnessing blackouts and load shedding which is mainly due to over strained power station that no longer meet demand. Electricity is of key importance to the education and residential sector as it helps improve the quality of livelihoods. Access to artificial lighting is required for extending the day when it gets dark and it is a direct benefit of electrification. On global scale lighting consumes 19% world's total electricity produced (UNEP, 2017) and the significant amount of this energy is used up in commercial and residential buildings. With the advent of electricity artificial lighting was greatly improved starting with the incandescent lamps introduced in the 19th century and this has proved to be of great importance.

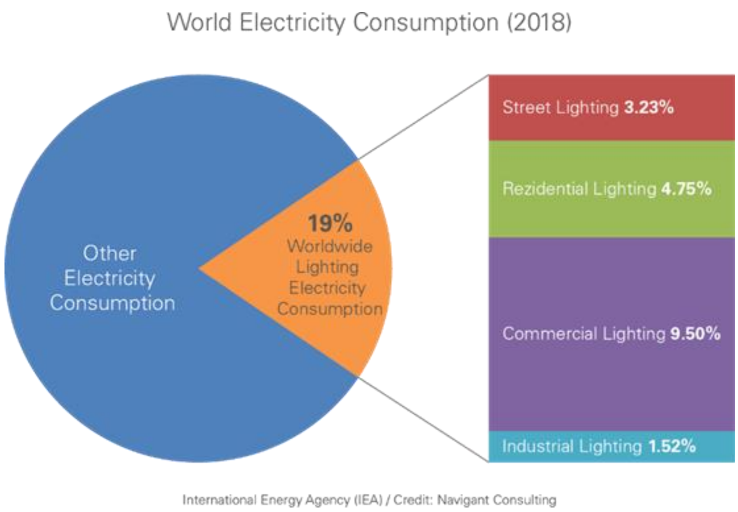



*Figure 2 :World's electricity consumption  Credit :Navigant Consulti*

Most people in Africa are not able access four hours of reliable lighting rated at least 300 lumens and affecting students (UNICEF, 2015). A study carried out by UNICEF and IES (2015) in certain parts of the continent yielded some results that showed the impact of lighting on the education sector. The study showed the current solutions that are being used by the students to alleviate this problem to lighting. The impacts of electrification and lighting on education sector leads to the reduced studying hours for the students, teachers will not have adequate time to mark assignments and proceed with their education.

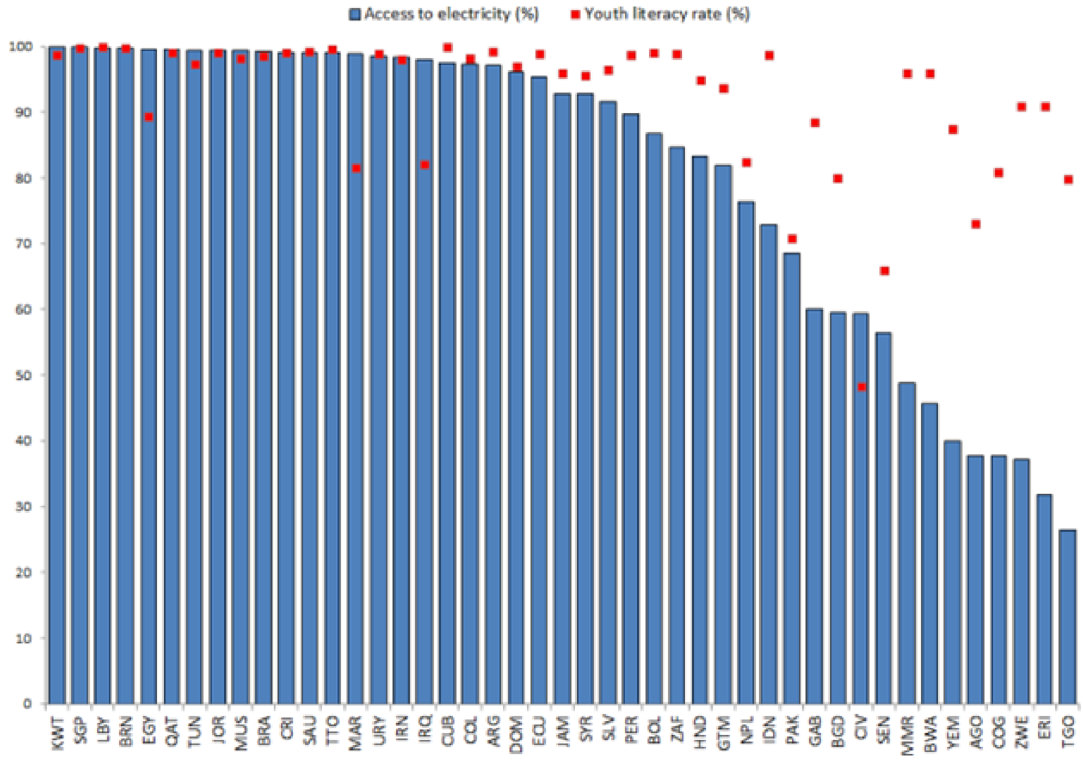



*Figure 3 : Graph showing how literacy and access to electricity are related in Africa credit UNDESA report 2014*

The above graph from World Bank 2014 shows a presentation of data drawn from 45 developing countries which, showed that countries with electrification rates below 80%, tend to have lower youth literacy rates. This showed that access to electricity improves quality and quantity of study by providing high quality of light [3]. Lack of lighting also prohibits adult learning and community activities that can only be done during the night due to a tight day schedule for adults. The overall impact of the reduced access to reliable lighting includes poor performance and reduced literacy rates, this has negatively affected the quality of education in Africa. A study carried out by UNICEF (2015) in certain provinces of Zimbabwe showed the lighting sources being widely used in rural schools were paraffin, diesel lamps and candles. Among these schools only 15% of the students had access to lighting provided by electricity. The research by UNICEF also gathered information on the times of the day that students were doing their homework and the results showed that more than 70% of the students did their work at night and the major limitation was poor access to lighting. This challenge of lighting also affected teachers as they were not able to cover much work after daylight.

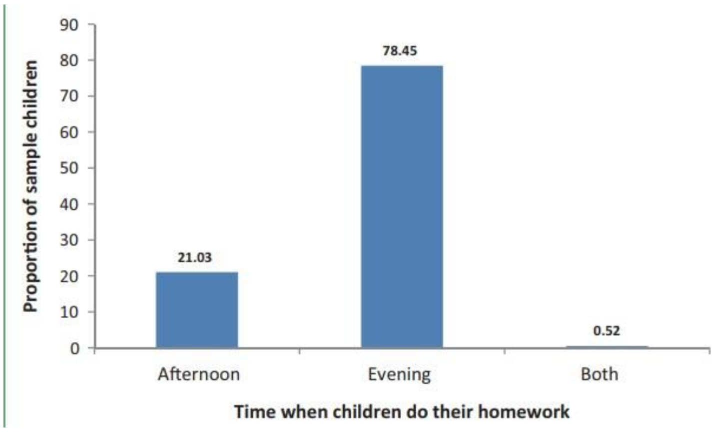



*Figure 4 : Graph showing the times children do their homework credit UNICEF Zimbabwe report*

Fuel lamps are the most popular mobile lighting solution that has been in use for the past decade. Fuels such as paraffin (kerosene) and diesel have been used to provide lighting in developing countries, with a significant number of users being from Africa. These lamps were highly favoured for their low initial investment cost and the ease of maintenance when compared to other lighting sources. The fuel lamps have negative health, environmental and economic impacts. Studies have shown that kerosene lamps contribute 7-9% to global warming (WHO, 2016). These lamps produce 270 000 tonnes of black carbon every year which is equivalent to 240 million tonnes of carbon dioxide every year in the world.

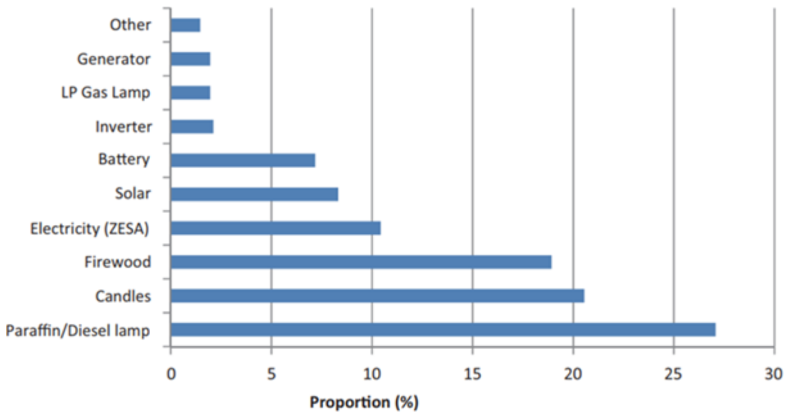



*Figure 5: Graph shows the different the light sources used by students*

These emissions from fuel lamps can be equated to that produced by 50 coal fired power stations (Next Billion, 2019). For every litre of kerosene burnt, 2.5 kg of carbon dioxide are released into the atmosphere. The emissions from the paraffin lamps contribute to climate change which has resulted in droughts and floods in some parts of the country. According to the World Health Organisation these fuel lamps are responsible for 25% of the deaths from COPD among other health complications. Fuel lamps have health implications which include lung cancer, asthma and cause visual impairment due to their low lumen output (UNICEF, 2014). They also cause accidents such as fires and a study carried out on local hospitals found out that paraffin ingestion was one of the major causes of child poisoning (Tagwireyi, 2000).

*Figure 6 :  A group of students studying using kerosene lamp*

The lamps also affect the economics of the household as they claim 15% to 20% of the income, yet the quality of light produced is very low (Solar Aid, 2014). The paraffin lamps also produce poor light output when compared to other light sources powered by electricity. Paraffin users pay more than 50% for a poor lighting when compared to electricity users (African Energy Outlook, 2015). To date most of the fuel lamps are no longer being used, as most people are now used to LED lights that are either rechargeable or non-rechargeable. The rechargeable LED lanterns are solar powered and they come in different shapes and sizes.

# CHAPTER THREE

## 3.0 BUILDING IDENTIFICATION AND SELECTION

The selection and identification of the buildings used for the research implementation was carried out in Zambia and Zimbabwe. The researcher travelled to different parts of these two countries to carry out assessments and then select the buildings. This section is covering the detailed identification and selection process.

### 3.1.1 ZAMBIA BUILDING SELECTION

The research was done in Chililabombwe which is a located in the Copperbelt province. Chililabombwe is mining town with an estimated population of 142 000 people according to the 2022 Zambia Census. Chililabombwe has a high voltage electrical network which supplies the mines in the town. The urban centre is fully electrified, new peri urban residential buildings are still being electrified however there is less expansion of the grid to areas that are on the outskirts which are mainly rural areas. The researcher visited the following places as part of the first objective.

1. Miteta Kanenga
2. Miliyash
3. Lubansa

*Figure 7 : Interview with Mr Siami during first visit in Zambia*

Among the three places I settled for Miteta Kanenga which is located on the eastern part of the Chililabombwe town. Miteta Kanenga is mainly occupied by refugees from Angola and local small-scale farmers. The electricity grid is 25 km from Miteta Kanenga and the first visit focused on assessing the nature of the buildings. Most of the buildings in the area were built using farm bricks .The farm bricks are made of ant hill soil mixed with water and then dried using fire hardened by burning or the sun. For roofing, most buildings used grass the structural integrity and roof type .The researcher made a final decision of implementing the off grid lighting system at the house of Mr Boniface Siame .Mr Siame is a retired human resources manager who has ventured in to small scale farming and animal husbandry .He owns a 4 hectare which has two buildings for workers accommodation .The houses are built using burnt farm bricks and roofed using galvanised metal sheets. The researcher went on to implement the lighting system, further details on implementation are covered in chapter 4.

*Figure 8 :Miteta Kanenga house assessment*

### 3.1.2 ZIMBABWE BUILDING SELECTION

In Zimbabwe the research was carried out in Masvingo province located on the south eastern part of Zimbabwe. The province is home to the Great Zimbabwe ruins a world heritage site and major tourist attraction site. Masvingo province has a population of 1.6 million people according to the 2022 Zimbabwe population census. In the province the researcher worked in two districts and carried out implementation of the project on a school and residential building.

*Figure 9 :Solar panel installed at a residential building in Zimbabwe*

### 3.1.3 GORONDONDO PRIMARY SCHOOL

Gorondondo primary school ,is located in Gutu district , the school was built in 1960 during the colonial era .It consist of 6 classes which have dilapidated ,leading to its decommissioning in 2020 .The researcher wanted to implement the off grid lighting system on a classroom at the school but due to the state of the building ,the installation was done at the teachers accommodation .The school has an enrolment of 250 students who come from surrounding communities .The school has 2 buildings that are used to accommodate teachers. The total number of teachers at the school is 12 .Six of the teachers use the buildings at the school as accommodation. One of the buildings was used for the implementation of the research after assessing the two buildings. The building at the school where built using cement bricks which are stronger when compared to the farm bricks .The roofing for this building was done using asbestos sheets .The building selected has six rooms and the details of the installation are covered in chapter 4.

*Figure 10 : Classrooms at Gorondondo Primary school*

### 3.1.4 ZIMBABWE RESIDENTIAL BUILDING

In Masvingo the researcher carried out another installation in Chingwete village located in Mazari .Mazari is part of the North Masvingo district ,and it shares its boundary with Gutu district where Gorondondo Primary school is located .The two districts are separated by Mutirikwi river .Chingwete village has an estimated number of 50 households .The area is reachable using a gravel road and the closest point with the electricity grid is 14km away .The homesteads in the village are far from each other making the building identification and selection process a challenge .The interviews carried out showed that most of the households are dependent on small scale farming and external funds provided by formally employed relatives .The main crops they farm include maize ,sun flower and cotton .The income generates per household ranged from USD$50 to USD $400 per month it was mainly from farming .

*Figure 11 :A typical homestead in Masvingo Province, Zimbabwe*

My assessment was limited to 3 residential buildings due to the sparse distribution of the households .The three buildings accommodated an average of 5 people and each house had at least 3 rooms .On all three households each at least had one round hut ,that is thatched with grass and one bedroom that is roofed using galvanised metal sheets .After making deliberations I settled for Mr and Mrs Venge homestead to carry out the implementation of the project .The homestead has 3 buildings that consist of two round huts and one bedroom. The building are built using farm bricks made of ant hill soil. For roofing two of the huts were done using grass and the bedroom was roofed with galvanised metal sheets. The building selected accommodates a family of 5 people and among them 2 are still going to school. The details of installation are covered in in chapter 4.

## 3.2 PRODUCTIVITY ASSESSMENT

### 3.2.1 ZAMBIA

The first visit focused on visiting different residential building and interacting with people finding out the different light sources they rely on .The assessment was carried out on five households from these five households their sleeping time was ranging between 8 pm to 10pm.The households assessed all had an average of 6 people living in the household .The people relied on candles, cell phone torch and solar lights for providing lighting when it gets dark .The  choice of lighting source was related to the number of people in the household and also the a income generated per household .Solar lights were found in most of the households  visited and most of these lights were broken.

*Figure 12:A typical LED light being used at one of the household in Zambia*

One key thing noted was that most households invested in a new solar light on average four times a year .The portable solar lights had a solar panel embedded on the back of light and the users had to move the light outside for charging .This led to quick failure of the light as the lights usually broke during this movement .Based on the interviews most parents stated that the  lights were usually broken by children .Some people relied more on cell phone lights but these lights did not provide enough light output .The monthly  income range for the households interviewed was between USD$50 to USD$550 and this was usually raised during harvest season .The income was also a driving factor on the time of use of the lighting source especially in the case of those lights with a replaceable battery.

### 3.2.2 ZIMBABWE

Interviews and observations carried out in Masvingo province showed that night time productivity is dependent on the light source available for use. The people relied on battery powered LED lights, solar lanterns, and cell phone torch for lighting. A few highlighted using candles and fire especially during cooking night time meals. Most people highlighted that they sleep at 8 pm because they will be saving on the cell phone or torch battery power. Those who used LED lights with replaceable batteries highlighted that the operational cost was high. The high operational cost limited their productivity as they had to save on power. Each household interviewed was productive for about 2 hours after it gets dark. The two hours were mainly allocated to cooking, resting and general lighting. Lighting was also being used for studying and doing homework. In one of the houses the children stated that they do not get sufficient time for studying as the some of their lighting sources did not last for more than 2 hours. The challenge of quick failure due to breaking of the solar lights was also highlighted in Zimbabwe.

*Figure 13: LED light with a separate solar panel*

The teachers at Gorondondo primary school slightly had different night time patterns from the residents interviewed .The assessment carried out on teachers showed that they had extra duties that required extra hours of lighting .On average the teachers required between 3 to 4 hours of lighting to be able to accomplish all their tasks .Their extra activities included marking school work and preparing for the next day's work .My observations also showed that the teachers had access to better lighting solutions and had better income streams as compared to the residents .The teachers also preferred the solar powered lights but the lights did not give them enough time to cover their night time activities. The other challenge highlighted was that the lights started to dim overtime making it more difficult to read. Quality of the light output was essential to the teachers.

*Figure 14:Assessing a household in Masvingo*

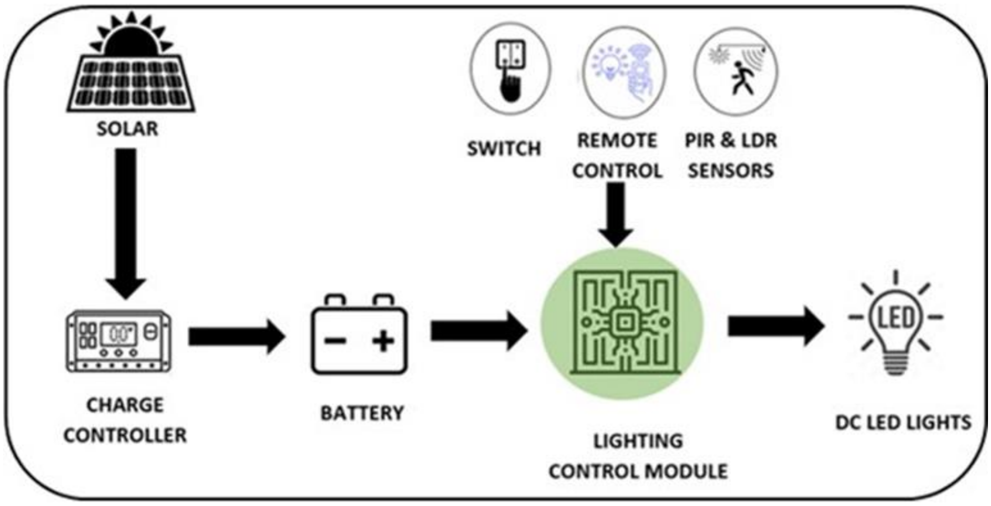
# CHAPTER FOUR

## 4.0 IMPLEMENTATION OF THE OFFGRID LIGHTING SYSTEM

This section covers the implementation and detailed description of the off-grid lighting system.

## 4.1 OFFGRID DC LED LIGHTING SYSTEM BACKGROUND

This is a sorely DC solar powered lighting system, that does not use any AC power. Lighting emitting diodes are DC component in nature ,for them to be used on an AC installation , LED drivers are required to convert the AC to DC .LED drivers use a process called rectification ,which is the process of converting AC to DC and it is usually achieved using sophisticated circuits .The DC LED lighting system also eliminates the use of inverters in off grid solar installations where AC LED bulbs are used .The inverter will convert DC power from the battery into AC power which then be supplied to the LED bulb .In this setup the power conversion is done twice ,by the inverter and  then by the LED driver .




The off-grid lighting system consist of solar panels which act as the main source of power for charging the batteries. The batteries store energy provided by the solar panels such that it can be used when the sun is no longer available. The charge controller regulates the charging process of the battery, it prevents over charging and deep discharging of the battery which affects its life span. The lighting system has a lighting control module (LCM) which was developed by the author. The LCM gives the user maximum control of their lighting through multiple ways of control. The LCM can incorporate functionalities like diming, remote control, and sensor integration.

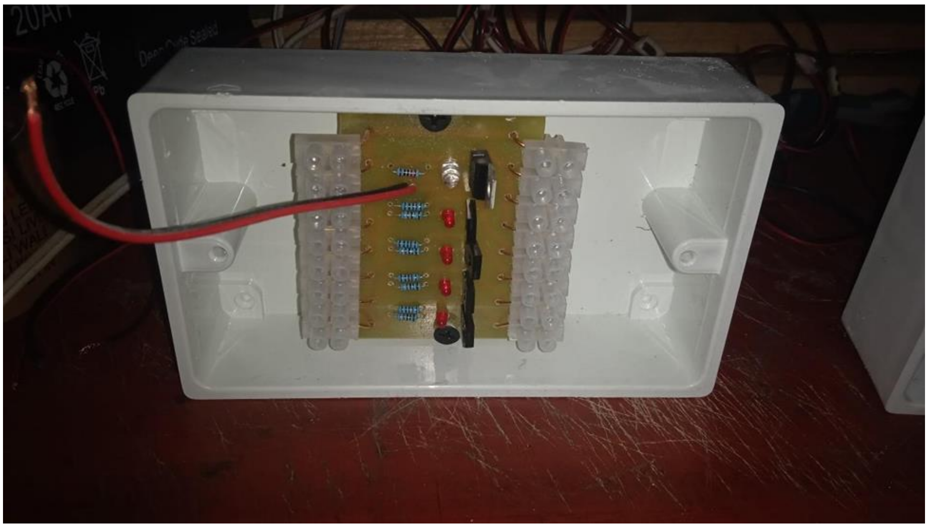


*Figure 15 : Basic lighting control module*

This research implementation only used the basic lighting control module which allows for ordinary switching of the lights. The lighting system uses DC LED lights and for the purpose of this research 12V LED lights were used, the LED bulbs have a B22 base and can fit in standard bayonet lamp holders. The off-grid lighting system also has capabilities of charging cell phones and other small devices like cell phones and radios. The wiring scheme used for installing the off-grid lighting system is done per lighting point through the LCM. The LCM has a load side where the LED bulbs are connected and a switch side where the input for controlling the lights is connected. The input can be from a sensor, ordinary rocker switch or a push button which can also be used for dimming. All wiring cables in the lighting system are concealed in trunking and conduits eliminating trailing cables. Before the implementation of the lighting system, the researcher did calculations to specify the LED bulbs and solar panels shown is done in the next section.

## 4.2 SIZING THE OFF-GRID DC LED LIGHTING SYSTEM

For the implementation of the lighting system, standard lighting calculations were used for specifying the lights and solar equipment required. Lumen method was used to calculate the number of lights required in every building, the process of calculating the number of lights required. Lumen method was used for this, it is a traditional methods for calculating the average illuminance required on a given surface. This method can be used to calculate the number of lights required if a specific type of lamp is selected and the size of the room is known. The number of lights required in each room was calculated using lumen method.

$$N = \frac{E\ x\ A}{\emptyset x UF x MF}$$

Where ***E - illuminance (lux/m2) ; A - floor area ; ∅ - luminous flux ;UF - utilization factor and MF- is the maintenance factor .***Using this formula, 6W DC LED bulb producing 560 lumens where selected as the light source, based on the average floor areas for the building selected for implementation.

## 4.3 SOLAR SYSTEM REQUIREMENTS

After calculating the number of lights required in each room the data was then used to size the solar equipment to be used. The calculation in this section was done for the Zambian residential installation, with 4 light off grid lighting system and it can charge 3 cell phones. The time of use was set to 6 hours which was slightly above the time stated by the teachers who required more lighting hours.

| Room | Power (W) | Time of Use (hrs) | Energy (Wh) |
|---|---|---|---|
| **LED lights** | 24 | 6 | 144 |
| **Cell phone** | 25 | 3 | 75 |
| **Total** | **49** | | **219** |

The size for the PV module required is calculated from the total energy required using the equation below

$$\boldsymbol{PV\ Module\ size = \frac{Total\ Daily\ Watthours}{Average\ solar\ daily\ insolation} = \frac{219}{5.6} = 39.1}$$

Using the value of 5.6 hours for the average daily insolation in Zimbabwe the solar panel size result is 39.1 Watts. Taking into consideration system losses as percentages i.e. 90% for temperature loss, 85% for battery losses, 97% for wiring losses we get total losses as follows

$$\boldsymbol{Total\ losses = 0.9\ x\ 0.85\ x\ 0.97 = 0.74}$$

The final PV module size was calculated as follows

$$\boldsymbol{Final\ PV\ module\ size = \frac{39.1}{0.74} = 52.8}$$

The next step was to size the battery which will provide power to the LED lights and charging small devices. The equation below was used.

$$\boldsymbol{Battery\ Capacity = \frac{Total\ Daily\ Watthours\ x\ DA}{Nef\ x\ DoD\ x\ Vs}}$$

Where ***DA*** *is the number of days of autonomy;* ***Nef*** *is the battery efficiency;* ***DoD*** *is the depth of discharge and* ***Vs*** *is the system voltage*.

For the standard system sizing one day of autonomy was used the other values were taken to be ***Nef =0.8, DoD = 0.8 and Vs = 12V***

$$\boldsymbol{Battery\ Capacity = \frac{39.1}{0.8x0.8x12} = 28.5Ah}$$

Between the battery and the panel a charge controller is required which will regulate the charging current to the battery. The charge controller was sized based on the maximum current from the panel and that going to the load as calculated below.

$$\boldsymbol{Charge\ Current = \frac{Pmax}{Vnom} = 4.1A}$$

Where ***Pmax is the maximum power from the panel and Vnom is the nominal voltage of the system***

From the results a standard 10A charge controller was selected for charging the battery and powering the LED lights.

## 4.4 WIRING SIZING

Sizing the wiring is of great importance since it reduces the amount of losses and affects the overall cost of the system, if not done properly. The wiring for the off grid lighting differs from the wiring done in AC lighting installations. Copper is widely used for wiring systems; this is due to its good conductivity and a low resistivity value of 1.7 $x$ 10−8 $\Omega m$ which is 0.02$\Omega m$ for a 1mm2 conductor. The resistance of conductors is also dependent on length and cross-sectional area of the conductor and this is given by the following formula.

$$\boldsymbol{R = \frac{\rho L}{A}}$$

Where $\rho$ *is the resistivit* ; $L$ *is Length* ; $A$ *is the cross sectional area of the conductor*

The above formula imply that resistance increase with length and decrease with the thickness of the conductor. Due to the existence of this resistance in a cable, they will be a voltage drop and power loss over the length of the cable. The voltage drop in the cable is given by

$$\boldsymbol{V = IR}$$

The power loss is given by

$$\boldsymbol{P = I^2R}$$

From the above equations it can be deduced that as we increase the current the power loss and voltage drop also increases, this will result in the heating up of the cable. The off grid solar lighting system wiring will be calculated for 12V and 24V LED lights, the permissible voltage drops for the two systems should be less than 0.5V and 1V respectively.

$$Vdrop = IR$$

Resistivity of copper is **0.02 Ωm** this give us the following formula

$$A = \frac{0.04IL}{Vdrop}$$

$where\ A - is\ the\ conductor\ CSA$ ; $I - current$ ; $L\ is\ the\ cable\ run\ length$

The table below shows the summary of wire sizes to be used for wiring the lights and the switches .The distance of 15m was used in this calculation as furthest distance from the lighting control module to the lights. Using the formula above the cable size was found to be 0.6 $mm^2$ and on the market 0.75$mm^2$ was available and they were used for the implementation of all the installations.

## 4.6 ZAMBIA LIGHTING INSTALLATION

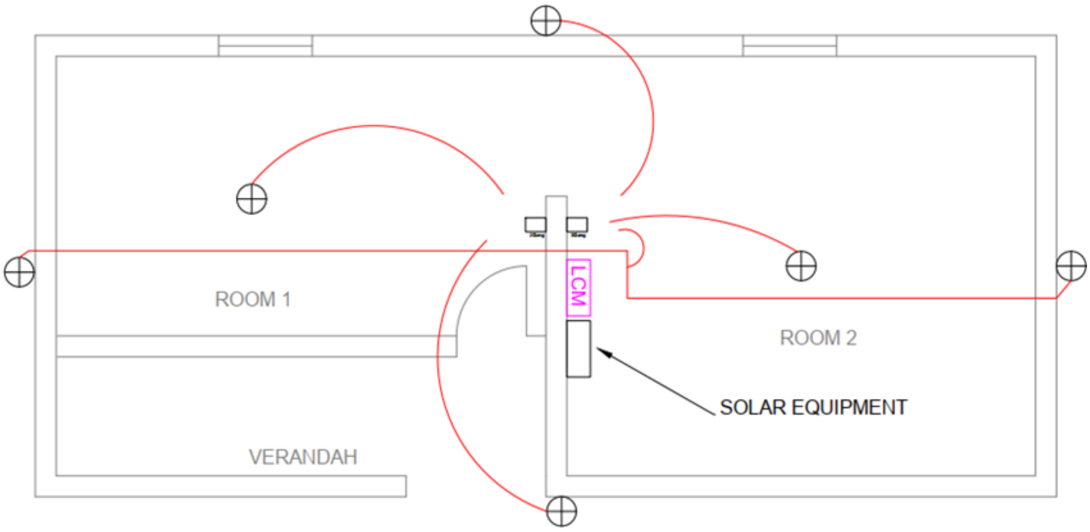



*Figure 16 :Floor plan for the residential building in Zambia*

The building selected in the first part of the research was used to implement the lighting system. This section covers all the technical details of the lighting installation .The house is located at a farm owned by Boniface Siame who is in to small scale farming and animal husbandry .The author recreated the floor plan the building using AutoCAD, the floor plan was then used to create a proposed lighting layout .The off grid lighting system was sized to power 6 LED bulbs and charging cell phones, the table below shows a summary of the solar equipment used.

| **Description** | **Rating** |
| --- | --- |
| Solar panel | 80W |
| Charge controller | 10A |
| Battery | 24Ah |

*Figure 17 :Installing the solar panel on a residential building in Zambia*

The lighting system used a 4 channel LCM with three of the outputs being used to control the lights inside the house while the remaining channel was used to control the outside lights .The calculations carried out in section 4.5 the cable size was found to be 0.6 mm2 ,this is not a standard cable found on the market .For wiring the lighting system 0.75mm2 twin flat speaker cables were used for the LED bulbs and 0.25mm2 was used for the switches .The summary of the bill of material used for this installation is provided below ,check appendix for the detailed bill of material .

| Item | Description | Total |
|---|---|---|
| 1 | Tubing Subtotal 1 | 29 |
| 2 | Wiring and Terminations Subtotal 2 | 63.5 |
| 3 | Lighting Subtotal 3 | 36.5 |
| 4 | Solar Equipment Subtotal 4 | 195 |
| 5 | **Material Total** | **324** |
| | Labour | 150 |
| | **Total** | **474** |

The installation took 8 hours to complete it ,the installation was done by the researcher alone, as they was a language barrier at the site of installation .The first four hours of the installation covered tubing ,wiring and the last part was for installing the solar equipment .The solar panel was mounted and secured on the zinc iron sheets that are covering the house .The LED lights were fitted on bayonet lamp holders and can be easily be changed in the case of failure .The charge controller and LCM were installed inside the house all cable were concealed in trunking and conduits .The overall cost of the installation was USD $474 ,this cost included labour which was calculated as 40% of the material used .

*Figure 18:Installed solar panel*

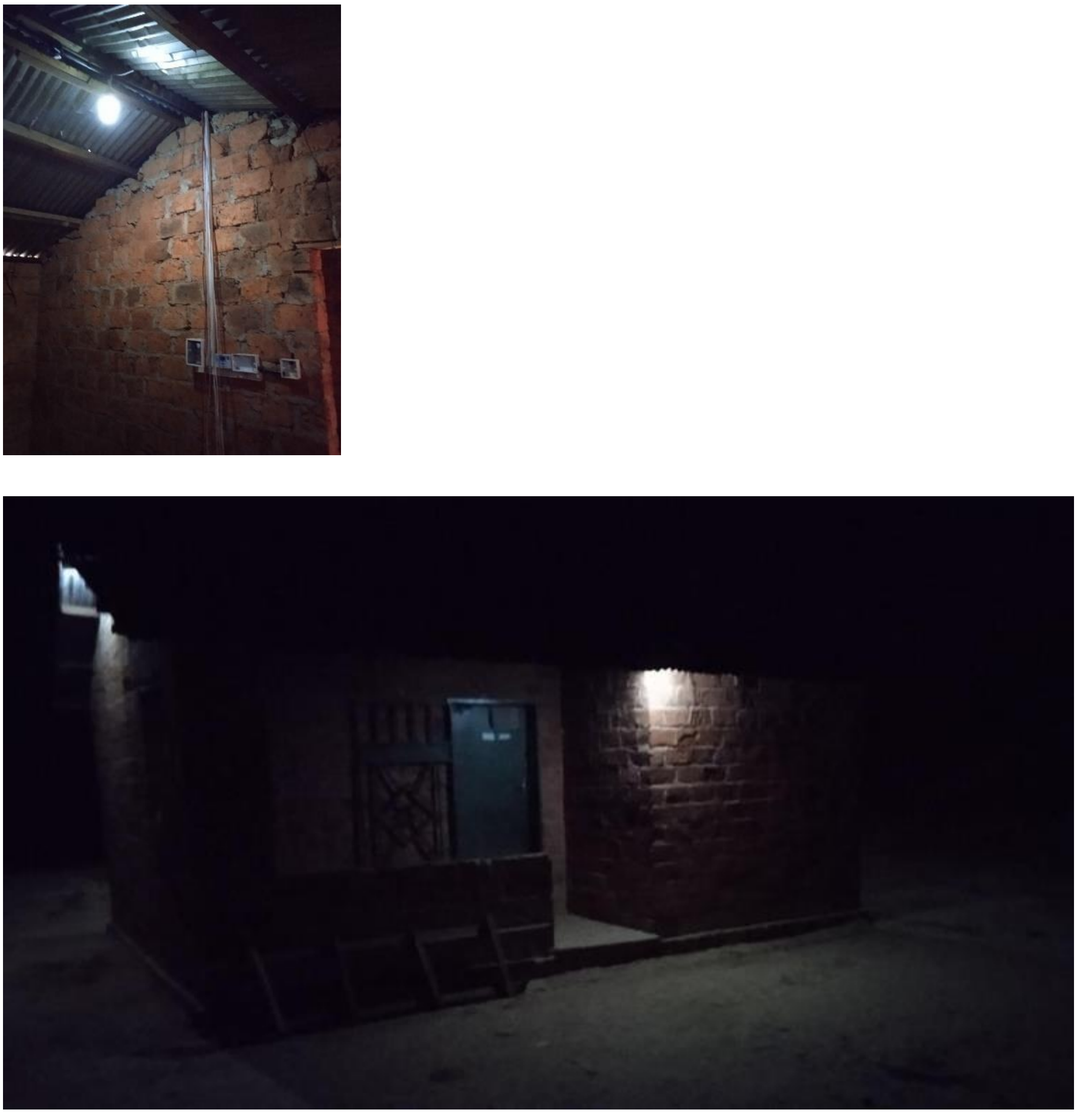
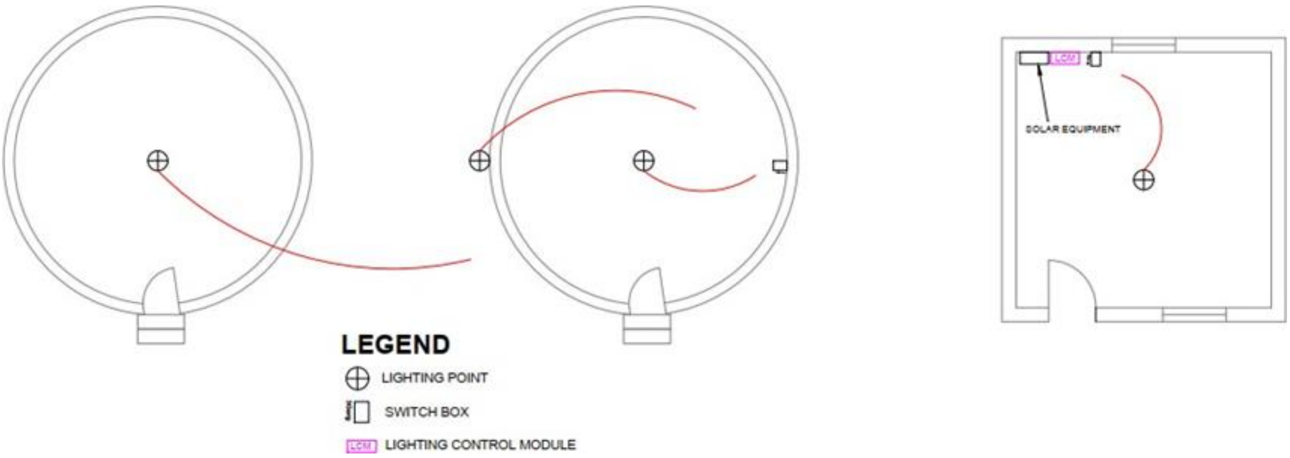


*Figure 19 :Night time image after implementing the off-grid lighting system*

## 4.7 ZIMBABWE LIGHTING INSTALLATION

The implementation in Zimbabwe was done on two residential buildings, the other building is located at a school. The identification and selection of these buildings were covered in chapter three. The implementation was done according to the layouts below.



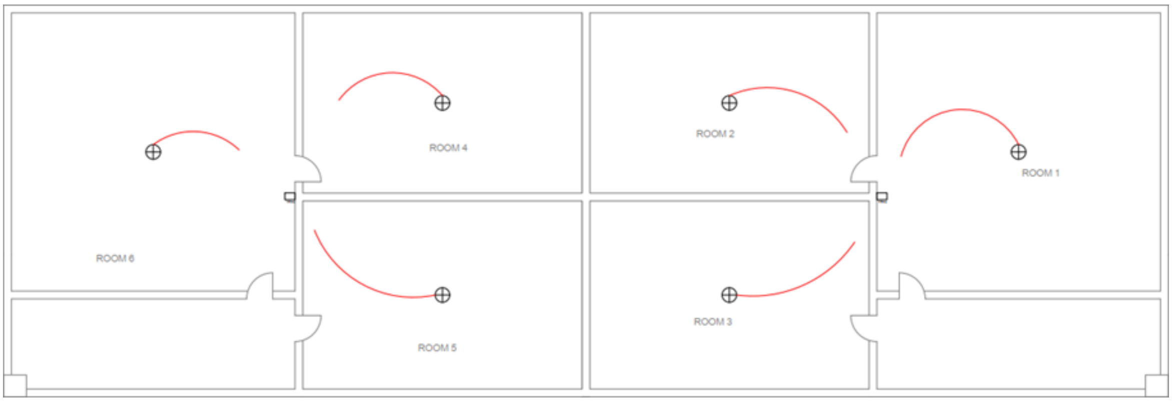

## 4.8 RESIDENTIAL BUILDING

The residential building selected in Zimbabwe consisted of 3 buildings that are separate with average of 2 meters distance apart them. The plan was recreated and a lighting layout was done based on the lighting calculation results. The installation took 4 hours to complete and the researcher had for two assistants who were helping with the work. The summarised bill of material is provided below, for the detailed information refer to the appendix. The off grid lighting installation at this building has the following solar equipment base on the calculation done in section 4.3

| Description | Rating |
|---|---|
| Solar panel | 50W |
| Charge controller | 10A |
| Battery | 20Ah |

The house was fitted with 4 DC LED lights, due to the separation of the buildings, the solar equipment was set up in one the rooms as shown on the layout above. The LED bulbs can easily be replaced in the event of failure. The cables were placed in conduits and trunking. Two of the buildings used grass thatching and the solar panel was installed on the room with metal sheets. The overall cost of this installation cost of this was USD $342.

## 4.9 SCHOOL BUILDING




The school selected for the research was Gorondondo primary school, the school has 4 classrooms which were decommissioned due to their dilapidated state .The school has two residential buildings which are used for accommodating the teachers who live at the school. The building has 6 rooms and its roofed using asbestos .The researcher resorted to installing the off grid lighting system at the teachers accommodation .The installation was fitted with the following solar equipment based on the sizing procedure covered in section 4.3.

| **Description** | **Rating** |
|---|---|
| Solar panel | 100W |
| Charge controller | 10A |
| Battery | 50Ah |

The lighting installation used two central switches to control the lights, each switch controlling 3 lights. The battery and charge controller were placed on one section of the building, while the solar panel was mounted and secured on the roof.The installation took 6 hours to complete and the researcher had two assistants. The total cost of this installation was USD $548.View detailed cost of installation at the appendix.

| **Item** | **Description** | **Total** |
|---|---|---|
| 1 | Tubing Subtotal 1 | 45 |
| 2 | Wiring and Terminations Subtotal 2 | 93 |
| 3 | Lighting Subtotal 3 | 53 |
| 4 | Solar Equipment Subtotal 4 | 172 |
| | **Material Total** | **363** |
| | Labour | 185 |
| | **Total** | **548** |


23


Charge Controller
10.5 V
RS-20A

# CHAPTER FIVE

This chapter provides comparison on the implementation of the off-grid lighting system and the productivity assessment after the installation of the off-grid lighting system.

## 5.1 INSTALLATION COST AND TIME COMPARISON

From the three installations the researcher went on to do comparisons on installing the DC lighting system against the standard AC lighting installations .The comparison where first done for time and cost of installation .After considering many cases and gathering information the cost of installing 4 AC LED lights was averaged at $280.The cost of cabling was higher on the AC installation as three cables are used which are live, neutral and earth. The DC LED lighting system uses two cables only .The cables used for wiring in AC system are standardized at 1.5sqmm for residential areas while in the DC lighting system the cable where calculated to be 0.75sqmm and could power 12W bulbs .The cost of bulbs was also compared using local and international price .One of the key findings in Zambia was that DC LED bulbs were not readily available in most retail shops making them more expensive than AC LED lights.After compiling the prices of the DC bulbs the average cost of the DC bulbs was found to be 0.17c/Watt while the price of AC LED bulbs was 0.33c/ Watt .The average price was determined from the local store and online shops for both Zimbabwe and Zambia .

*Figure 20:DC LED light in a retail outlet in Zambia*

For the AC lighting system, the author did not cater for the connection fee which is paid to the electricity supplier which made the huge difference in cost of implementation. The DC LED lighting system uses solar power and the equipment required for the solar installation made up 40% of the total bill, leading to a high initial cost. However, the AC LED lighting system requires the user to be paying monthly fees to the electricity supplier. The cost of the switches was the same for both the AC and the DC LED lighting system. The summary of the comparison is provided below.

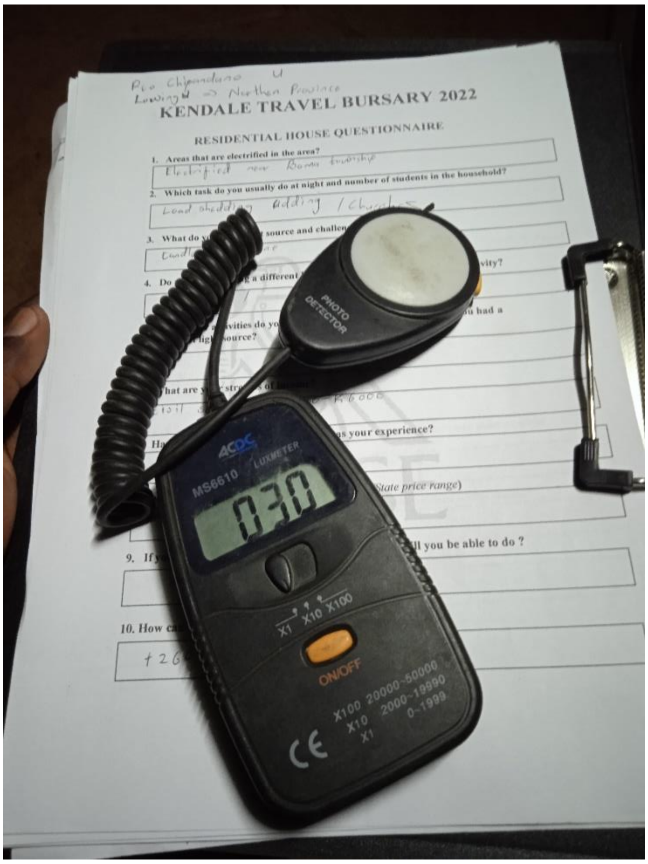
| | **AC LIGHTING SYSTEM** | **DC LIGHTING SYSTEM** |
|---|---|---|
| **DC LED BULBS AVAILABILITY** | Available in most retail shops | Not readily available in Zambia |
| **LED BULBS COST** | 0.33 cents /Watt | 0.17 cents /Watt |
| **WIRING COST** | More expensive | Less expensive |
| **SWITCHES COST** | Same | Same |
| **SETUP COST** | Low | High |
| **INSTALLATION TIME** | 4 hours for installing 4 lights | 6 hours for installing 4 lights |

The time for installing four lights was 6 hours for the off-grid lighting system and 2 hours of the time was taken up by setting the solar system and equipment. For AC LED lighting the same installation takes an average of 4 hours to complete. The time of installation of the off-grid lighting system is well within range when compared to AC lighting.

## 5.2 LIGHTING EFFEIENCY AND RELIABILTY COMPARISON

LED lights are DC components by nature for the lights to be used on AC systems they is need for a circuit to convert AC to DC and these are called drivers. The process of converting AC to DC is called rectification and it is achieved using diodes .Rectification causes power losses, and usually 15% is lost during this process .The drivers also have a lifespan which is below that of the LED chip and most of the time the driver fails first .Most solar home system use an inverter, in this case power is converted twice .The first stage of conversion will be from DC to AC and this done by the inverter. The second stage will be converting from AC back to DC that is required by the LED chip .The DC LED lighting system takes its power directly from the battery removing all AC to DC conversions ,this reduces the amount of power losses .The DC LED lights also do not use any drivers hence their life span is longer .The lighting system proved to be reliable when compared to the fixed and mobile lighting solutions .The fixed lighting solutions are mainly used by those connected to the grid ,and they depend on the availability of electricity. Most countries in Southern Africa face unreliable power supply ,meaning the households will not be able have reliable lighting .The mobile lighting solutions which include solar lanterns and torches were prone to breaking as they were moved around for charging .For the solar lanterns the lights usual break when they are being charged or in use .

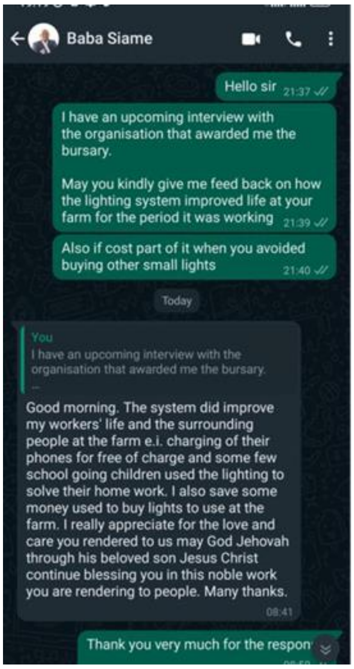
The off grid solar powered DC LED lighting system proved to be more reliable when compared to the other lighting solutions. The solar panel is fixed on the roof and it is not movable, preventing it from breaking. The installations do not have any trailing cables as all the wires are enclosed in conduits and trunking. The switches for the lights are installed on the walls and the DC LED bulbs are mounted on a bayonet type lamp holder making them easy to replace in the case of failure.

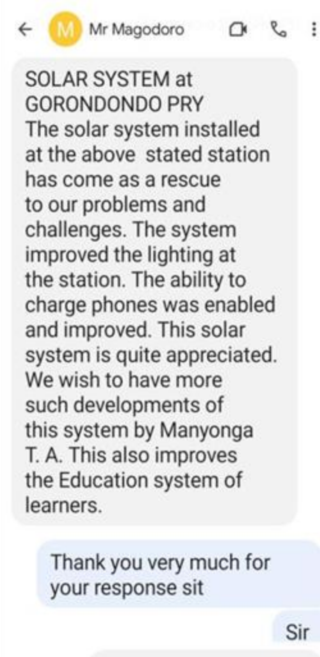



## 5.3 PRODUCTIVITY ASSESSMENT

The researcher gathered regular feedback from the 3 installations implemented in Chapter 4.Access to lighting improved in the three households and the users highlighted that this solution was more reliable when compared to their existing lighting solutions .The system can provide lighting for up to 6 hours and the users highlighted they could now do more activities .Productivity in the three installations increased by 2 to 4 hours ,the household could now extended their night time activities up to 10pm .They also highlighted that during winter when we have longer nights they could have sufficient lighting, in the morning making it possible to wake up earlier. The lighting system also improved security at the residential building in Masvingo ,due to sparse distribution of the buildings ,people could now move around in a more safe environment .The installation in Zambia also included a multiport cell phone charger ,which made it easy for cell phone charging .The teachers at Gorondondo primary school stated that their night time productivity improved as they required more lighting hours .The teachers where now able to cover more work and the off grid lighting system provided high quality lighting .School teachers could now easily prepare for the next day's work, which they usually do manually .Assessing homework at night was now easy as the lighting system provides reliable lighting .For the school lighting early in the morning was very crucial as the teachers start preparing early ,when it will be usually dark .The users also highlighted they were no longer worried about staying in the dark ,due to forgetting to charge their lights as in this case the panel was mounted on the roof .Mr Siame highlighted that the student were now able to study at his house .The off grid lighting system made it more easy for the students to study as the light was fixed on one point and it provides more lighting hours .

## 5.3 USER FEEDBACK



# CHAPTER SIX

## 6.0 RECOMMENDATION AND CONCLUSION

This chapter provides conclusion for the research and some recommendations for further research and study.

## 6.1 CONCLUSION

Poor access to lighting in Southern Africa is mainly driven by poor access to electricity and rural areas are the most affected. In urban areas, people are affected by unreliable power supply leading to unreliable lighting. Alternative lighting solutions such as solar lights, LED torches with replaceable batteries and cellphone torches are more popular in the rural areas. The research assessed the use of off grid DC LED lighting system for improving access to lighting in Southern Africa.

The research was focused on Zambia and Zimbabwe and implementations where carried out in those two countries .After the implementation of the off grid lighting system night productivity increased by 2 to 4 hours in the 3 buildings .The off grid lighting system provides lighting for up to 6 hours ,giving users enough time to carry out their night time activities .The lighting system was installed at a primary school in Zimbabwe and this improved the productivity for the teachers who were benefitting from this system .The teachers highlighted that the lighting could positively impact the quality of education at the school. The lighting system also offers provision for cell phone charging, this improves access to digital services.

The lighting system is solar powered cutting down greenhouse emissions, making it a net zero lighting solution .The downside of the system is its high initial cost of installation, which is a barrier to the rural communities .The people rely on farming which does not provide a lot of income and it makes it difficult for them to afford the system .However the off grid lighting system do not have any running cost after the installation. The lighting system has a lower operational cost and saves money for replacing batteries, refilling kerosene and monthly electrical bills. The system is more durable as it is fixed and all cables are concealed in conduits and trunking.

From the three installations done in Zambia and Zimbabwe off grid solar powered lighting the researcher came to a conclusion that this solution can improve access to lighting in areas that lack electricity .The system has a great impact on the residential and school building by improving night time productivity.

Off grid solar powered DC LED lighting system can be made a new standard for lighting up buildings that have poor access to lighting and in turn improve lives of rural communities.

This research concludes that off grid solar powered DC LED lighting can improve reliability and access to lighting in Southern Africa. They is need for some further research on how this solution can benefit everyone and these are provided in the recommendations section.

## 6.2 RECOMMENDATIONS

This following recommendations on improving access to lighting using the off grid solar powered DC LED lighting may be used for further research or study .Further research on the effects of LED lighting on nocturnal insects ,this is crucial since most rural areas in Africa are still in their natural state .Studying on ways of subsidizing solar powered lighting in the rural communities that cannot afford the high initial cost the installation .The lighting system at a large scale can make an impact on eliminating carbon emissions from lighting .The solar powered DC LED lighting concept has potential of being implemented in the commercial buildings if further research is done .

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## APPENDIX

Bill of material for Gorondondo Primary School teachers accommodation off grid lighting system implementation

| **Tubing** | | | | |
|---|---|---|---|---|
| **Item** | **Description** | **Quantity** | **Price USD** | **Total USD** |
| 1 | 19mm PVC Conduits | 10 | 2 | 20 |
| 2 | 25mm PVC Conduits | 0 | 0 | 0 |
| 3 | 25 x 40 PVC trunking | 1 | 5 | 5 |
| 4 | PVC Round boxes | 30 | 0.15 | 4.5 |
| 5 | 3x3 Surface PVC box | 5 | 0.5 | 2.5 |
| 6 | PVC Round box cover | 10 | 0.05 | 0.5 |
| 7 | 19mm couplings | 50 | 0.05 | 2.5 |
| 8 | 19mm nipples | 50 | 0.04 | 2 |
| 9 | Solvent Cement | 1 | 3 | 3 |
| 10 | Saddles | 20 | 0.1 | 2 |
| 11 | Screws, fisher plugs | 1 | 3 | 3 |
| **Subtotal 1** | | | | **45** |
| | | | | |
| **Wiring and Termination** | | | | |
| **Item** | **Description** | **Quantity** | | |
| 1 | 0.25sqmm twin flat cable 50m roll | 1 | 15 | 15 |
| 2 | 0.75sqmm twin flat cable 50m roll | 2 | 25 | 50 |
| | 2.5sqmm twin flat cable | 20 | 0.25 | 5 |
| 3 | 6.0sqmm solar cable | 15 | 1.5 | 22.5 |
| 4 | 6mm lugs | 2 | 0.25 | 0.5 |
| **Subtotal 2** | | | | **93** |
| | | | | |
| **Lighting** | | | | |
| **Item** | **Description** | **Quantity** | | |
| 1 | 6W DC Lights (12V) | 6 | 2 | 12 |
| 2 | Lambholders | 6 | 0.5 | 3 |
| 3 | 1 Gang Switch | 0 | 2.5 | 0 |
| 4 | 2 Gang Switch | 0 | 3.5 | 0 |
| 5 | 3 Gang Switch | 2 | 4 | 8 |
| 6 | Basic Lighting control module | 2 | 15 | 30 |
| **Subtotal 3** | | | | **53** |
| **Solar Equipment** | | | | |
| **Item** | **Description** | **Quantity** | | |
| 1 | 100W Solar panel | 1 | 56 | 56 |
| 2 | 50Ah 12V Battery | 1 | 59 | 59 |
| 3 | 10A PWM Charge controller | 1 | 20 | 20 |
| 4 | 4 Way DB | 1 | 8 | 8 |
| 5 | MCBs | 3 | 3 | 9 |
| 6 | 5 port cellphone charger | 1 | 20 | 20 |
| **Subtotal 4** | | | | **172** |
| 1 | Tubing Subtotal 1 | | | 45 |
| 2 | Wiring and Terminations Subtotal 2 | | | 93 |
| 3 | Lighting Subtotal 3 | | | 53 |
| 4 | Solar Equipment Subtotal 4 | | | 172 |
| 5 | **Material Total** | | | **363** |
| | Labour | | | 185 |
| | **Total** | | | **548** |

Bill of material for the Zambia off grid lighting system implementation

| Tubing | | | | |
|---|---|---|---|---|
| **Item** | **Description** | **Quantity** | **Price USD** | **Total USD** |
| | | | | |
| 1 | 19mm PVC Conduits | 5 | 2 | 10 |
| 2 | 25mm PVC Conduits | 0 | 0 | 0 |
| 3 | 25 x 40 PVC trunking | 1 | 5 | 5 |
| 4 | PVC Round boxes | 10 | 0.15 | 1.5 |
| 5 | 3x3 Surface PVC box | 3 | 0.5 | 1.5 |
| 6 | PVC Round box cover | 10 | 0.05 | 0.5 |
| 7 | 19mm couplings | 30 | 0.05 | 1.5 |
| 8 | 19mm nipples | 25 | 0.04 | 1 |
| 9 | Solvent Cement | 1 | 3 | 3 |
| 10 | Saddles | 20 | 0.1 | 2 |
| 11 | Screws, fisher plugs | 1 | 3 | 3 |
| **Subtotal 1** | | | | **29** |
| | | | | |
| **Wiring and Termination** | | | | |
| **Item** | **Description** | **Quantity** | | |
| 1 | 0.25sqmm twin flat cable 50m roll | 1 | 15 | 15 |
| 2 | 0.75sqmm twin flat cable 50m roll | 1 | 25 | 25 |
| 3 | 6.0sqmm solar cable | 15 | 1.5 | 22.5 |
| 4 | 6mm lugs | 4 | 0.25 | 1 |
| **Subtotal 2** | | | | **63.5** |
| | | | | |
| **Lighting** | | | | |
| **Item** | **Description** | **Quantity** | | |
| 1 | 6W DC Lights (12V) | 6 | 2 | 12 |
| 2 | Lambholders | 6 | 0.5 | 3 |
| 3 | 1 Gang Switch | 1 | 2.5 | 2.5 |
| 4 | 2 Gang Switch | 0 | 3.5 | 0 |
| 5 | 3 Gang Switch | 1 | 4 | 4 |
| 6 | Basic Lighting control module | 1 | 15 | 15 |
| **Subtotal 3** | | | | **36.5** |
| | | | | |
| **Solar Equipment** | | | | |
| **Item** | **Description** | **Quantity** | | |
| 1 | 80W Solar panel | 1 | 65 | 65 |
| 2 | 24Ah 12V Battery | 1 | 70 | 70 |
| 3 | 10A PWM Charge controller | 1 | 25 | 25 |
| 4 | 4 Way DB | 1 | 6 | 6 |
| 5 | MCBs | 3 | 3 | 9 |
| 6 | 5 port cellphone charger | 1 | 20 | 20 |
| **Subtotal 4** | | | | **195** |
| | | | | |
| 1 | Tubing Subtotal 1 | | | 29 |
| 2 | Wiring and Terminations Subtotal 2 | | | 63.5 |
| 3 | Lighting Subtotal 3 | | | 36.5 |
| 4 | Solar Equipment Subtotal 4 | | | 195 |
| 5 | **Material Total** | | | **324** |
| | Labour | | | 150 |
| | **Total** | | | **474** |

Bill of material for the residential building in Zimbabwe off grid lighting system implementation

| Tubing | | | | |
|---|---|---|---|---|
| **Item** | **Description** | **Quantity** | **Price USD** | **Total USD** |
| 1 | 19mm PVC Conduits | 5 | 2 | 10 |
| 2 | 25mm PVC Conduits | 0 | 0 | 0 |
| 3 | 25 x 40 PVC trunking | 1 | 5 | 5 |
| 4 | PVC Round boxes | 10 | 0.15 | 1.5 |
| 5 | 3x3 Surface PVC box | 3 | 0.5 | 1.5 |
| 6 | PVC Round box cover | 4 | 0.05 | 0.2 |
| 7 | 19mm couplings | 20 | 0.05 | 1 |
| 8 | 19mm nipples | 20 | 0.04 | 0.8 |
| 9 | Solvent Cement | 1 | 3 | 3 |
| 10 | Saddles | 10 | 0.1 | 1 |
| 11 | Screws, fisher plugs | 1 | 3 | 3 |
| **Subtotal 1** | | | | **27** |
| | | | | |
| **Wiring and Termination** | | | | |
| **Item** | **Description** | **Quantity** | | |
| 1 | 0.25sqmm twin flat cable 50m roll | 1 | 15 | 15 |
| 2 | 0.75sqmm twin flat cable 50m roll | 1 | 25 | 25 |
| 3 | 6.0sqmm solar cable | 10 | 1.5 | 15 |
| 4 | 6mm lugs | 4 | 0.25 | 1 |
| **Subtotal 2** | | | | **56** |
| | | | | |
| **Lighting** | | | | |
| **Item** | **Description** | **Quantity** | | |
| 1 | 6W DC Lights (12V) | 4 | 2 | 8 |
| 2 | Lambholders | 4 | 0.5 | 2 |
| 3 | 1 Gang Switch | 2 | 2.5 | 5 |
| 4 | 2 Gang Switch | 2 | 3.5 | 7 |
| 5 | 3 Gang Switch | 0 | 4 | 0 |
| 6 | Basic Lighting control module | 1 | 15 | 15 |
| **Subtotal 3** | | | | **37** |
| | | | | |
| **Solar Equipment** | | | | |
| **Item** | **Description** | **Quantity** | | |
| 1 | 50W Solar panel | 1 | 25 | 25 |
| 2 | 20Ah 12V Battery | 1 | 20 | 20 |
| 3 | 10A PWM Charge controller | 1 | 25 | 25 |
| 4 | 4 Way DB | 1 | 6 | 6 |
| 5 | MCBs | 2 | 3 | 6 |
| 6 | 5 port cellphone charger | 1 | 20 | 20 |
| **Subtotal 4** | | | | **102** |
| | | | | |
| 1 | Tubing Subtotal 1 | | | 27 |
| 2 | Wiring and Terminations Subtotal 2 | | | 56 |
| 3 | Lighting Subtotal 3 | | | 37 |
| 4 | Solar Equipment Subtotal 4 | | | 102 |
| | **Material Total** | | | **222** |
| | Labour | | | 120 |
| | **Total** | | | **342** |

**Filled Questionnaires**

# KENDALE TRAVEL BURSARY 2022

| | | |
|---|---|---|
| Student performance data | | |
| Teacher productivity | | |
| Rural schools vs Urban schools disparity | | |
| Student populations | | |
| | | |
| **BUILDING STRUCTURES** | | |
| Dimensions of class | | |
| Common brick types used | ✓ | Ant hill bricks |
| Roof types | ✓ | Zinc metal shits |
| Typical houses | ✓ | Two rooms with [illegible] |
| Number of rooms | ✓ | Two to three rooms |
| | | |
| **Students and Teachers** | | |
| Current light sources | ✓ | Cellphones, Mobile lantons |
| Reliability of light sources | ✓ | Quickly damaged |
| Operational cost of lighting | | |
| Walking distances | | |
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# KENDALE TRAVEL BURSARY 2022

## RESEARCH CHECKLIST

| DESCRIPTION | CHECKED | COMMENT |
|---|---|---|
| **ELECTRICITY SUPPLY** | | |
| Electricity grid network | ✓ | 330KV in the area for Mines |
| Power stations and their distribution network | ✓ | Coal Power station in the area |
| Levels of electrification | ✓ | Urban town only |
| Maintenance of the network | | |
| Cost of connecting to the grid | | |
| Load shedding schedules if any | ✓ | Sometimes for 4 hours |
| | | |
| **AFFORDABILITY and EMPLOYMENT** | | |
| Employment rates in civil service (teachers) | | |
| Employment rates in private sector | | |
| Levels of urbanisation | ✓ | Peri Urban areas around |
| Sources of income | ✓ | Farming maize & vegetables |
| Schools electrification funding | | |
| | | |
| **SKILLS AND EQUIPMENT** | | |
| Availability of skills - electricians | ✓ | Mr Mulenga |
| Availability of skills – welder | ✓ | No longer Require |
| Tools availability | ✓ | Can be organised |
| Electrician payment rates | ✓ | K2500 charged |
| | | |
| **EQUIPMENT SUPPLY AND PRICES** | | |
| Solar panels | ✓ | P. Need to look for other quotes |
| Cables and conduits | ✓ | Cables I need to look for cheaper option |
| Battery and charge controller | ✓ | Other quotes |
| Breakers, DBs and other accessories | ✓ | Bring from Zim |
| Solar Installers charges | ✓ | Managed to get a contact Mulent |
| | | |
| **CHILILABOMBWE SCHOOLS** | | |
| No of schools and distribution | | |
| Electrification status | | |
| Terrain and road networks | ✓ | Poor road in Miteto |
| Teacher accommodation in rural schools | | |

Boniface Siarne / Miteta Karenga

# KENDALE TRAVEL BURSARY 2022

## RESIDENTIAL HOUSE QUESTIONNAIRE

1. **Areas that are electrified in the area?**

Not electrified

2. **Which task do you usually do at night and number of students in the household?**

3. **What do you use a light source and challenges faced?**

Solar lantern

4. **Do you think having a different lighting source will affect your productivity?**

safety

5. **What other activities do you think you will be able to carry out if you had a different light source?**

studying

6. **What are your streams of income?**

Farming Soya, Maize, Sunflower, Beans

7. **Have you used solar before and how was your experience?**

→ Some one in the area
→ For lighting.

8. **Do you afford this DC LED lighting system?** *(State price range)*

Affordable

9. **If you had a new lighting system which other task will you be able to do ?**

→ Charging phones
→ students study

10. **How can I get in touch with you when I have left?**

→ Record keeping
→ Whatsapp. / Good network

5 2 rooms 7m x 3m
5 conduits
2 x
Community studying center

Reo Chipandano U
Luwingu => Northen Province

# KENDALE TRAVEL BURSARY 2022

## RESIDENTIAL HOUSE QUESTIONNAIRE

1. **Areas that are electrified in the area?**

   Electrified near Boma township

2. **Which task do you usually do at night and number of students in the household?**

   Load shedding adding / Churches

3. **What do you use a light source and challenges faced?**

   Candles / Kerosene

4. **Do you think having a different lighting source will affect your productivity?**

   We agree /

5. **What other activities do you think you will be able to carry out if you had a different light source?**

6. **What are your streams of income?**

   civil servants K3000-K6000

7. **Have you used solar before and how was your experience?**

8. **Do you afford this DC LED lighting system?** *(State price range)*

   ~~K90~~ Its not afferdable

9. **If you had a new lighting system which other task will you be able to do ?**

10. **How can I get in touch with you when I have left?**

    +260 971 63 0098

Lubansa → Fr Dominic

# KENDALE TRAVEL BURSARY 2022

## RESIDENTIAL HOUSE QUESTIONNAIRE

1. **Areas that are electrified in the area?**

clinic & Hospital

2. **Which task do you usually do at night and number of students in the household?**

3 students @ Lubansa electrified

3. **What do you use a light source and challenges faced?**

LED Lanterns rechargable, buying batteries, 6 months K150,

4. **Do you think having a different lighting source will affect your productivity?**

Improved / A more modern perspective

5. **What other activities do you think you will be able to carry out if you had a different light source?**

→ Security improved / Studying
→ Quality of lighting impacts on the health.

6. **What are your streams of income?**

→ Farming vegetables, maize, cassava, sweet potatoes
→ K500 ⇒ Monthly K2000.

7. **Have you used solar before and how was your experience?**

TV setup small inverter

8. **Do you afford this DC LED lighting system?** *(State price range)*

5 rooms
Affordable for most

9. **If you had a new lighting system which other task will you be able to do ?**

A

10. **How can I get in touch with you when I have left?**

+260 969 48 73 86
Network challenge.

# KENDALE TRAVEL BURSARY 2022

Mapinga

## RESIDENTIAL HOUSE QUESTIONNAIRE

1. Areas that are electrified in the area?

2. Which task do you usually do at night and number of students in the household?

8pm sleep time
Homework 3 students One secondary Two primary

3. What do you use a light source and challenges faced?

Torch with replaceable battries
Candles before the torch

4. Do you think having a different lighting source will affect your productivity?

No change in time work

5. What other activities do you think you will be able to carry out if you had a different light source?

6. What are your streams of income?

Supported by husband
Farming not productive.

7. Have you used solar before and how was your experience?

- No
- Children might break the lights

8. Do you afford this DC LED lighting system? *(State price range)*

Income not sufficient

9. If you had a new lighting system which other task will you be able to do ?

10. How can I get in touch with you when I have left?

~~No~~ Do not use mobile device ~~due~~ to religious reasons

Mrs Mwansa (DEBS secretary)
Chingola / Choma => 3 rooms

# KENDALE TRAVEL BURSARY 2022

## TEACHER QUESTIONNAIRE

1. Do you work on school tasks at night?

Cooking
Studying /

2. How many hours do you usually work at night?

→ 1 hour
→ Good listener.

3. What do you use a light source and challenges faced?

Solar system / Unreliable / no sun.
Torches / ~~Nayo~~ Safe & improved life span. / MTN Phoenix

4. Do you think having a different lighting source will affect your productivity?

Improved productivity / K210 × 1 year 8 mont
K750 ~~K1~~

5. What other activities do you think you will be able to carry out if you had another lighting source?

Study more
Good meals

6. How many kilometers do you travel to school ?

No teachers houses
15km ? /

7. If your school had lights, would you want to go back to finish your tasks or assist your students?

- Schemes of work & planning.
- Adult learning

8. Do you think having lights at the school will improve student performance?

Better results

9. Will the students be willing to travel back to school to study?

Yes

Cost Aspect

K 6 240 => Affordable
→ Payment Plans

# KENDALE TRAVEL BURSARY 2022

Mundoga
0777 517 264

## RESIDENTIAL HOUSE QUESTIONNAIRE

1. Areas that are electrified in the area?

2. Which task do you usually do at night and number of students in the household?

   6 - 8pm
   Grinding Mill. One primary school

3. What do you use a light source and challenges faced?

   Solar Lantern
   Not lighting up for long.

4. Do you think having a different lighting source will affect your productivity?

   No
   unless home work is available

5. What other activities do you think you will be able to carry out if you had a different light source?

   N/A

6. What are your streams of income?

   Buying and selling
   Grinding Mill

7. Have you used solar before and how was your experience?

   Yes
   Only providing lighting.

8. Do you afford this DC LED lighting system? *(State price range)*

   I can afford

9. If you had a new lighting system which other task will you be able to do ?

   N/A.

10. How can I get in touch with you when I have left?

    Phone call s

# KENDALE TRAVEL BURSARY 2022

Mrs Mutsvedu.

## RESIDENTIAL HOUSE QUESTIONNAIRE

1. **Areas that are electrified in the area?**

At a school Guni Secondary School 8km away

2. **Which task do you usually do at night and number of students in the household?**

3 student ~~two~~ in primary & one secondary
Studying & general lighting

3. **What do you use a light source and challenges faced?**

Lanterns & battery powered lights
Quick failure

4. **Do you think having a different lighting source will affect your productivity?**

More permanent solution
Increase productivity & entertainment

5. **What other activities do you think you will be able to carry out if you had a different light source?**

Studying

6. **What are your streams of income?**

Farming Maize and Cotton
Generating about $600 from maize alone

7. **Have you used solar before and how was your experience?**

Yes
No need to change batteries

8. **Do you afford this DC LED lighting system?** *(State price range)*

Yes
Payment terms would be required

9. **If you had a new lighting system which other task will you be able to do ?**

More time to study

10. **How can I get in touch with you when I have left?**

On whatsapp