Experimental Analysis of Liter of Night Light

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I, The Undersigned, declare that this thesis is my original work under Center of Energy Technology, AAiT, and has not been presented by any other person for an award of degree in this or any other university and all the resources of material used for the thesis have been duly acknowledged.

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ABSTRACT

Liter of night light is a solar powered light, that is constructed from waste plastic bottles which lights up the rural community. This paper is about experimental analysis of liter of night light. The technology uses environmental friendly and locally available materials to glow light at night to the rural communities. The system is provided with battery storage, which allows it to operate for 13.5 hours continuously at full charge. Solar radiation is converted by PV solar panel to electric current.

Circuit board is developed and fabricated to regulate and deliver consumable amount of voltage by the rechargeable lead acid battery. After testing five different solutions, the study found out that vinegar solution as the optimal solutions for the technology that can deliver 27lux of light to the surrounding. Simultaneously the study found out, that the light that is emitted from the bottle bulb is a function of volume, depth and solution type. And for this relationship curves and equations are developed. And, the technology can be used for rural communities as it is.

Key Words: Liter of Light, Experimental analysis, Night light, Curve Fitting, LED Light.

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LIST OF ACRONYMS

UN	United Nations
LED	Light Emitting Diode
PV	Photovoltaic
PVC	Polyvinyl Chloride
DC	Direct Current
UNESCO	United Nations Scientific and Cultural organization
NARM	National associations of roof light manufacturers
DIY	Do it yourself
GENI	Global Energy Network Institute
PCB	Printed Copper Board.

1.INTRODUCTION

1.1 Background of the Study

According to (IEA, 2017) efforts to promote electricity access are having a positive impact in all regions, and the pace of progress has accelerated. IEA's analysis shows that the number of people without access to electricity fell to 1.1 billion people for the first time in 2016, with nearly 1.2 billion people having gained access since 2000. The same report tells that there are still more people without electricity today than there were in 2000. From this it is understandable that electrification growth is much slower than the population growth. The report also mentioned that 14 % of the world population still lacks access to electricity, 84% of which live in rural areas.

According to (Infrastructure, n.d.) combustible renewable resources (biomass, animal wastes, municipal and industrial wastes) largely dominate energy consumption in Africa. The same book mentioned energy from biomass accounts for more than 30 percent of the energy consumed and more than 80 per cent in many sub-Saharan countries.

(Avila, Carvallo, Shaw, & Kammen, 2017b) Said that Sub-Saharan Africa, home to more than 950 million people, is the most electricity-poor region in the world. More than 600 million people lack access to electricity, and millions more are connected to an unreliable grid that does not meet their daily energy service needs.("Off-Grid Solar Lighting Up Ethiopia," 2016) reported that for the millions of people living in remote rural areas of Ethiopia who lack access to the power grid or cannot afford electricity, solar energy represents an important first step on the energy access ladder. Instead of relying on kerosene, candles, dry cell batteries and other fossil fuel-based sources of power.

(Inhabitat, n.d.) said that, liter of night light is as simple as a plastic bottle filled with water and integrated with small LED light powered by small PV panel could mean the difference between light and darkness. the almost no cost solution is uplifting the quality of life of thousands of impoverished families in the Philippines who have no access to electricity and use dangerous kerosene lamps indoors.

These makeshift solar lamps basically act as skylights, and reflect and amplify the rays of the sun during daylight hours effectively performing the work of indoor light bulbs but without using any electricity at all (Inhabitat, n.d.). (Zayed Future Energy Prize, 2015) said that Liter of Light is unique as it uses waste bottles, PVC pipes, and local components to manufacture solar solutions for mobile chargers, lamps, and streetlights for communities. Small solar is affordable and easy to fix.

The main purpose of this project will be in performing experimental analysis for the liter of light technology to get best system composure, and this is to enhance sustainable and replicable electrification in Ethiopia. Since reliable and affordable sources of energy are fundamental for wellbeing, economic growth and poverty reduction. Therefore, it is vital to solve the rural electrification problem in economic and efficient manner.

Though there are many findings in the litter of light technology, there are still many gaps to be filled accordingly. My shelter foundation uses plastic Bottles for the technology; from light physics and light refraction one can understand that as light travels in different medium it refracts in different angles therefore the medium in which the light travels is vital for this kind of applications and the materials which comprises the system should undergo through experimental analysis to get the optimal material which can deliver the maximum possible light, also in any of the studies the container of the water materials characterization and its effect in light refraction is not studied yet. In any of the innovations related to the litter of light technology no one is able to develop mathematical model for such systems; hence mathematical models will help to upgrade the system in simulations.

In order to be applicable in all areas the technology must be able to coup with any environmental conditions. Still there is no scientific and engineering approach for such systems, and it is a must to study the system in engineering way. From all those gaps, it is recommendable to go through experimental analysis, optimization, mathematical modeling of the system.

1.2 Problem Statement

(Mills, 2016) said that Fuel-based lighting is a significant cause of severe burn injuries, with particularly high death rates (24% of those admitted to hospitals, on average) and also reported that unintentional ingestion of kerosene is the leading cause of child poisoning in the developing world. It is typically the number-one cause of child poisoning in developing countries, with an average mortality rate of 7%. From this it evident that solely depending on kerosene and biomass will affect the socio-economic life of the community.

(Cabraal, Barnes, & Agarwal, 2005) said that hundreds of millions of people live in informal settlements worldwide. Many of these dwellings lack windows or adequate lighting and residents often resort to kerosene, candles or inventive wiring for light, risking health and safety in the process and many simply go without proper electricity is not usually an option. According to (Mohamed, 2017) more than 41 million live below the poverty line in Ethiopia due this they cannot afford for clean. (Sanbata, Asfaw, & Kumie, 2014) said that an estimated 95% of the population of Ethiopia uses traditional biomass fuels to meet house hold energy needs. Sanbata also said that due to the harmful smoke emitted from the combustion of biomass fuels, indoor air pollution is responsible for more than 50,000 deaths annually and causes nearly 5% of the burden of disease in Ethiopia

The growing problem with access and affordability of indoor lighting in developing countries has led to the renewed interest in studies of solar lights. The access to electricity for indoor lighting in developing countries is very important for growth, both socially and economically(The et al., 2008). One can understand that above listed problems are the main issues to be addressed by litter of light night. It is known that litter of night light is environmentally friendly and it reduces all the mentioned problems. Many of the liters of light technology use simple plastic bottles, and LED lights with simple electric circuit. Although it is important technology, its efficiency is under question. Therefore, to address all the listed problems this technology should go through experimental analysis.

1.3 Objectives

1.3.1 Main Objectives

The Main objectives of this project is performing experimental analysis of liter of light night for better efficiency.

1.3.2 Specific Objectives

As specific objectives are the procedures one must follow to accomplish the main objective. It is proposed to accomplish the following specific tasks.

- To design electrical circuit for the system

- To select suitable materials for the system
- To assemble those materials as per the system design
- To proceed experimental test and to have recording
- To select the best solution system

1.4 Delimitation

The project mainly focuses on experimental analysis of liter of night light. It will not include other related works for example mobile charger integration with liter of night light. And also, it will not include integration of litter of night light with grid application.

1.5 Procedural Framework of the study

To achieve appropriate and optimized liter of night light through experimental analysis one must follow the following steps.

- Design and development of circuit board**.**

This stage is the main stage in the system design. In this stage, the electric flow and the control system of the technology will be designed. After the completion of the circuit design the circuit board will be prepared for the assembly. The circuit board is designed to deliver a constant of 1.5-watt DC power to the LED light.

- Assembly of the system

In this stage, all the components of the system will be assembled. The bottles will be filled with water, bleaches or chlorides will be added to the water to reject the development of algae, the circuit will be integrated with the solar panel, and the panel also integrated with the battery and finally is ready for the testing.

- Experimental analysis

This is done by taking different control units that are helpful to deal with experimental analysis. In this stage liquid solutions with different depth and volume will be tested.

- Selection of best system

After completion of the assembly by varying the bottle materials, LED light and the chemicals inside the water different experiments will be done and the system with highest illumination will be selected. Why different chemicals? Because instruction of chemicals will alter the water property. Therefore, varying the amount of bleaches and chlorides will affect the light refraction either in positive or negative way, so the right concentration must be known through going different experimentation.

- Comparison of results from the experimentation

In this stage, the results will be recorded as per the criteria's and will go through comparison. And based on the result of the comparison conclusions will be passed.

2. LITERATURE REVIEW

2.1 Energy Overview

According to (International Energy Agency, 2017) world energy production was 13,790 million tons of oil equivalence in 2015, 0.6% more than in 2014. The report also mentions that oil production increased the most for the second year in a row (+2.3%), followed by renewables (+1.9%), natural gas and nuclear (+1.4% for each). One of the positive results found is fossil fuels accounted for 81.7% of production, which is a (0.2%) decrease compared to 81.9% in 2014. From time to time energy production is increasing and this is due to the demand derived by population growth and development. (Fankhauser & Jotzo, 2017) said that energy is needed for economic growth, and access to cheap, reliable energy is an essential development objective. Fankhauser and Jotzo also mentioned that, historically most incremental energy demand has been met through fossil fuels, but in future that energy will have to be low-carbon and ultimately zero carbon.

(World Energy Council, 2016) said that unexpected high growth in the renewables market, in terms of investment, new capacity and high growth rates in developing countries have changed the landscape for the energy sector. The report states that the growth of renewables market contributed to falling prices and the increased decoupling of economic growth and GHG emissions. Due to this decoupling most countries have achieved a more diversified energy mix with a growth in community ownerships and an evolution of micro grids. According to (McCrone, Moslener, D'Estais, & Grünig, 2017) the pursuit of clean energy is at the heart of world's aspirations for a better future, as reflected in the 197 countries that have signed up to the Paris Agreement on Climate Change. As clean energy is moving from fossil fuels to renewable sources such as solar and wind is key to achieving social, economic and environmental development. Therefore, clean energy is a big concern for socioeconomic and environmental development. (Khan & Singh, 2017) Sub-Saharan nations are facing a lot of challenges for the planning of their future energy sector, especially the rural areas of Sub-Saharan nations are victims of scarcity of energy and this is due to lack of grid facilities, less financial and technical support, pressure from foreign institutions, excess of energy export. This all factors forces the rural community to relay on fossil fuels, but solely depending on fossil fuels will affect the life the rural community.

2.2 Impacts of fossil fuels lightings on the rural community

(Khan & Singh, 2017) Sub-Saharan nations are facing a lot of challenges for the planning of their future energy sector. Particularly, the rural areas of Sub-Saharan nations bear scarcity of energy access as there is a lack of grid facilities, less financial and technical support, pressure from foreign institutions, excess of energy export.(Avila, Carvallo, Shaw, & Kammen, 2017a) said that due to energy poor households suffer from a wide range of impacts, from increased risk of premature death due to indoor pollution to forgone productivity gains and lower quality of life. The same report outlines that on top of these impacts, energy-poor households must spend a greater proportion of their income to meet their basic energy needs. The rural community also sacrifices their time on engaging in energy intensive tasks than do wealthier households who have access to modern energy sources. Therefore, relying on fossil fuels have got socio economic and environmental impact.

According to (Exposomics, 2017) the open flame of kerosene lamps also poses as an obvious danger to households. Moreover, impoverished families spend up to half of their income on kerosene which not only provides inadequate illumination but also emits extremely harmful black carbon into the Earth's atmosphere. Kerosene lamps contribute to a vicious cycle of poverty that needs to be broken.

(Buragohain, 2012) said that rural electrification was not considered as a basic human need like water and food in the past. A number of recent studies provide insight into how rural electrification helps in the betterment of rural society in various ways. (IEG, 2009) studied that rural electrification results great benefits such as improvements of health facilities, better health from cleaner air as household reduce use of polluting fuels for cooking, lighting and heating, improved knowledge through increase access to television and better nutrition from improved knowledge and storage facilities from refrigerator.

(Fitch, 2009) by increasing access to affordable lighting, communications and refrigeration, improved public health, and energy for productive activities, renewable energy systems offer an unprecedented opportunity to accelerate the expansion of energy access in remote and rural areas while at the same time contributing to the transition to modern energy services. Renewable energy can expand access to modern energy services in developing countries, both rapidly and cost effectively. Therefore, renewable energy is the only solution that can fill the gap. Among all renewable energy sources solar energy is the one to be considered for the rural communities as it can be used in a very small-scale application.

2.3 Solar Energy as an option for Rural Electrification

(Bansod, 2015) said that that solar power is the conversion of sunlight into electricity. So, today, World is facing so many problems such as pollutions, water for drinking purpose, food problems, and electrical. yes, electricity problem is one of the major problem which is increasing rapidly day by day. According to (Bansod,2015) 90%of the world people are poor. So, the electricity is not lightening the houses of each person because of it is not affordable for every person and someone who can afford it, getting no electricity and this is the worst tragedy. (Mr.Bhawar Tushar, 2016) said that the energy extracted from solar radiation by solar cells is vital to expanding our source of energy. The study mentioned solar energy as is ultra clean, natural and sustainable source of energy that can be utilize in use of making solar electricity, solar heating appliances, solar lighting appliances and many more. (Mr. Bhawar Tushar,2016) said that in developing countries there isn't much source of electricity. Hence to use solar as largest source of energy one can build own solar based light bulb without any electricity cost. Many people do not have access to light or cannot cover the cost for electricity. Thus, they do not have light in their homes, even during the day.

According to (Mr.Bhawar Tushar, 2016) everybody knows the importance of Solar Energy in today life. It is ultra clean, natural and sustainable source of energy that can be utilize in use of making solar electricity, solar heating appliances, solar lighting appliances and many more. The benefit to the local community above all is access. The second is livelihood creation. Once a seeding program of a few hundred bulbs is put in a village, the effect is immediate, as neighbors get to see how the bulbs are made by the organization and volunteers and the improvement of internal living conditions in the household. It is evident that developing countries, there isn’t much source of electricity. Hence to use solar as largest source of energy one can build own solar based light bulb without any electricity cost, therefore employing and using liter of night light in developing countries reduce the worse of the problems listed above. It also gives an advantage to upraise the health status of the rural community as it is pollution free. Therefore, dealing with this kind of technology is vital even to increase the life quality of the rural population. There are three options in which the rural community can benefit from solar powered lights.

2.3.1 Liter of Day Light

According (Building and Social Housing Foundation, 2014) liter of light is a simple device consisting of a 1.5–2 liter plastic bottle filled with water plus a little bleach to inhibit algal growth and fitted into a hole in a roof to refract sunlight. The study mentioned also that the device functions like a deck prism. The water inside the bottle refracts sunlight during day time delivering the same power as (40-60) watt incandescent bulb to the inside of the house.

Figure 2.1: Liter of day light (Manila, 2011)

According to (Manila, 2011) there are several areas that the Solar Bottle Bulb makes sense in creating a low carbon emission through the program appliance. And also, the study mentioned that liter of light is a free energy, no carbon emissions, and immediately scalable by social enterprise and lastly is easily replicated by the local government using its more considerable resources. Further (“Technology Liter of Light in India , Workshop,” n.d.) strengths that liter of Light is also a solution to various environmental challenges since it adopts the concept of up recycling. It also mentions that the technology is a zero-carbon emission solar lighting project. Therefore, liter of day light is a good one in introducing solar light to houses with limited day light source. But, it is limited to day time application only.

2.3.2 Solar LED Light

(Jacobson & Bond, 2013) Replacing inefficient kerosene lighting with electric lighting or other clean alternatives can rapidly achieve development and energy access goals, save money and reduce climate warming. According to (International Year of Light, 2015) difficulty convincing these off-grid communities that sustainable, high-tech lighting alternatives is the reason many are still using kerosene lamps. There are countless organizations that devote their efforts towards providing clean lighting in the form of solar and LEDs, but it is not always an easily executed task. As the price of LED and photovoltaic technology decreases, however, implementing these technologies will become increasingly actionable. It is known that these technologies are versatile and can cover tremendous amount of the rural community as the technology is affordable, but in a country like Ethiopia its affordability is under question, as the cost of the technology is much higher, and limited amount of supply as well.

2.3.3 Liter of Night Light

According to (Mr.Bhawar Tushar, 2016) development of solar power based lighting system is very much essential in rural and hilly areas where electricity is not easily available. The study further outlines the need for rural resident to light and charge phones during the hours of the day when sunlight is available and the need to cut down the level of carbon emission is major concern. And the study proposed that to achieve this solar powered to a bulb light and mobile phone charger will be needed. Therefore, with the help of solar bottle bulb this problem can be solved. According to (Building and Social Housing Foundation, 2014) Liter of Light (Night) began by using the database of households with the daylight bottle bulbs in their roofs, the study mentioned that the technology upgrades 1-watt ($10/unit) or 2-watt ($15/unit) LED, with Pv solar and integrating with battery which would give another 10 hours of light at night. The study also mentions the system composure; as a simple circuit panel, drill and soldering, the night solar LED light is built and inserted into the already installed bulb.

2.4. Literature Gap

(Mr.Bhawar Tushar, 2016) tried to study and compare the performance of liter of light with regular electric bulb, they said that the performance of the average brightness of solar bottle bulbs is almost similar to the conventional 40-Watt bulb. They have used for experimentation a single type of solution which is a soda bottle solar light. Though, they have made the comparison they don't put results in figures. Their study was limited only on a single solution and their results were not numerically available, therefore this reduces the trust of their research.

(Wang, Rahim, Yusoff, Rahman, & How, 2015) studied on the critical view of solar bottle bulbs, and mentioned that, despite the positive aspects of solar bottle bulbs, peoples are not believing the ability of the technology to provide lighting, they said that this confusion is because of ; as there were no published experiments providing precise data regarding the performance and characteristics of light produced by these bottles, therefore there should be a study which can amend the people by justifying the performance of the technology.

(C Wang, VL HOW, 2013) studied the performance of solar bottle bulbs at different interior exposure levels. They said that different sizes and arrangements of solar bottle bulbs affect the lighting delivered and there is no general agreement on the best interior bottle exposure levels. From their study, they found that in terms of bottle exposure levels, the half level of the bottle performs best. But they were not capable of finding the parameters affecting that the best level to be at the middle of the bottle, they don't have studied that this property is for all solutions are for specific type of solutions.

Though, many have tried to study the technology, none of the studies have addressed the following issues, and this research will try to solve and address the issues mentioned below

I. There is no engineering way of the system design.
II. The mixture of water and bleach are only used as a working fluid of the system, the impact of other fluids is not studied

III. The positioning of LED light in the system is arbitrary. Its right position to give maximum possible amount of refraction from the system as function of the solution is not studied.

IV. Depth, volume, solution type effect on the light refraction is not studied.

Therefore, all the mentioned gaps of the technology and the socioeconomic, health impacts of other technologies should be addressed. The solution for all mentioned limitations and gaps is having experimental analysis on liter of night light for better efficiency, that is why this study is very important.

3. METHODOLOGY

3.1 Solar Panel Selection

The solar panel collects the solar radiation from the sun and hence it is PV (photovoltaic); it converts the solar flux to electrical energy. There are three different types of solar panels:

- Monocrystalline
- Polycrystalline
- Amorphous

For our purpose, we have to select the appropriate type of solar panel with best efficiency. To do so we must first set criteria's.

3.1 .1 Criteria's to Select Solar Panel Type

Hence, selecting the appropriate type of solar panel is very important. Therefore, the following criterions are selected to undergo the comparison.

I. Cost: cost of the solar panel is very crucial issue. Hence, we are planning a technology that is affordable to the rural community.
II. Efficiency: is the main criteria in which the performance of the solar panel is measured. For our system, better efficiency is good
III. Size: big sizes are not good for the system and the main purpose of the technology is to manufacture portable light.
IV. Weight**:** again, here as it is planned to manufacture portable technology it is important to consider the weight.

3.1.2 Multi Criteria Decision to Select the Solar Panel

In order to go through comparison, the criteria's must be weighted. The criterions are weighted using analytical hierarchical process (AHP) since the problem is decision making under certainty.

The first step in AHP is determining the relative weights to rank the decision alternatives. Since there are 4 criteria's, a 4 by 4 pairwise comparison matrix A should be developed. Matrix A indicates the relative importance of the different criteria. Form a pairwise comparison matrix $\boldsymbol{A}$, where the number in the i^{th} row and j^{th} column gives the relative importance of (criteria) O_i as compared with (Criteria) O_j.

Using a 1–9 scale, with

- ✓ $a_{ij} = 1$ if the two objectives are equal in importance
- ✓ $a_{ij} = 3$ if O_i is weakly more important than O_j
- ✓ $a_{ij} = 5$ if O_i is strongly more important than O_j
- ✓ $a_{ij} = 7$ if O_i is very strongly more important than O_j
- ✓ $a_{ij} = 9$ if O_i is absolutely more important than O_j

The following matrix A is developed

	Cost	Efficiency	Size	Weight
Cost	1	1	3	5
Efficiency	1	1	5	5
Size	1/3	1/5	1	2
Weight	1/5	1/5	½	1

$$A = \begin{bmatrix} 1.00 & 1.00 & 3.00 & 5.00 \\ 1.00 & 1.00 & 5.00 & 5.00 \\ 0.33 & 0.20 & 1.00 & 2.00 \\ 0.20 & 0.20 & 0.50 & 1.00 \end{bmatrix}$$

To normalize the weights, the sum of each column is divided by the corresponding sum of each column. Then the normalized matrix $\bar{A}$ is given by

$$\bar{A} = \begin{bmatrix} 0.395 & 0.417 & 0.316 & 0.385 \\ 0.395 & 0.417 & 0.526 & 0.385 \\ 0.130 & 0.083 & 0.105 & 0.154 \\ 0.200 & 0.083 & 0.053 & 0.077 \end{bmatrix}$$

Then, the weights of the criterions are found by taking the average values of each row as per AHP decision making process rules. And the weight matrix is given by;

$$W_T = [0.37, 0.43, 0.12, 0.08]^T$$

Using the weights given in the transpose matrix the comparison has been made in the following table and the appropriate solar panel type is being selected based on the weight calculated for the criterions.

Table 3.1: Multi criteria decision for the solar panel selection

Solar panel Types	Criteria's				Total Percentage
	Cost (37%)	Efficiency (43%)	Size (12%)	Weight (8%)	(100%)
Monocrystalline	25	43	12	8	88%
Polycrystalline	32	32.5	8	8	80.5%
Amorphous	37	17.2	6	3.2	63.4%

Therefore, monocrystalline solar panel is selected for the system.

3.1.3 Capacity of The Solar Panel

It is obvious now there are so many technologies in which LED lights are powered by solar power, as this project tries to find a way in which small solar panels to power small LED lights and then to refract the light using water to get large lux. Therefore, a monocrystalline solar panel with 3-Watt power and 8.97 volts is selected, as this sized solar panels are most common in the local market.

3.2 Solar Battery sizing

Depending on the solar panel solar battery manufacturers catalogue on Appendix A1: for 8.97V solar panel it is recommendable to use 6V rechargeable lead acid battery.

3.2.1 Solar Battery Charging Principle

Solar battery charger circuit operated on the principle that the charge controller circuit will produce the constant voltage. It is known that the voltage produced by the solar panel is not at a constant manner it fluctuates as sun light intensity fluctuates. The charging current must pass through voltage regulator in which current and voltage are regulated to the consumable amount by the battery. To avoid the backflow of voltage it is must to use diode, this diode gives protection for the solar panel.

3.3 Solar Battery Charging Circuit Design

Figure 3.1 shows that the charging current passes to LM317 voltage regulator through the 1N4001 Diode. The output voltage and current are regulated by adjusting the adjust pin of LM317 voltage regulator and then the battery is charged by the same current.

LM317 Voltage regulators are always connected to R_1 (240**Ω**) as shown in figure 3.1 below therefore other resistance Values (R_2 and R_3) are determined depending on the output voltage required by battery.

$$V_{out} = 1.25V\left(1 + \frac{R_2}{R_1}\right) \tag{3.1}$$

Where V_{out} is the battery voltage which is 6V?

$$6v = 1.25V\left(1 + \frac{R_2}{240\Omega}\right)$$

$$R_2 = 1140\Omega$$

But in local market, a resistance with resistivity of 1140**Ω** is not available, therefore it should be approximated either in to 1.1k**Ω** or to 1.2k**Ω** because this are the available sizes of resistors in local market. But reducing and approximating resistance to 1.1k**Ω** damages the battery, therefore it is approximated to 1.2K**Ω**., this can be done by adding additional resistor R_3 as shown in figure 3.1.

After approximating $R_2 = 1.2K\Omega$, using this let and calculating

$$R_1{}' = R_2 + R_3 \tag{3.2}$$

$$V_{out} = 1.25V\left(1 + \frac{R_2}{R_1{}'}\right)$$

$$6v = 1.25V\left(1 + \frac{1.2k}{R_1{}'}\right)$$

$$R_1{}' = 252.6\Omega \approx 253\Omega$$

$$R_1{}' = 252.6\Omega$$

Applying equation 3.2 above $R_3 = 13\Omega$ and, $R_2 = 240\Omega$ which is always a standard resistance value given with LM317 voltage regulators.

Here again, 13Ω resistors are not common in local market; therefore, it is approximated to be 15Ω, then the circuit looks like as follows.

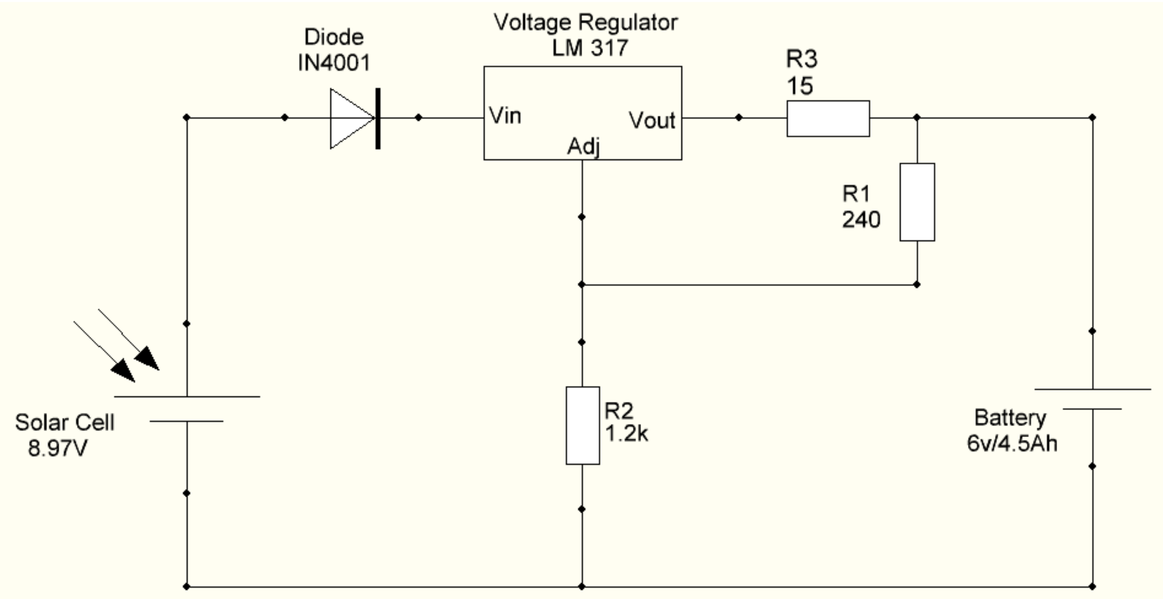


Figure 3.1: Charging Circuit

Operation Principle of Charging Circuit

According to principle of photovoltaic effect, the solar panel receive solar radiation during day time and convert it to electrical energy, as solar power varies with hours of the day, the voltage generated by the PV panel is not always constant. The battery should be supplied with constant voltage for charging, to do this LM317 voltage regulator is used and this regulator regulates the voltage generated by the PV panel to consumable amount by the battery. To protect the PV panel IN4001 diode is used, which allows current to flow in forward direction only.

Charging Circuit Components

- Solar Panel-9V
- Voltage Regulator- LM317
- Dc Battery-6V,4.5AH
- Diode-1N4001

- Resistors-15, 1.2k, and 240
- Connecting wire

3.3.1 Why Diode 1n4001?

It is known that the most common function of a diode is to allow an electric current to pass in one direction (called the diode forward direction) thus the diode can be viewed as an electric version of a check valve. In the circuit above the diode is connected with the positive side of the power supply and it operates as a reverse protection diode. It ensures that current can flow in the positive direction and the power supply only applies a positive voltage to the current.

According to Appendix A2 1N4001 diode can safely pass 1A average current continuously and can protect against up to 50V reverse voltage and have about 0.7 voltage drop for typical usage.

3.3.2 Why Lm317 Voltage Regulator?

The LM 317 device is an adjustable three terminal positive voltage regulators capable of supplying more than 1.5A over an output voltage range of 1.25V to 37V this is as per recommended operating condition by Appendix A3. it requires only two external resistors to set the output voltage.

Here LM317 can produce a voltage from 1.25V-37V maximum and maximum current of 1.5 ampere. This voltage regulator has typical voltage drop of 2V-2.25V. so solar panel is selected such that it should have much voltage than the load. That is why it is decided to be 9volts/3W solar panel for 6-volt battery.

Rechargeable battery which is used here has specification 6V/4.5Ah. In order to charge this battery, the following are required: -

- ✓ 1N4001 used to protect the LM317and panel from reverse voltage generated by the battery when it is not charging
- ✓ LM317 to regulate the voltage and current passing to the battery at a fixed charging value

For charging 6v battery

The output voltage from the solar panel should be limited to 8.97 volts. This voltage is the maximum voltage generated by the solar panel.

Charging Current

The charging current which is the right current to charge the battery is calculated as follows: -

$$Charging\ Current = \frac{Solar\ panel\ Wattage}{Solar\ Panel\ Voltage} \tag{3.3}$$

$$Charging\ Current = \frac{3W}{8.97V}$$

$$Charging\ Current = 0.35A$$

Here LM317 voltage regulator can provide current up to 1.5A. Therefore, it is recommendable to this voltage regulator for the circuit developed above as the charging Current is below 1.5A. It is important to note that to use high wattage panel if more current is required for the circuit. But here the battery we have selected requires maximum of 1.35A, but from the calculation above we found our initial current to be 0.35 which is much less than the maximum and it remains safe. If the battery requires initial current more than 1.5A, it is not recommendable to use LM317. But in this case the calculated initial current and the one mentioned on the battery as maximum initial current are below 1.5A. Therefore, it is correct to use LM317 Voltage regulator.

The circuit must have adjustable voltage regulator as the voltage from the solar panel varies with hours of the day. So that variable voltage regulator LM317 is selected.

3.3.3 Time Taken for Charging

$$charging\ time = \frac{Battery\ amper\ hour}{Charging\ Current} \tag{3.4}$$

$$charging\ time = \frac{4.5Ah}{0.35A} = 12.85\ hours$$

The effective hours per day is 9 hours. Therefore, for the battery to be fully charged it takes 1.4 day.

3.3.4 Power Dissipation

Here the solar panel has 3 watts, and we have calculated the charging current above in equation (3.3). Therefore, the power going in to the battery will be: -

$$power\ going\ in\ to\ the\ battery = output\ voltage\ \times charging\ current \tag{3.5}$$

$$power\ going\ in\ to\ the\ battery = 8.97V\ \times 0.35A$$

$$power\ going\ in\ to\ the\ battery = 3.12Watt$$

In this project power is limited because of the thermal resistance of LM317 voltage regulator and the heat sink. To keep the temperature of the circuit, the power should be limited. LM317 voltage regulator internally has temperature limiting circuit so that if it gets too hot, it shut down automatically.

When Battery is charging, heat sink becomes warm. When completing the charging at maximum voltage heat sink runs hot. This heat is because of excess power that is not needed in to the process of charging battery.

3.3.5 Back Up Time of the Battery

$$Back\ up\ time = watt\ hour\ of\ battry/Load \tag{3.6}$$

The total power of the LED light is about 1.5watt, which is our load

Therefore,$back\ up\ time\ = 4.5Ah * \frac{6V}{1.3watt} = 13.5\ hours$

Assuming an average consumption of night light in the rural community to be 4 hours per day therefore, the system will run for 3.4 days.

3.3.5 Circuit Protectors

The following components of the charging circuit are serving as protection for all the circuit:

- Solar panel: - as the solar panel provides constant current, it acts as a current limiter
- diode: -protects the circuit from reverse polarity
- Voltage regulator: - provides voltage regulation at the right amount needed by the battery

3.3.6 Solar Battery Charger Circuit Advantages

It is known that now some days most solar systems are sold with power conditioning unit and charge controller. But in this project those components are rejected and the system is employed with a simple and reliable charging circuit which can be made easily. And it has the following advantages over the power conditioning and charge controller units on the market.

- Adjustable output voltage
- Circuit is simple and inexpensive
- Circuit uses commonly available components
- Zero battery discharge when no sunlight on the solar panel

3.4 Design of lighting circuit

In section 3.3 the charging circuit for the system has been designed. Here below a add a single resistor is add to the charging circuit and a load to our system. Hence the battery selected is with capacity of 6V/4.5Ah. Therefore, the capacity of the load is calculated as follow: -

Initial Values: -

Voltage = 6V

Power of the load (LED light) = 1.5-Watt desired output from the system

Therefore, now let us determine the current in the final loop

$$p = IV \quad (3.7)$$

$$\mathrm{I} = \frac{p}{V} = \frac{1.5\ watt}{6V} \quad (3.8)$$

$$I = 0.25A$$

The calculating for the resistance of the resistor

$$V = IR \quad (3.9)$$

$$R = \frac{V}{I} = \frac{6V}{0.25A} \quad (3.10)$$

$$R = 24\Omega$$

24Ω resistors are difficult to find in the market therefore, instead 25Ω or 30Ω resistor is to be used.

For our case 25-ohm resistor will be putted before the load in order to let give the right amount of current for the system. in which our load functions in the desired power range.

After having those values. The resistance and the current for the load circuit after the battery. The circuit is developed as shown below. These circuit is the final which is going to be put on the PCB to develop the complete system.

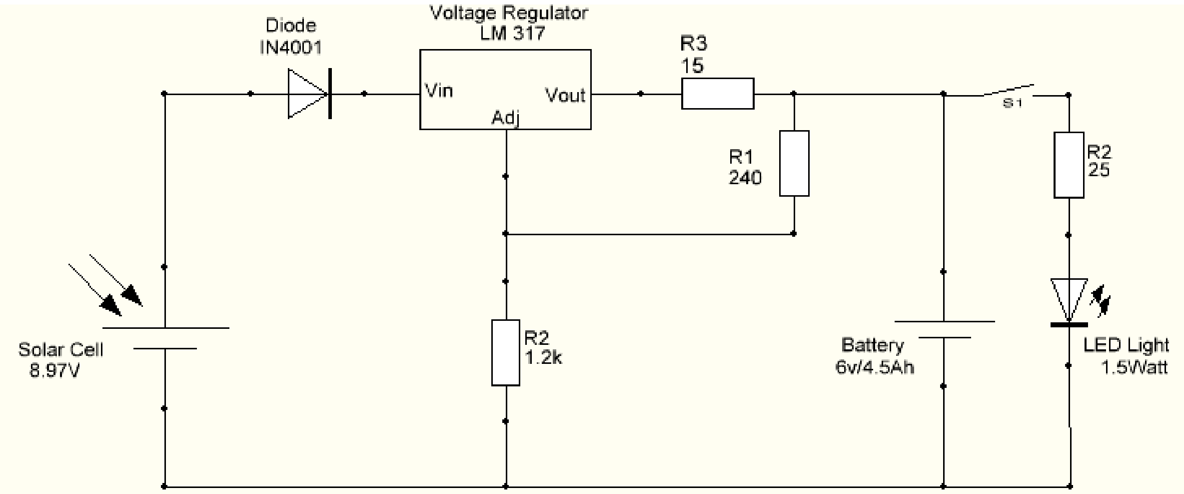


Figure 3.2: Lighting circuit

3.5 PCB Design

The PCB drawing of section 3.4 is made using PCB Artist software. And it is the physical model of the circuit. printed circuit boards are physical components of electronic devices. They are made up of a board, which is typically resin or plastic, and solder, the conductive metal parts that channel energy, usually made of copper. the solder makes the electrical connections between the PCB and the parts of the device possible.

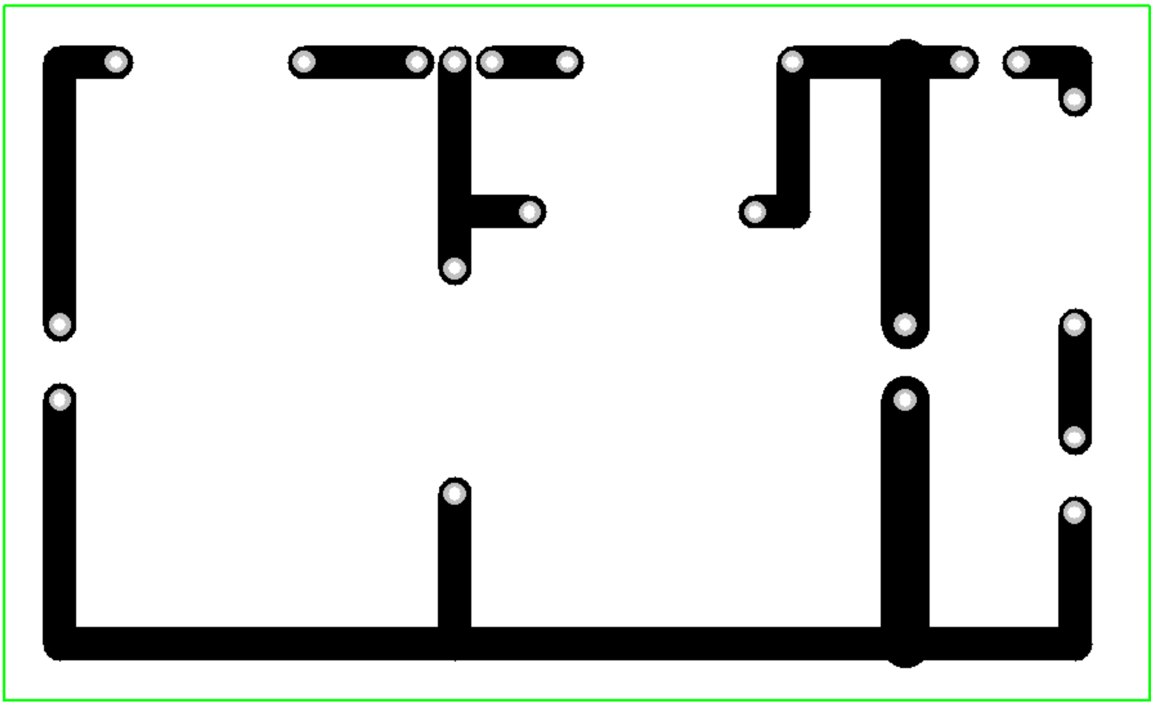


Figure 3.3: PCB design for the circuit of the system

3.6 Circuit Board construction

Once the PCB is designed using the PCB artist software the next step will be constructing the PCB following the steps below: -

Step 1: Printing out of Circuit Board Layout:

Using laser printer and A4 paper the hardcopy of the PCB design is printed. Hence, it was difficult to get the photo Paper/glossy paper A4 paper was used for the printout. Before printing the output was selected in black from the PCB design software and the printer driver setting.

Step 2: Making Transparent the Printed-Out Copy:

For printing it normal white A4 paper was used, and it has to be made transparent. Therefore, using paraffin and painting it gently the print out was made transparent. Its transparency is required because as exposing machine is used to print the circuit on the photo sensitive board.

Figure 3.4: making transparent Printed PCB

Step 3: Cut the Copper Plate for The Circuit Board:

In this step, the photos sensitive board is cut as per the size of the layout using anticutter.

Step 4: Transfer the PCB Print onto The Copper Plate

In this step, the printed Image (taken from a laser printer) is transferred from A4 paper to the board. First put the printed layout on the surface of exposing machine then put the copper surface of the photo sensitive board on the printed layout. Ensure that the board is aligned correctly along the borders of the printed layout. Then run the machine for 7 minutes, the exposing machine will transfer the layout to the photosensitive board within 7 minutes. After a provided time, setup, the following layout was printed on the photosensitive material and it is shown in fig below

Figure 3.5: Transferring PCB layout in to photo sensitive material

Step 5: Treating with Developer Solution

In this step, the board which has shown in Fig above, will be treated by the developer solution in order to washout the hard part of the photo sensor board exposing copper. In this project Sodium Hydroxide is used as a developer solution. After finishing this process, the plate should be washed by pure water for the sake of safety.

Step 6: Etching the Plate

In this step, the excess copper on the board will be removed using ferric chloride. When performing this step, it is must to wear rubber or plastic gloves, when dipping the plate to the ferric chloride ($FeCl_3$) solution the $FeCl_3$ reacts with the unmasked copper and removes the unwanted copper from the PCB. Finally, the plate looks like fig. 3.6 below:

Figure 3.6 Etching the plate

STEP 7: Drilling

Now, drill holes using a PCB driller as shown in fig. 3.7 below

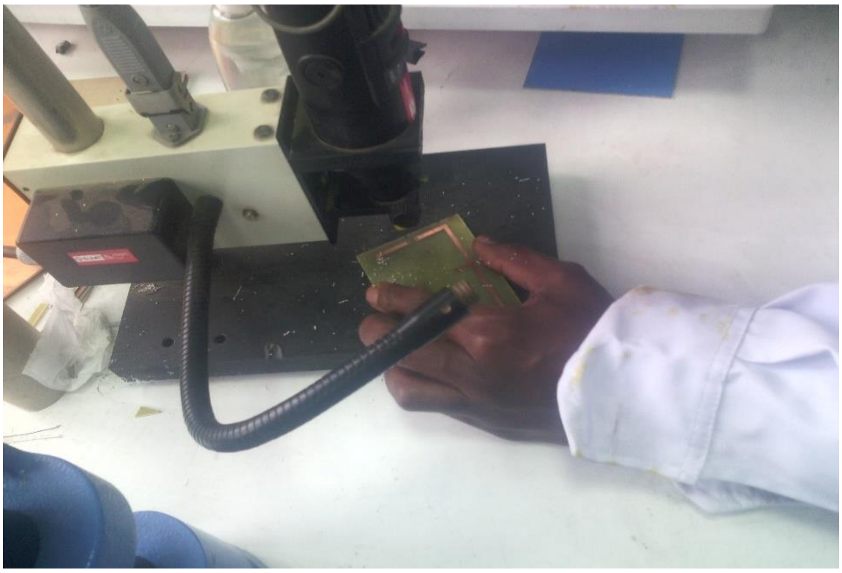


Figure 3.7: Drilling the PCB

3.8 Soldering of circuit components

The circuit components are soldered using lead and ironing machine, finally the circuit board looks like the following figure

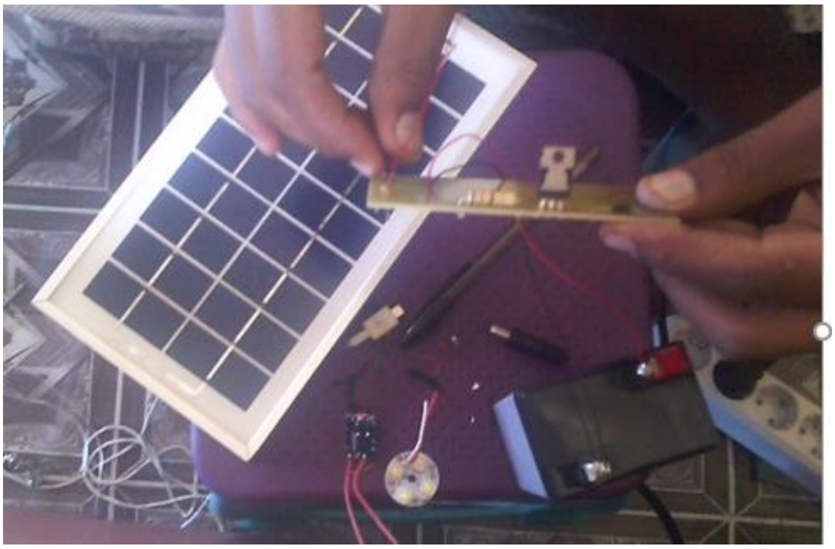


Figure 3.8: integrated electrical system for liter of night light

3.9 Bottle Type selection for experimentation

In the section, the solution container types in which the refraction takes place will be selected. But to select these materials we must set criteria's first. Those criterions with their reasoning are listed below: -

- **The solution container or holder must be locally available**. Hence, the main purpose of this project is to design a system which is versatile to rural applications. Therefore, the system should be composed of locally available materials, unless its application will be limited. Availability is the main issue when dealing with this kind of technologies as it is aimed to compute with other solar technologies.

- **The container should be transparent material**. When scattering light (Tyndall effect) through crystals it is best to use a clear and colorless crystal. Those colorless crystals will increase the scattering of light as light travels across their boundary. Therefore, the material should be transparent to upraise the amount of light traveling through it.

- **The container must be very cheap**. Cost is the main concern of any system. As the cost raises its affordability will decrease. This design mainly targets the rural community to enhance off grid electrification. As the technologies affordability mainly depend on its cost not only the solution type. Therefore, any materials selection related this technology is targeted to be with the list price.

- **The container must be light weighted**. As solution is filled to the container and it is hanged in the desired height the weight is very crucial. As the container weight being very light then the issue will be to worry only with the height of the hanging, if not it is obvious that it will be difficult to hang the system, and one must deal with other structural support.

Weighting the criterion

The relationship between criterions has been mentioned section 3.1.2 for AHP, since this problem is also type of decision making under certainty. The following matrix A which is the pricewise comparison matrix is developed

	Availability	Transparency	Cost	Lightness
Cost	1	1	1	1
Efficiency	1	1	1	1
Size	1	1	1	1
Weight	1	1	1	1

$$A = \begin{bmatrix} 1.00\ 1.00\ 1.00\ 1.00 \\ 1.00\ 1.00\ 1.00\ 1.00 \\ 1.00\ 1.00\ 1.00\ 1.00 \\ 1.00\ 1.00\ 1.00\ 1.00 \end{bmatrix}$$

To normalize the weights, the sum of each column is divided by the corresponding sum of each column. Then the normalized matrix $\bar{A}$ is given by

$$\bar{A} = \begin{bmatrix} 0.25\ 0.25\ 0.25\ 0.25 \\ 0.25\ 0.25\ 0.25\ 0.25 \\ 0.25\ 0.25\ 0.25\ 0.25 \\ 0.25\ 0.25\ 0.25\ 0.25 \end{bmatrix}$$

Then, the weights of the criterions are found by taking the average values of each row as per AHP decision making process rules. And the weight matrix is given by;

$$W_T = [0.25,0.25,0.25,0.25]^T$$

Using the weights given in the transpose matrix the comparison has been made in the following table.

Table 3.2: Bottle type selection

Candidate materials	**Availability (25%)**	**Transparency (25%)**	**Cost (25%)**	**lightness (25%)**	**Total (100%)**
Glass Bottles	20	25	20	18	83
Plastic Bottles	25	22	25	25	97

From the table 3.2 above, it is understandable that plastic bottles are appropriate for the system to be installed. Therefore, in this project transparent plastic bottles will be used throughout all the experimentation.

3.10 liquid Solutions selection

Before directly selecting the solutions, which are appropriate to the system it must be dealt with vital issues which determine which kind of liquid solutions are appropriate for this type of applications. And those considerations are discussed below

3.10.1 The Tyndall Effect

(Marie, 2017)said that The Tyndall effect is the scattering of light as a light beam passes through a colloid. The individual suspension particles scatter and reflect light, making the beam visible. And this effect allows visible light to glow as those colloidal materials scatter light in different angles.

(Marie, 2017) said that to be classified colloidal, a material must have one or more of its dimensions (length, width, or thickness) in the approximate range of 1-1000 nm." Because a colloidal solution or substance (like fog) is made up of scattered particles (like dust and water in air), light cannot travel straight through. Rather, it collides with these micro-particles and scatters causing the effect of a visible light beam. This effect was observed and described by John Tyndall as the Tyndall Effect. Therefore, adding some colloidal impurities in a given solution will upraise the amount of visible lights as this material scatter light to visible range, and using colloidal materials in a small amount for this kind of applications (Liter of night light Technology) scatters light in a worthy amount.

3.10.2 Refractive Index of a Solution

(Brittanica, 2016)refractive index**,** also called index of refraction, measure of the bending of a ray of light when passing from one medium into another. If *i* is the angle of incidence of a ray in vacuum (angle between the incoming ray and the perpendicular to the surface of a medium, called the normal) and *r* is the angle of refraction (angle between the ray in the medium and the normal), the refractive index *n* is defined as the ratio of the sine of the angle of incidence to the sine of the angle of refraction; i.e., $n = \sin i / \sin r$. Refractive index is also equal to the velocity of light *c* of a given wavelength in empty space divided by its velocity *v* in a substance, or $n = c/v$.

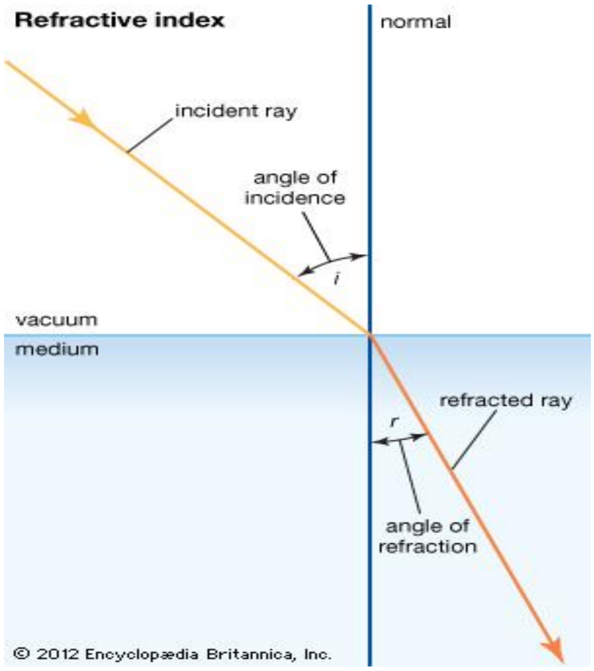


Fig.3.9: Refractive Index (Brittanica, 2016)

It is known that when the velocity of light in a given substance decreases its refractive index increases. Ehen the speed of a photon decreases there will be a chance to increase there will be a chance to increase its density in the given substance. Therefore, the intensity of the light in the substance will increase and this is happening because of refraction. In this project, the solutions that are going to be selected preferred to have higher refractive index in order to increase the intensity of the light, which an advantage for the technology.

3.10.3 Availability of a Solution

Availability is very crucial issue. Hence, in this project it is planned to gain a system that made of locally available components, and this increases its versatility. Above all availability affects the technology usage in the rural community. Therefore, the solutions should be available in the local community.

3.10.4 Cost of a Solution

Cost is the main issue when dealing any type of technology. It is obvious that any technology can breakthrough when its cost is affordable by the many. As the solution is one integral part of the technology its cost should be affordable, this means the cost of the solution must be cheap.

3.10.5 Free from Hazard

The solution must not be flammable to reduce hazard and again the solution must not have acidic or basic content. As this technology is targeted to help the rural community which are not enlighten, using hazardous solutions with instruction is not recommendable as they don't understand any written instructions. It seems not serious, but now a day many people are dying of misusing technologies. This misusing is the result of lesser understanding of technology, therefore this technology will never ever use hazardous solutions as a light refraction medium.

3.10.6 Fluid Selection Based on Multi Decision Criterion

The above criterions from section 3.10.1 to 3.10.5 have to be weighted before developing the comparison table. Therefore, they are weighted as follows: -

The relationship between criterions has been mentioned in section 3.1.2 for analytical hierarchical process, since this problem is type of decision making under certainty. The following matrix A which is the pricewise comparison matrix is developed

	Tyndall Effect	Refractive Index	Availability	Cost	Hazard free
Tyndall Effect	1	1/2	2	1/3	1
Refractive Index	3	1	2	1	3
Availability	1	2	1	3	1
Cost	3	1	1/3	1	2
Hazard Free	1	1/3	1	1/2	1

$$A = \begin{bmatrix} 1.00 & 0.50 & 2.00 & 0.33 & 1.00 \\ 3.00 & 1.00 & 2.00 & 1.00 & 3.00 \\ 1.00 & 2.00 & 1.00 & 3.00 & 1.00 \\ 3.00 & 1.00 & 0.33 & 1.00 & 2.00 \\ 1.00 & 0.33 & 1.00 & 0.50 & 1.00 \end{bmatrix}$$

To normalize the weights, the sum of each column is divided by the corresponding sum of each column. Then the normalized matrix $\bar{A}$ is given by

$$\bar{A} = \begin{bmatrix} 0.11 & 0.104 & 0.316 & 0.057 & 0.125 \\ 0.33 & 0.207 & 0.316 & 0.172 & 0.375 \\ 0.11 & 0.414 & 0.158 & 0.515 & 0.125 \\ 0.33 & 0.207 & 0.052 & 0.172 & 0.250 \\ 0.11 & 0.068 & 0.158 & 0.086 & 0.125 \end{bmatrix}$$

Then, the weights of the criterions are found by taking the average values of each row as per AHP decision making process rules. And the weight matrix is given by;

$$W_T = [15,28,26,20,11]^T$$

Using the weights given in the transpose matrix the comparison has been made in the following table.

Table 3.3: Decision matrix for solution selection

S.no	Liquid Solutions	Criterions					Total (100%)
		Tyndall Effect (15%)	Refractive Index (28%)	Availability (26%)	Cost (20%)	Hazard Free (11%)	
1	Bottled Water	8	24.2	26	20	10.95	89.1
2	Sugar solution	13	27.4	19.5	16	10.95	86.85
3	Baking Soda	12	25.8	23.4	16	9.49	86.69
4	Sodium bicarbonate solution	13	24.6	23.4	16	10.22	87.22
5	Salt Solution	13	28	24.7	19.2	10.95	95.85
6	Vinegar	11	25.8	24.7	17.6	10.95	90.05
7	Paraffin	12	26.9	22.1	14.6	3.65	79.25

From table 3.3: above five solutions are selected to go through experimentation after evaluated by the criteria's salt solution, sugar solution, sodium bicarbonate solution, bottled water and vinegar ale selected.

3.11 Working Principle of Liter of Night Light

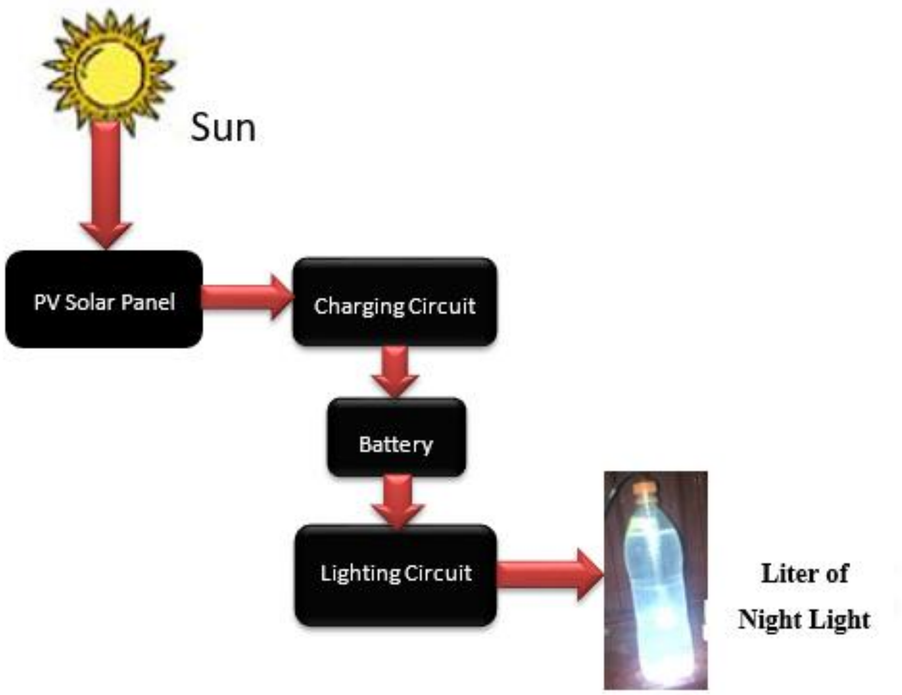


Figure: 3.10 Schematic Diagram of Liter of Night Light

Working Principle of Liter of night Light

The solar radiation is collected by PV solar panel, and the PV panel generates electric current. This voltage and current from the solar panel are regulated to consumable amount by the battery in the charging circuit. the electrical energy stored in the battery is regulated by the lighting circuit and delivered to the LED light inside a solution. This LED light is further refracted by the solution, and this depends on the type of solution used.

3.12 Experimentations

The experimentation was made in Ethiopian conformity assessment agency laboratory in a black room designed for lux measurement. The room area is about $9m^2$ and for measurement the bottles are hanged two meters from the ground. The test was conducted using lux meter at 1-meter height from the ground. The data's recorded from experimentation are presented in section 4.1.

When measuring light using lux meter one should be aware of this, and it is mainly to deal with the fact that different wavelengths of light are not sensed equally by human eye. If all the wavelengths of contained the same intensity, the lux reading would be same but humans see more light of certain color and may say brighter but this is not always true.

4. RESULT AND DISCUSSION

In this section of the project, the results gained from the experimentation are documented and their meaning with the technology is discussed in detail. Also, optimization by experimental analysis has been developed. So that, the best system which can refract light and deliver huge amount of lux is identified.

4.1 Experimental Results

The experiment was performed in Ethiopian Conformity Assessment laboratory in $9m^2$ black room at the height of 2 meters from the ground, and the measurement is taken at the height of 1 meter from the ground. Obtained results from experimentation are reported in the next sections (4.1.1 and 4.1.2).

4.1.1 Experimental Results for LED Lights

In order to compare the effect of the solutions the LED light that has been used as a light source for the liter of light technology has been tested at the same height with liter of night lights as mentioned in section 4.1 above. Accordingly, the amount of lux delivered by the LED light in the black room is measured to be 7.4 lux.

Another light that has been tested is 7w alpha power emergency light which has been shown in Appendix C9. This bulb is rechargeable bulb and it was charged to be full before the experiment. And, the light intensity of this LED light is around 19.3 lux.

4.1.2 Experimental Result for Liter of Night Light

The results obtained from experimentation are reported in the following two tables. It is evident that the amount of light to be refracted in those solutions is a function of depth, Volume, radius and the type of solution. Note that, all the experimental tests were conducted based on the specification reported in section 4.1., Below the test results are summarized in table 4.1 and table 4.2.

Table 4.1: Experimental result for 7.64 cm radiused Transparent plastic bottle

S.No.	Name of the solution	Depth(cm)	Radius(cm)	volume (cm^3)	Lux
1	Salt Solution	0	7.64	0	6.4
		4		183.3	7.7
		8		366.56	10.1
		12		549.84	8.8
		16		733.12	4.4
2	Sugar Solution	0	7.64	0	5.3
		4		183.3	7.4
		8		366.56	8.1
		12		549.84	7
		16		733.12	6.2
3	Sodium bi Carbonate Solution	0	7.64	0	4.9
		4		183.3	8.2
		8		366.56	17.9
		12		549.84	10.1
		16		733.12	4.1
4	Bottled Water	0	7.64	0	2.8
		4		183.3	8
		8		366.56	9
		12		549.84	19.1
		16		733.12	7.9
5	Vinegar Solution	0	7.64	0	5.7
		4		183.3	10.1
		8		366.56	21.5
		12		549.84	27
		16		733.12	8

Table 4.2: Experimental result for 6.7 cm radiused Transparent plastic bottle

S.no	Name of the solution	Depth(cm)	Radius(cm)	volume (cm^3)	Light Intensity (Lux)
1	Salt Solution	0	6.7	0	4.4
		3		105.72	5.3
		6		211.73	5.4
		9		317.2	4.9
		12		422.86	4.8
2	Sugar Solution	0	6.7	0	5.2
		3		105.72	5.3
		6		211.73	6.7
		9		317.2	5.4
		12		422.86	5
3	Sodium bi Carbonate Solution	0	6.7	0	5.2
		3		105.72	13.5
		6		211.73	9.2
		9		317.2	5.6
		12		422.86	5.2
4	Bottled Water	0	6.7	0	4.5
		3		105.72	5.3
		6		211.73	6.2
		9		317.2	7.2
		12		422.86	7
5	Vinegar Solution	0	6.7	0	5.2
		3		105.72	7.8
		6		211.73	10.5
		9		317.2	9.6
		12		422.86	7.8

The above Tables (4.1 and 4.2) reveals that as the depth, volume and solution type varies the amount of light scattered by the system is also varied. In the coming sections the effect of those parameters on the amount of light obtained is explained in detail.

4.2 Volume effect on the amount of light Refracted

For experimentation five solutions are used as listed in table 4.1 and 4.2, and the lux amount obtained is varied as function of volume. Therefore, in these sections the effect of volume in each solution is discussed in Detail. It is known that solutions have their own tendency to refract light but these tendencies vary as function of volume and these has been discussed below for each experimentation solutions.

4.2.1 The Effect of Salt Solutions Volume on Light Refraction

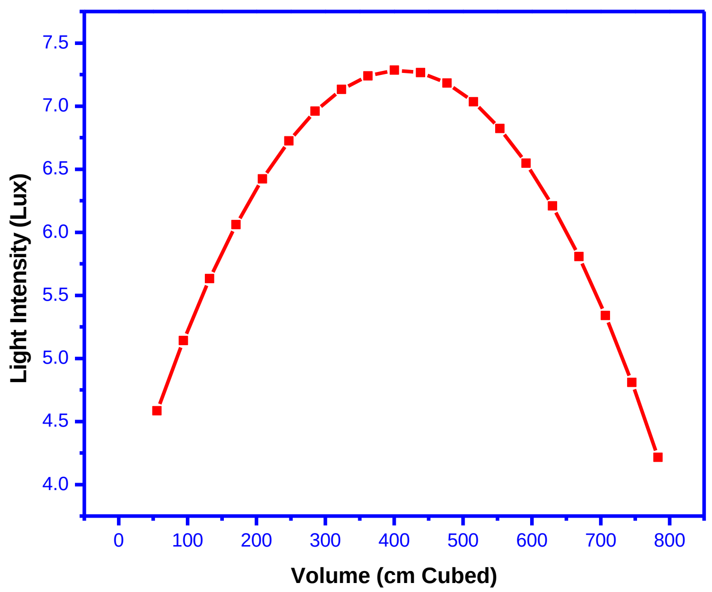


Figure 4.1: The Effect of salt Solutions Volume on the amount of Lux

The volume of the salt solution and lux amount have a parabolic relationship. Though, the data points taken from Table 4.1 and table 4.2 give irregular curve between volume and amount of light, the irregular relationship is approximated by polynomial fit of order 2 (because polynomial fit with order 2 approximates the function in better way) and their relationship is given by equation 4.1below:

$$\emptyset = -2.2e^{-5}V^2 + 0.0018V + 3.7 \quad (4.1)$$

From figure 4.1 above it is easy to understand that the volume of the salt solution should be in the range of 350cm^3 and 450cm^3 to give a maximum amount of refraction. In other cases, the it is giving much lesser amount of refraction. Therefore, employing such systems with salt solution is approximated to be in the specified range.

4.2.2. The Effect Sugar Solutions Volume on Light Refraction

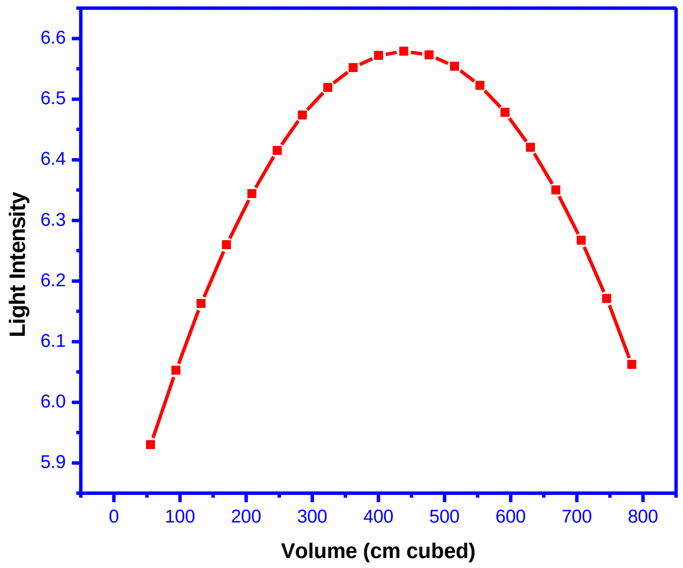


Figure 4.2: The Effect of Sugar Solutions Volume on the amount of Lux

In the same manner the data from Table 4.1 and Table 4.2 are approximated by polynomial fit order of 2, and the above graph is obtained. And, it shows that in what manner light refraction from the LED light source is affected in Sugar solution.

As the volume Sugar increases from 100cm^3 to 400cm^3 the lux amount also increases rapidly and at 400cm^3 it will get the solutions maximum. Actually, what we are seeing in figure 4.2 above is not the exact value that supposed to be the right volume for the maximum possible amount of light refraction throughout the system. Because the graph is developed by approximation of the points obtained from the experimentation, which helps us to understand how the amount of lux behaves as the volume changes. And their relationship is expressed in the following equation: -

$$\emptyset = -4.4e^{-6}V^2 + 0.0039V + 5.7 \qquad (4.2)$$

As the volume increases beyond 3000cm^3 the amount of lux drops very fast. Therefore, having a system with big volumes doesn't guarantee larger lux amount.

4.2.3 The Effect Sodium Bicarbonate Solutions Volume on Light Refraction

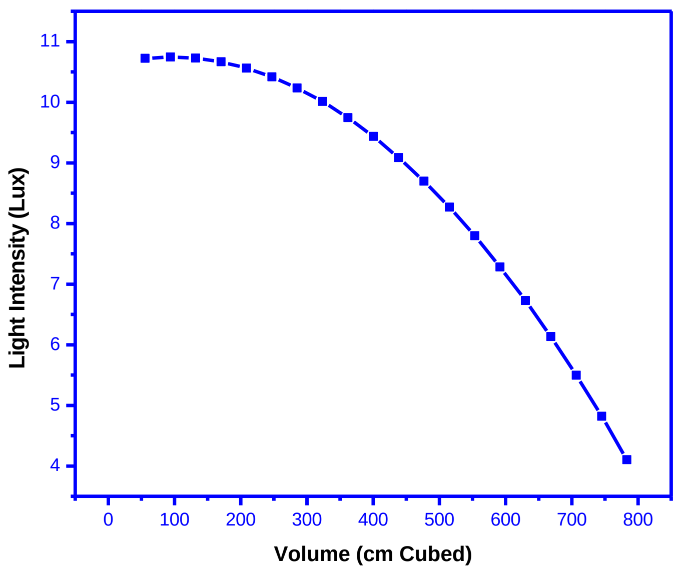


Figure 4.3: The Effect of Sodium Bicarbonate Solutions Volume on the amount of Lux

As it is shown in figure (4.3) above Sodium bicarbonate solution gives better refraction at smaller volumes. Around 100cm^3 it gives the best out of it, and then as the volume increase the lux amount delivered by the system declines.

These graph is also developed by polynomial fit order of 2, by approximating the data's obtained from table 4.1 and 4.2. and, their relationship is given by the following equation:

$$\emptyset = -1.4e^{-5}V^2 + 0.0026V + 11 \qquad (4.3)$$

The graph explains the way in which the amount of volume and lux are related. The lux amount values in figure 4.3 above cannot be used to optimize the system as function of volume, as it is approximate value.

Here, also one can understand that the amount of lux delivered out by the system is a function of volume, the solution has its own property that lets it to refract light, in better way and the solutions property is upgraded as function of volume.

In this case the amount of the light that has been released from the system is decaying as the volume increases for this specific solution (Sodium Bicarbonate) commonly known as bleach.

4.2.4 The Effect Bottled Water Solution's Volume on Light Refraction

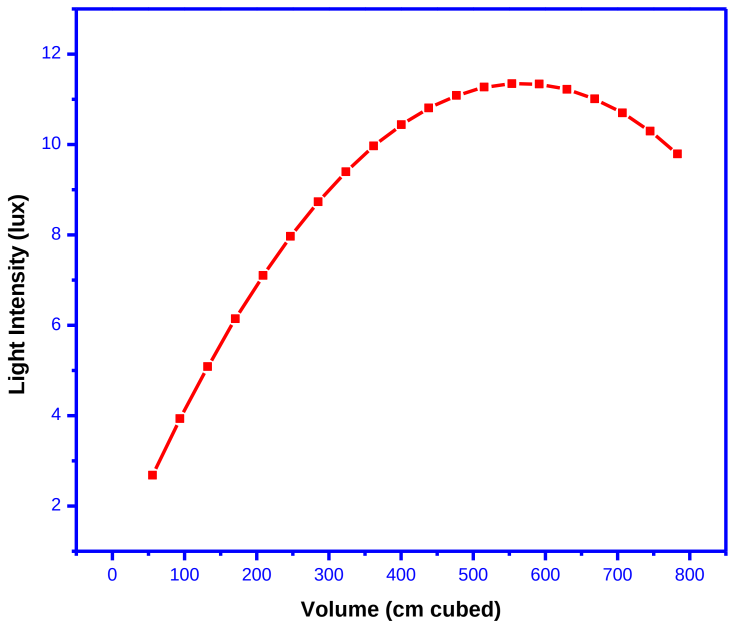


Figure 4.4: The Effect of Bottled Water Volume on the amount of Lux

Here, at small volumes the amount of light refracted to the surrounding is very small, as the volume increases from 100cm^3 to 550cm^3 the lux amount increases slowly and it gets its peak at around 550cm^3. Then it starts to fall slowly from its peak as the volume increases.

For bottled water in at small volumes its refraction is very small. The lux amount increase as function of volume till the volume reaches around 550cm^3 which is the peak out of the approximated polynomial fit. And, the graph is expressed by the following equation:

$$\emptyset = -3.3e^{-5}V^2 + 0.038V + 0.69 \quad (4.4)$$

From the graph it is obvious to understand that, how the volume of water affects the amount of light refracted by the system, and this supports our function defined in section 4.1, and supports that the amount of light is a function of volume and other properties.

4.2.5 The Effect of Vinegar Solutions Volume on The Amount of Light Refracted

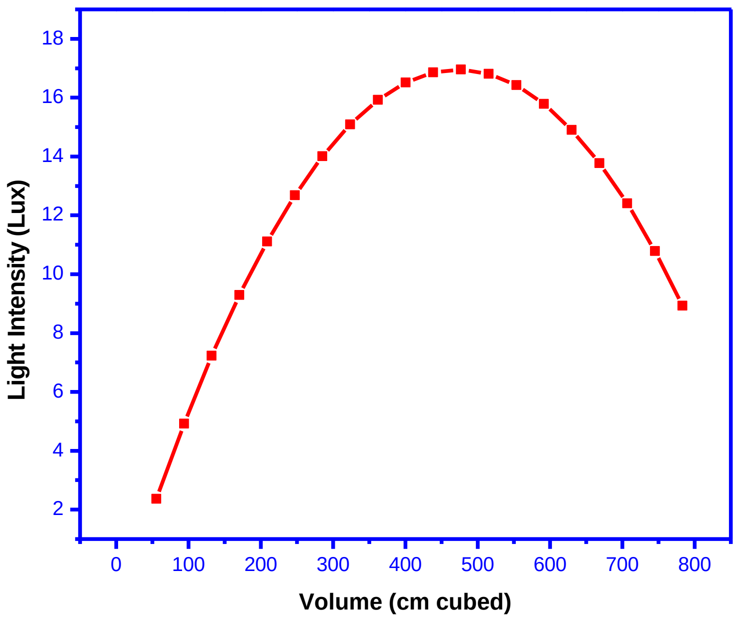


Figure 4.5: The Effect of Volume of Vinegar Solution's on the amount of Lux

The data collected from experimental results (Table4.1 and 4.2) for this specified solution are plotted and approximated by polynomial fit of order 2 to give the above curve. And the equation of the curve is given by: -

$$\emptyset = -8.4e^{-5}V^2 + 0.079V - 1.8 \quad (4.5)$$

From the curve we see that at small volumes light refraction to the surrounding is very small. As the volume of the vinegar solution increases the lux amount increase rapidly. When the volume reaches around 480cm^3 the lux amount reaches its peak and then after it starts to fall slowly as the volume exceeds the 480cm^3.

These proves that the amount of light diffused in our cylindrical bottle is a function of volume and it depends on the volume which strongly support our initial statement on section 4.1.

4.3 Depth effect on the amount of light refracted

In section 4.1 we have said that, the amount of light refracted by the system is function of volume, radius depth and type of solution. In this section, the light intensity dependence on depth(z) will be discussed based on the results recorded on table 4.1., the plots and the relationships of depth vs lux amount of table 4.2 are given in Appendix B

In these sections all the graphs are plotted by taking data from table 4.1 and approximating the irregular curves by polynomial fit order of three (order three because they can approximate the irregular curves obtained from better than other orders for this specific application.

4.3.1 Depth Dependency of Light Intensity in Salt Solution

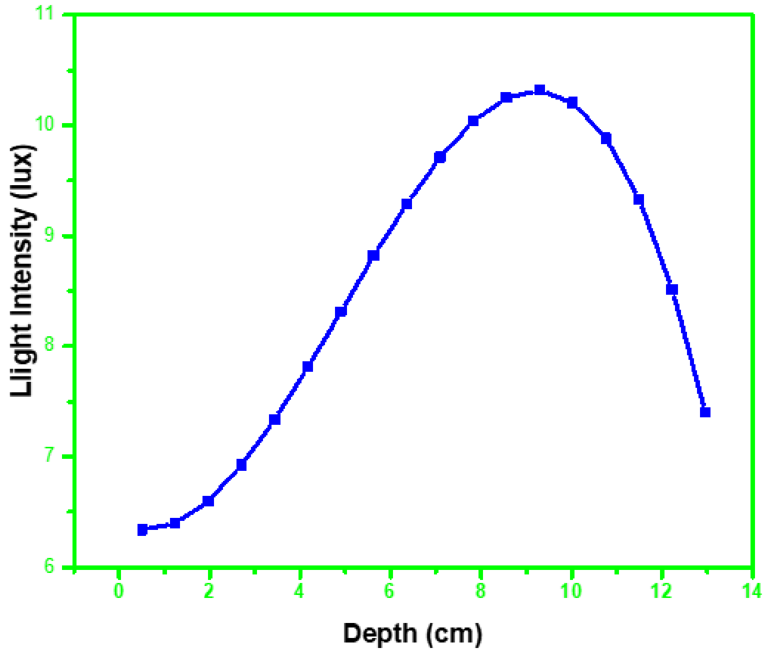


Figure 4.6: Depth dependency of Light Intensity in salt Solution

At small depth the lux amount is also small as we can see from the figure 4.6 above, till the depth approaches to 9.5cm the lux amount also increases with the depth. But after 9.5 cm it declines rabidly. This relationship, what we are seeing from the graph assures that the intensity of light is dependent on the depth of the solution. And this relationship expressed by the curve equation given below:

$$\emptyset = -0.0055h^3 + 0.064h^2 + 6.3 \qquad (4.6)$$

Salt solutions have 1.54 refractive index, though it is highest among the solutions, this only doesn’t let the solution to have higher refraction out from the system.

4.3.2 Depth Dependency of Light Intensity in Sugar Solution

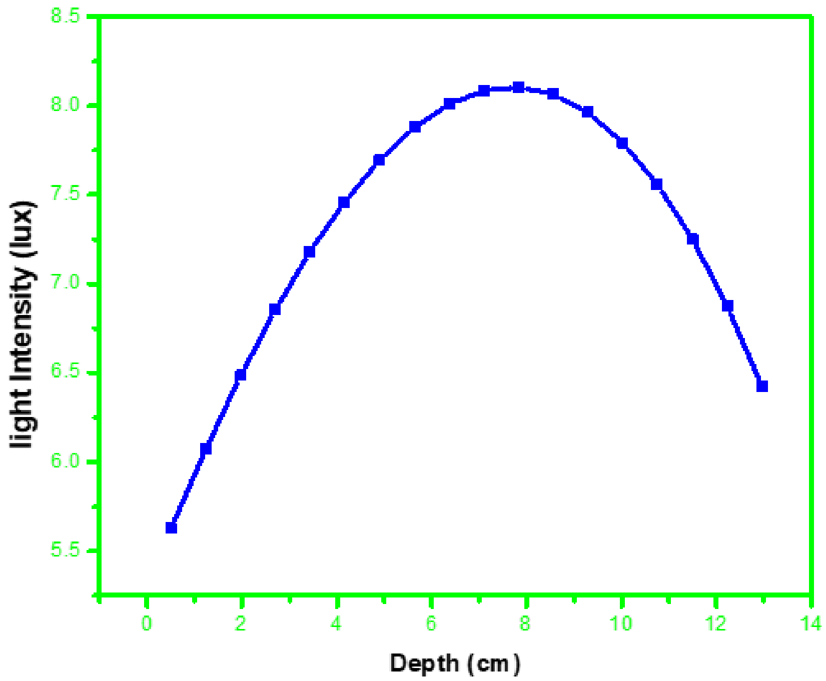


Figure 4.7: Depth dependency of Light Intensity in sugar solution

Here also, the amount of light out from the system is greater around 9cm which is more similar to section 4.3.1 but the curve is a bit different.

As the LED light source inside the bottles approached to the bottom of the plastic bottle the amount of light out from the system is very small. And, the curve equation for this relationship is given by:

$$\emptyset = 0.0022h^3 - 0.087h^2 + 0.088h + 5.5 \quad (4.7)$$

To get best out of the system one must follow the curve recommendations, that placing the LED light source at around 9cm height. The light intensity out from the system is therefore strongly dependent on the depth of the sugar solution. And this proves that light intensity is dependent on depth of the solution.

4.3.3 Depth Dependency of Light Intensity in Sodium Bicarbonate Solution

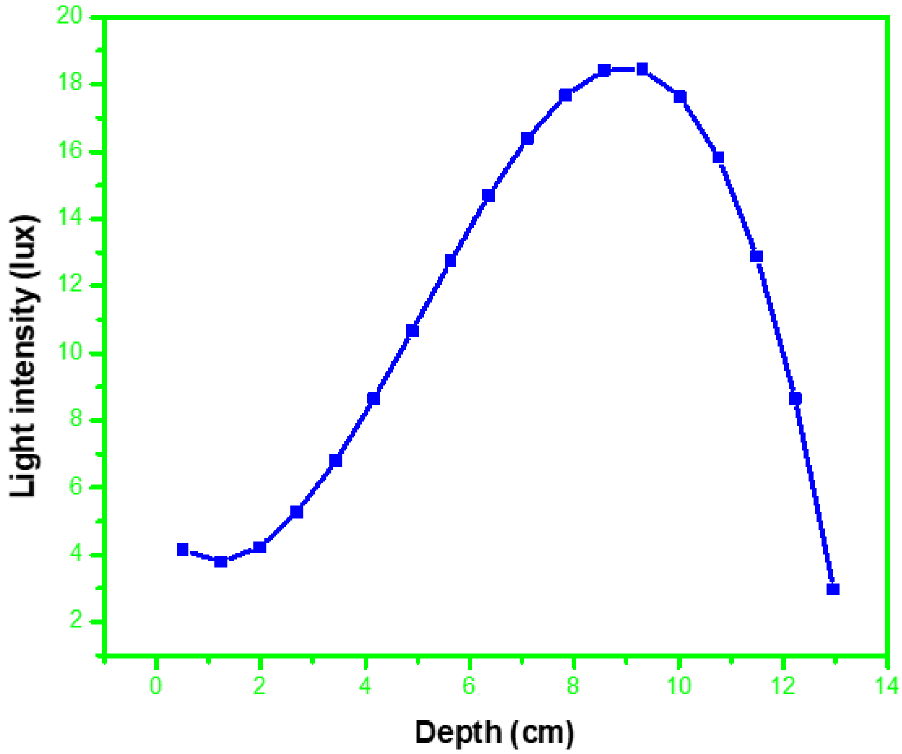


Figure 4.8: Depth dependency of Light Intensity in sodium Bicarbonate solution

Sodium bicarbonate is a solution which has been used for this technology since a long time, in this section the light amount delivered from this solution to the surrounding is approximated by figure 4.6.

From figure 4.6, we can see the manner in which the light amount is varied with the depth of solution increment. At the beginning or at zero depth the amount of light intensity was around 4.5. as the depth increases from 0 to 1 the lux amount decreased from 4.5 to 3.9 and again it starts increasing with depth after depth equals 1cm. and the relationship is expressed by the curve equation given by:

$$\emptyset = -0.006 - 0.017h^2 + 1.8h + 4.3 \quad (4.8)$$

Finally, the dual increment of depth and lux end at depth equals 9cm and then another relationship begins, as depth increases the amount of lux released by the system drops after depth equals 10.

4.3.4 Depth Dependency of Light Intensity in Bottled Water

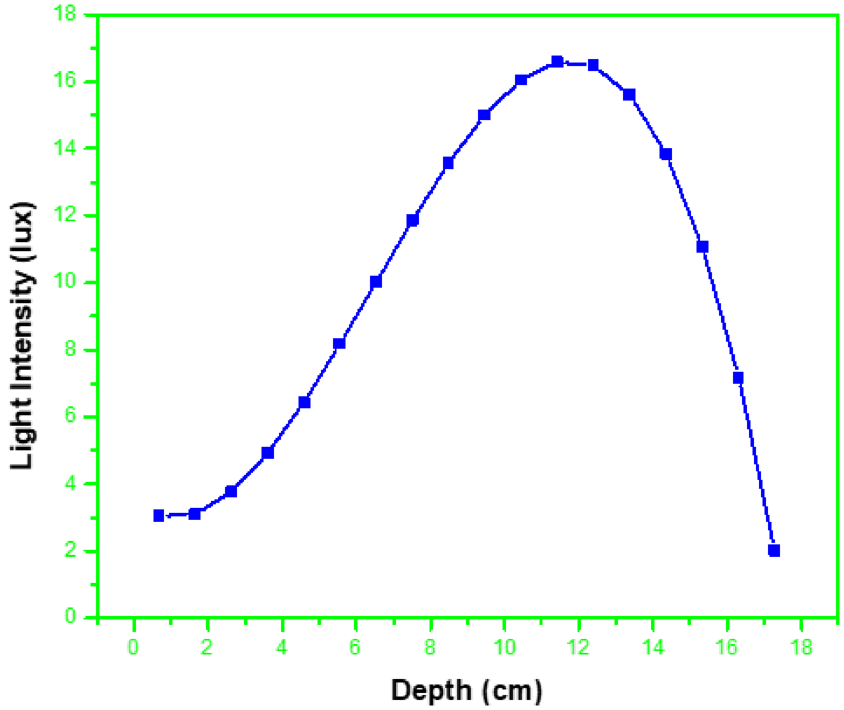


Figure 4.9: Depth dependency of Light Intensity in Bottled Water

As it is shown in the figure above light intensity is dependent on the depth of the solution and its relation is well explained in the curve developed by approximating the data points. And the relationship is given by the following equation:

$$\emptyset = -0.002h^3 + 0.43h^2 - 0.84h + 53.4 \tag{4.9}$$

The curve tells us that, as depth increase from 0cm to 12cm the light amount released to the environment increases in the same way. But, increasing depth of the sugar solution beyond 12cm results reduced amount of light to the environment. Therefore, the same is true that the amount of light is dependent on the depth of the sugar solution.

4.3.5 Depth Dependency of Light Intensity in Vinegar Solution

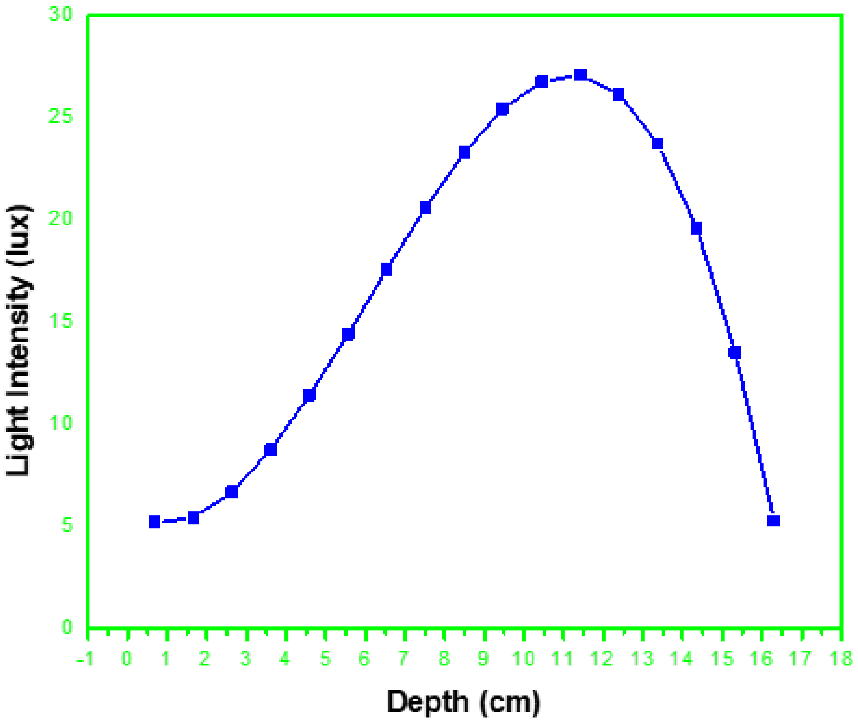


Figure 4.10: Depth dependency of Light Intensity in Vinegar solution

Figure 4.10 above shows that how depth affect the amount of light that has been refracted to the surrounding. The systems give its best at depth equals 12cm, and the it falls. This vinegar solution has its own properties but those properties optical properties are magnified as a function of the curve. And, the curve equation is given by:

$$\emptyset = -0.04h^3 + 0.75h^2 - 1.3hh + 5.8 \tag{4.10}$$

Here also one can easily understand that lux amount is dependent on the depth of the vinegar solution. When dealing with this system employing the light at around 12 cm height with specified radius in table 4.1 is mandatory, if it is determined to get out of the system. This section also justifies that the amount of light is dependent on the depth of vinegar solution.

4.4 Solution type Effect on the amount of light refraction

For experimentation 5 different solutions have been used. And the solution effect on the amount of light is studied by testing all the solution at specific height and diameter of container to be 12cm in this case.

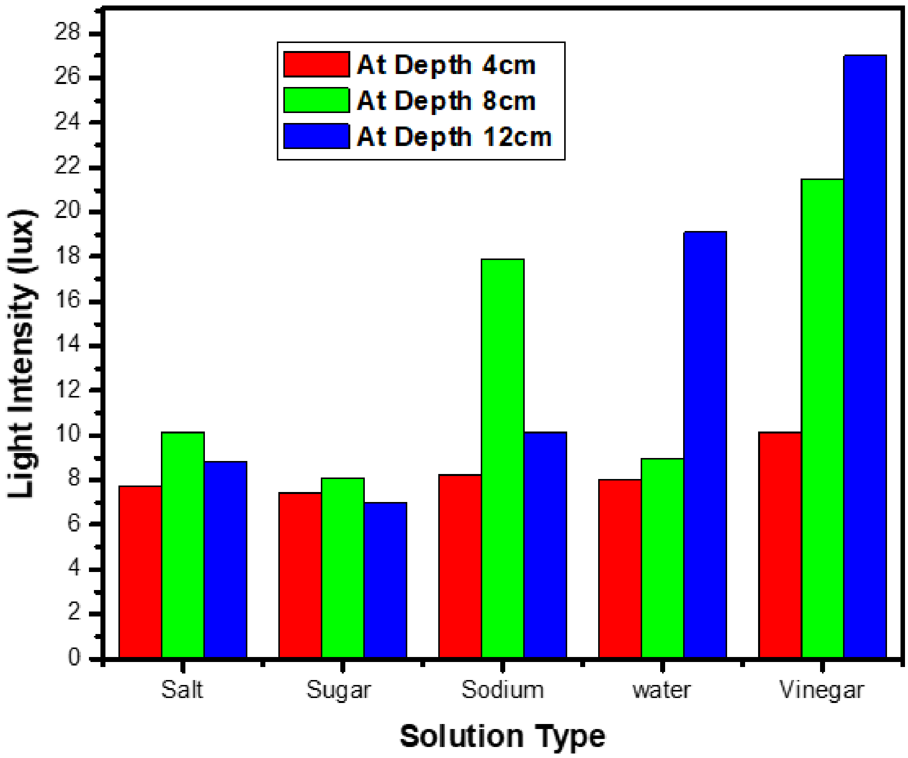


Figure 4.11: Solution Type dependency of Light intensity

From figure 4.11 above vinegar solution light intensity increases with depth increment, also the water solution does the same, but the rate at which both solutions light intensity increment is different. From this it is understandable that height is not the only parameter that affect the amount of light delivered by the system. For the same height increment both solutions should go in the same rate of increment but they didn't.

Again, looking at salt, sugar and sodium bicarbonate solutions we can understand that they behave in different manner when compared to water and vinegar solutions. If height is the only parameter all the solutions should behave in the same manner for the selected depth levels. The solution type has its own impact on the amount of light released out from the system.

4.5 Selection of best Volume, Depth and solution type

In this section selection was performed depending on the parameters affecting the amount of light out from the system, those parameters are discussed from section 4.2 to 4.4. here below their best operating ranges of the parameters are decided based on the experimental results.

4.5.1 Selection of Best Volume for Each Solutions

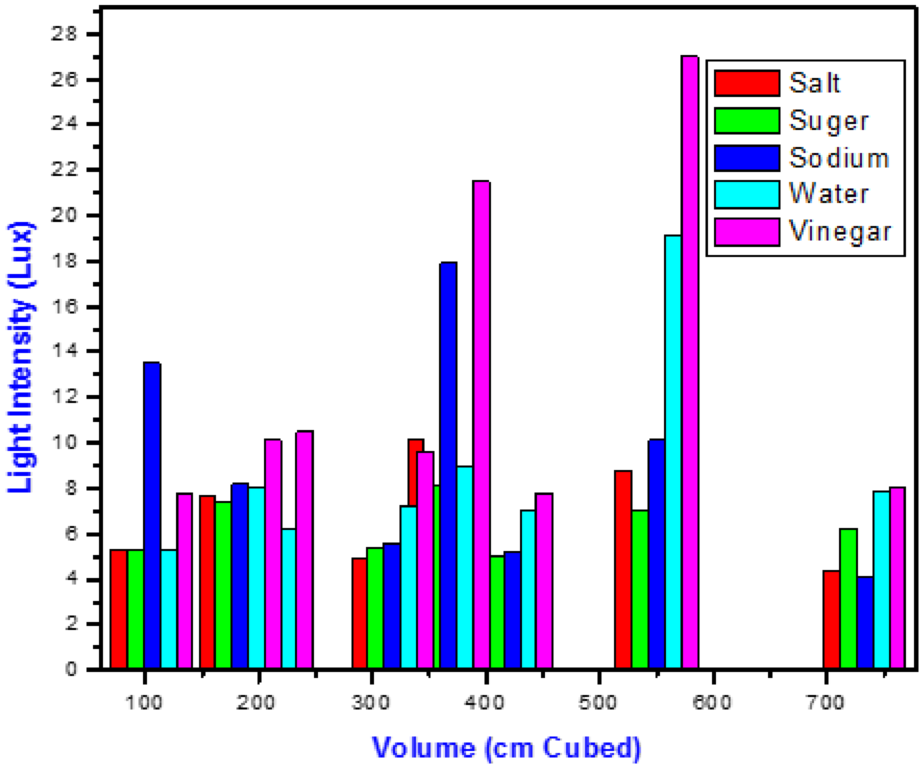


Figure 4.12: volume light Intensity relationship

The target is to obtain the best volume size that can deliver the maximum amount of light to the surrounding. Hence, the technology is volume dependent, therefore the right amount should be determined. From figure 4.12 the following best volume for each amount of solutions are found: -

- The best volume for salt solution is 340cm^3
- The best volume for sugar solution is 350cm^3
- The best volume for Sodium bicarbonate is 360cm^3
- The best volume for bottled water is 565cm^3
- The best volume for Vinegar Solution is 580cm^3

4.5.2 Selection of Best Depth for Each Solutions

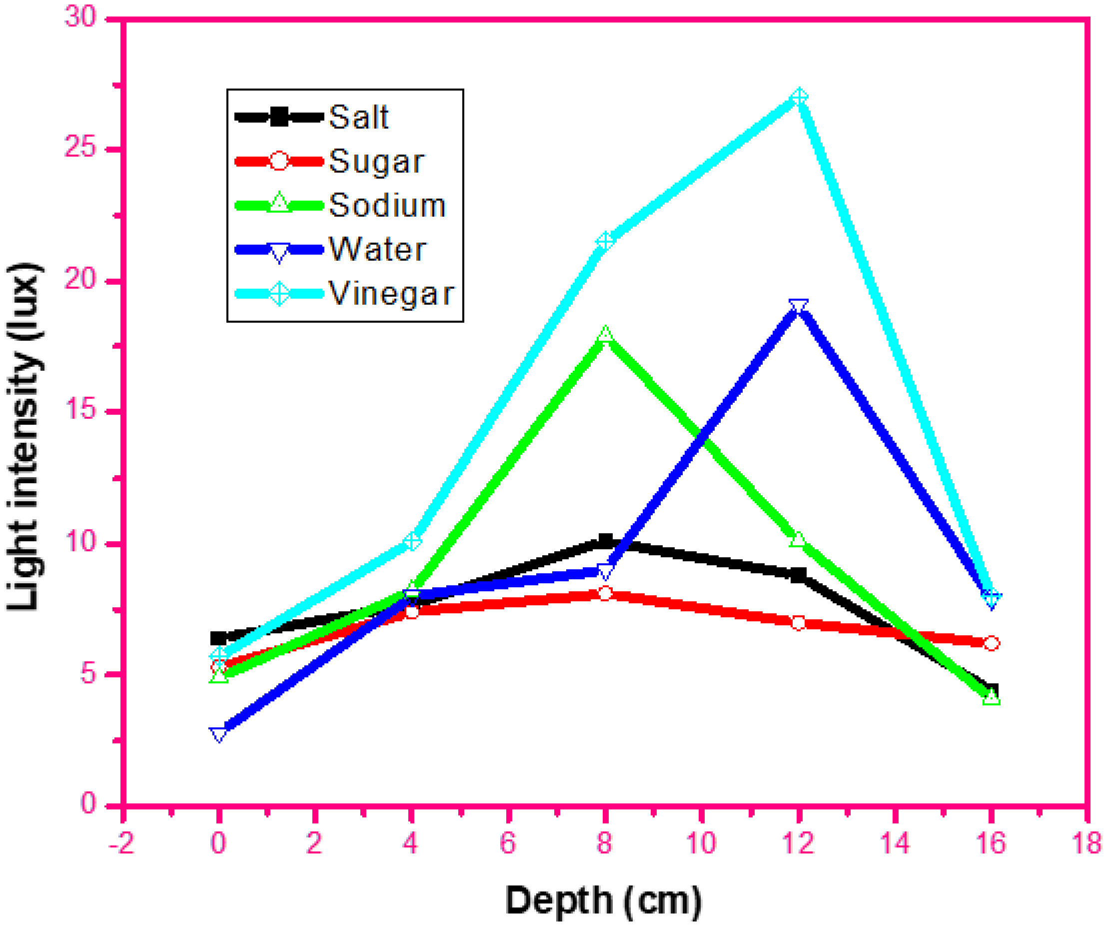


Figure 4.13: Depth of the solution light Intensity relationship

Based on the figure 4.13 it is obvious to select the height as function of the solution to get best luminance out from the system. for each solution the best height is selected based on the experimental data. And the best depth of the solutions is listed below: -

- The best depth for the salt solution is around 8cm.
- The best depth for the sugar solution is around 8cm.
- The best depth for the sodium bicarbonate solution is 8cm.
- The best depth for bottled water is 12cm.
- The best depth for vinegar solution is about 12cm.

4.5.3 Selection of Best Solution Type

In section 4.4 the effect of solution type has been discussed. In reference of figure 4.11 the best solution among the candidates is the vinegar solution which was able to give about 27 lux amounts to the surrounding. Therefore, the best solution that can refract the best out from the system is vinegar solution.

4.5.4 Selection of Best System

hence, our main target is selecting the best solution, with optimum volume and depth, the vinegar solution becomes the best out of all and its best volume is 580cm^3 and the LED light should be employed to these volumes about height equals 12cm.

for the system once, the volume and the height are given, it is not difficult to get the radius of our system, but in this case the radius is about 7.64 centimeters.

4.6 Comparison of LED lights Intensity with the optimal liter of light

Table 4.3: Comparison table LED lights with liter of night light technology

S.no.	Name of the light bulb	Intensity (lux)	Rank
1	LED light used for liter of night light	7.4	3
2	7W alpha power emergency bulb	19.3	2
3	Vinegar solution liter of night light	27	1

From the table above the vinegar solution liter of night light is much greater than the source LED light and the alpha power emergency light. Therefore, it is very crucial to employ this vinegar lights to the community.

4.7. How to Use Vinegar Solution Liter of Night light level for 9m^2 room

According to Panasonic standard of light amount in Appendix A6, the recommended light level for a living room is about 50 Lux. But the vinegar solution delivers 27 Lux only in a 9m^2 room. Therefore, installing two vinegar plastic bottle bulbs will solve the problem. Concluding, for 9m^2 room two vinegars solution bottle bulbs can glow the light amount specified by Panasonic standards.

5. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

The goal of this thesis was to select best liter of night light system by performing experimental analysis. To get ready our system for experimentation the electrical circuit has been designed, and then suitable materials for the technology are selected. The system was developed by assembling all materials as per the design and experimentation was performed. After experimentation, the results have been recorded and analyzed and on the following conclusions are found.

Firstly, almost all PV systems are controlled by charge controllers, but this system is controlled by LM317 voltage regulators these increases the easiness of the technology.

Secondly, the liter of night light technology is dependent on the solution used to refract the light out from it. Five different solutions are tested and five of them have shown different capacities of refracting light. In methodology section it was believed that solutions with higher refractive index will refract light in better way than solutions owning lesser refractive index. But, the situation after experimentation explains how the premises was wrong as vinegar which is with much lesser refractive index than Salt and Sugar solutions becomes the best solution. Therefore, there should be other properties that are not studied in this thesis.

Thirdly, it was found that the amount of light refracted from the system is a function of the depth, volume of the solution. These relationships vary from solution to solution, Salt and sugar solutions operate good at a depth of 8cm in 7.64cm container. While Vinegar and bottled water function good at a depth about 12cm in the same container. It was able to find an equation that explains the relationship between Lux and Volume, and also Lux and Depth of the solution.

Fourthly, among the tested solutions vinegar solution has been found to be best, even that the LED light should be employed in the appropriate depth and volume unless it will not give the desired amount of light,

Fifthly, the vinegar solution based liter of night light is much better than alpha power 7watt Emergency light which is now in controlling the market.

5.2 Recommendations

So far it has been done a strained effort on the project; there are still a lot to be improved, the following directions of work are recommended in the modification of the technology in order to increase its versatility;

- Shape factor of the solution container is not included in this study; therefore, I recommend that somebody to study this. This is very helpful as it is important parameter in developing mathematical model.
- All the measurements results resulted in this project are only direct lights to the lux meter, and the diffused light is not measured, therefore I recommend one to test this solution in spherical light intensity measuring devise, to account the diffused light too.
- I recommend that using the technology as per this design is better for the rural community. And, the technology to be commercialized.
- Finally, I recommend that the materials science of the solution containers to be studied, hence it may have significant effect on light refraction whether in positive or negative way.

APPENDIX A: STANDARD TABLES

Appendix A1: Relationship between solar panel and Battery size

Configuration Relationships between solar panel and Batteries		
Batteries	**Solar Panel**	**Related Products**
1.2V	1.8V~2V	**2V solar panel**
1.5V	2.2V-2.5V	**2V solar panel**
2.4V	3.6V~4V	**4V solar panel**
3.2V	4.5V-5V	**5V solar panel**
3.7V	5.5V-6V	**6V solar panel**
5V	7V-8V	**8V Solar Panel**
6V	9V	**9V solar panel**
9V	12V-13.5V	**13V solar panel**
12V	17.2~18V	**18V solar panel**
18V	24V	**24V solar panel**
24V	36V	**36V solar panel**
36V	48V	**54V solar panel**

Appendix A2: Maximum Power Rating of IN4001 diode

Rating	Symbol	1N4001	1N4002	1N4003	1N4004	1N4005	1N4006	1N4007	Unit
†Peak Repetitive Reverse Voltage Working Peak Reverse Voltage DC Blocking Voltage	V_{RRM} V_{RWM} V_R	50	100	200	400	600	800	1000	V
†Non–Repetitive Peak Reverse Voltage (halfwave, single phase, 60 Hz)	V_{RSM}	60	120	240	480	720	1000	1200	V
†RMS Reverse Voltage	$V_{R(RMS)}$	35	70	140	280	420	560	700	V
†Average Rectified Forward Current (single phase, resistive load, 60 Hz, $T_A = 75°C$)	I_O	1.0							A
†Non–Repetitive Peak Surge Current (surge applied at rated load conditions)	I_{FSM}	30 (for 1 cycle)							A
Operating and Storage Junction Temperature Range	T_J T_{stg}	−65 to +175							°C

Appendix A3: Recommended Operating conditions for LM317 Voltage regulator

		MIN	MAX	UNIT
V_O	Output voltage	1.25	37	V
$V_I - V_O$	Input-to-output differential voltage	3	40	V
I_O	Output current	0.01	1.5	A
T_J	Operating virtual junction temperature	0	125	°C

Appendix A4: Refractive Index Table

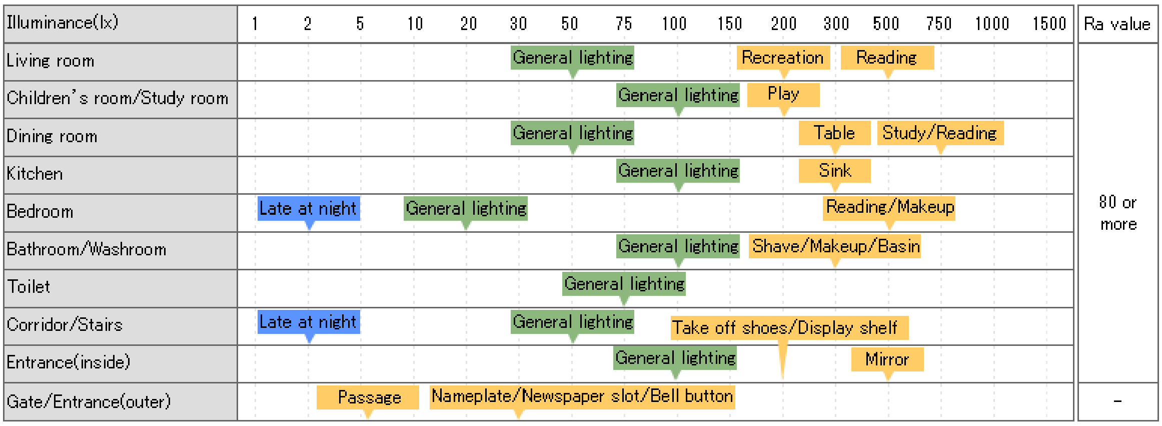
S.no.	Name of Solution	Refractive Index
1	Bottled Water	1.333
2	Concentrated Sugar Solution	1.5
3	Concentrated baking Soda Solution	1.4
4	concentrated Sodium bicarbonate	1.3334
5	concentrated salt Solution	1.54
6	10% Vinegar Solution	1.42
7	Paraffin	1.46

Appendix A5: Roots of Bessel Functions (15 digits)

The n-th roots of Jm(x)=0.

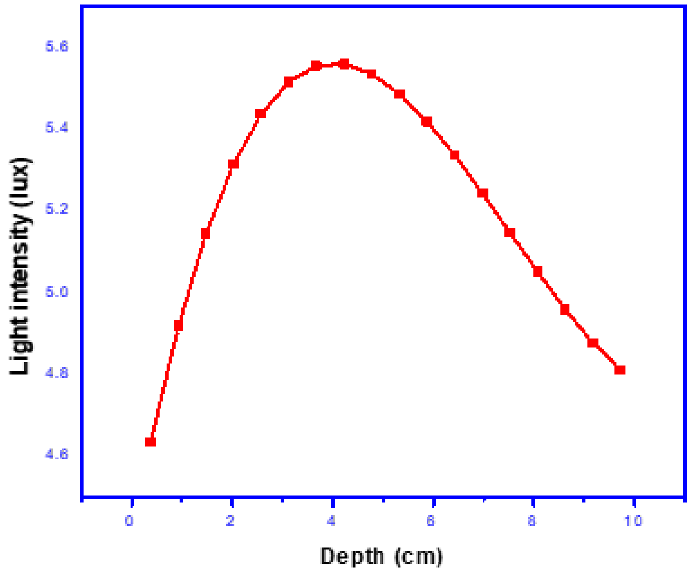
m \ n	n=1	n=2	n=3	n=4	n=5
m=0	2.40482555769577	5.52007811028631	8.65372791291101	11.7915344390142	14.9309177084877
m=1	3.83170597020751	7.01558666981561	10.1734681350627	13.3236919363142	16.4706300508776
m=2	5.13562230184068	8.41724414039986	11.6198411721490	14.7959517823512	17.9598194949878
m=3	6.38016189592398	9.76102312998166	13.0152007216984	16.2234661603187	19.4094152264350
m=4	7.58834243450380	11.0647094885011	14.3725366716175	17.6159660498048	20.8269329569623
m=5	8.77148381595995	12.3386041974669	15.7001740797116	18.9801338751799	22.2177998965612
m=6	9.93610952421768	13.5892901705412	17.0038196678160	20.3207892135665	23.5860844355813
m=7	11.0863700192450	14.8212687270131	18.2875828324817	21.6415410198484	24.9349278876730
m=8	12.2250922640046	16.0377741908877	19.5545364309970	22.9451731318746	26.2668146411766
m=9	13.3543004774353	17.2412203824891	20.8070477892641	24.2338852577505	27.5837489635730
m=10	14.4755006865545	18.4334636669665	22.0469853646978	25.5094505541828	28.8873750635304

Appendix A6: Panasonic Standard of light amount for Living room

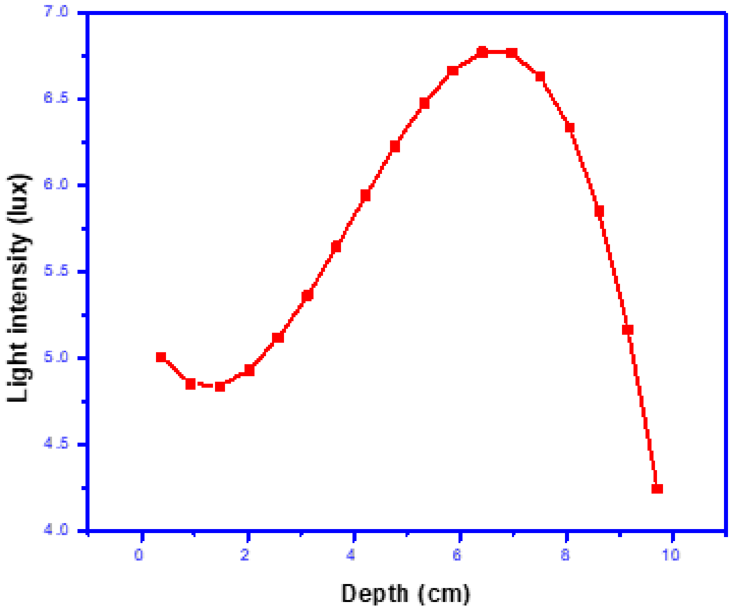


APPENDIX B: DEPTH DEPENDENCY OF LIGHT IN 6.7 CM RADIUSED CONTAINER.

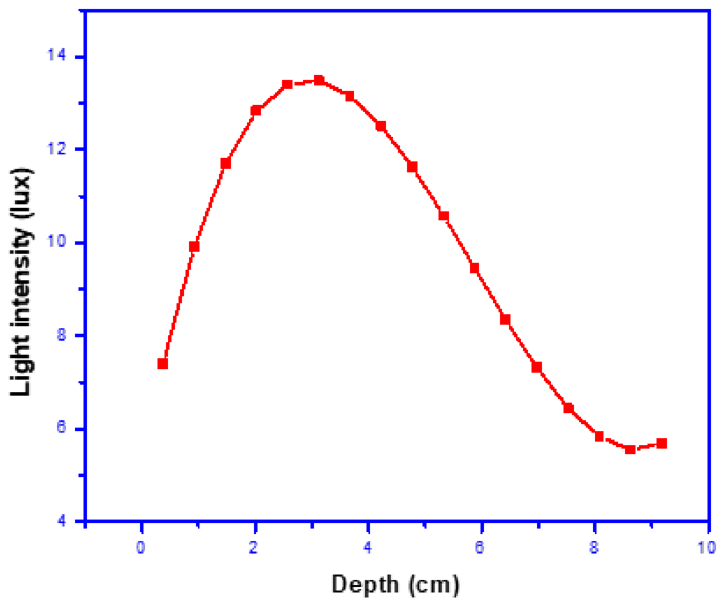
Appendix B1: Depth dependency of light intensity in Salt solution



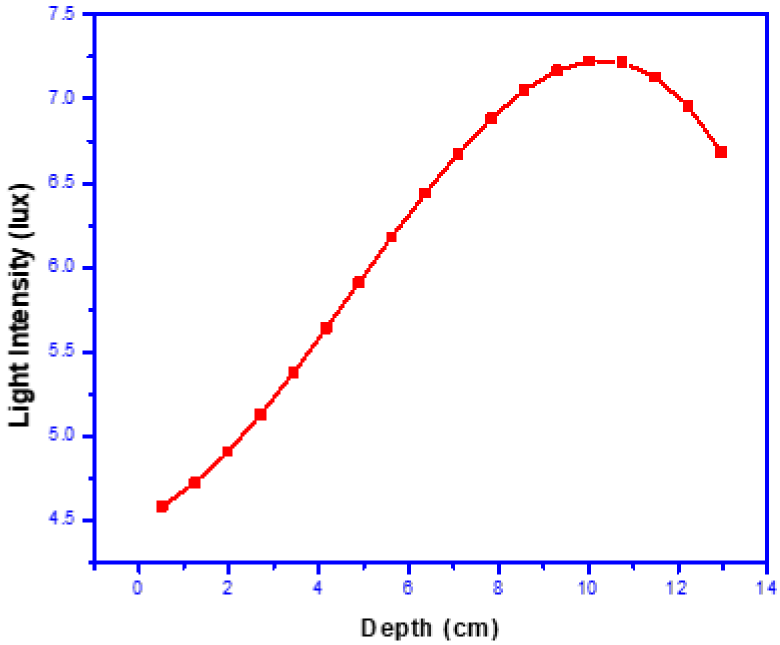
Appendix B2: Depth Dependency of Light Intensity in Sugar Solution



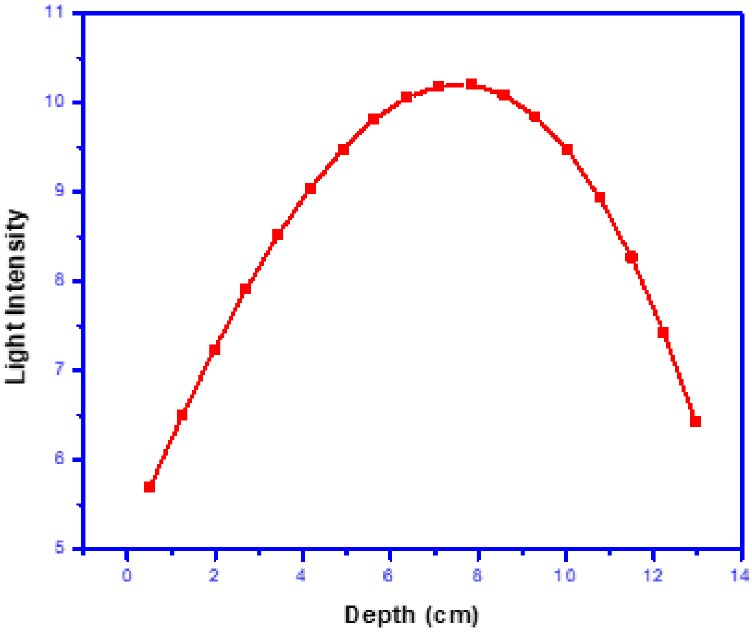
Appendix B3: Depth Dependency of Light Intensity in Sodium Bicarbonate Solution



Appendix B4: Depth Dependency of Light Intensity in Bottled Water Solution



Appendix B2: Depth Dependency of Light Intensity in Vinegar Solution

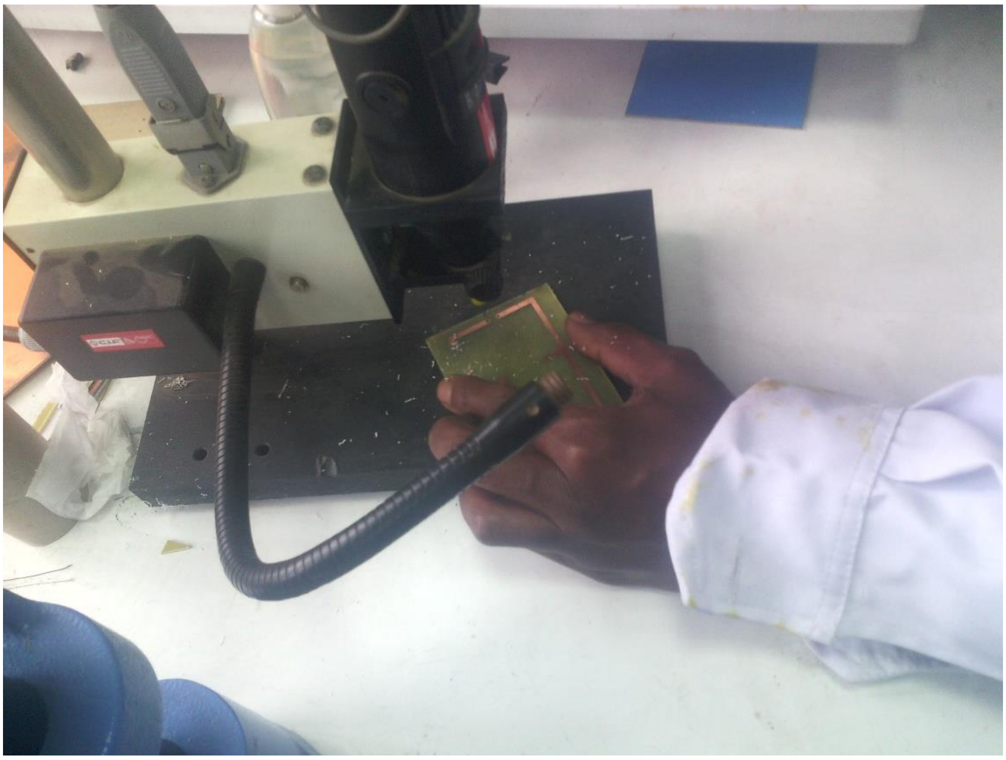


APPENDIX C: SYSTEM CONSTRUCTION PICTURES

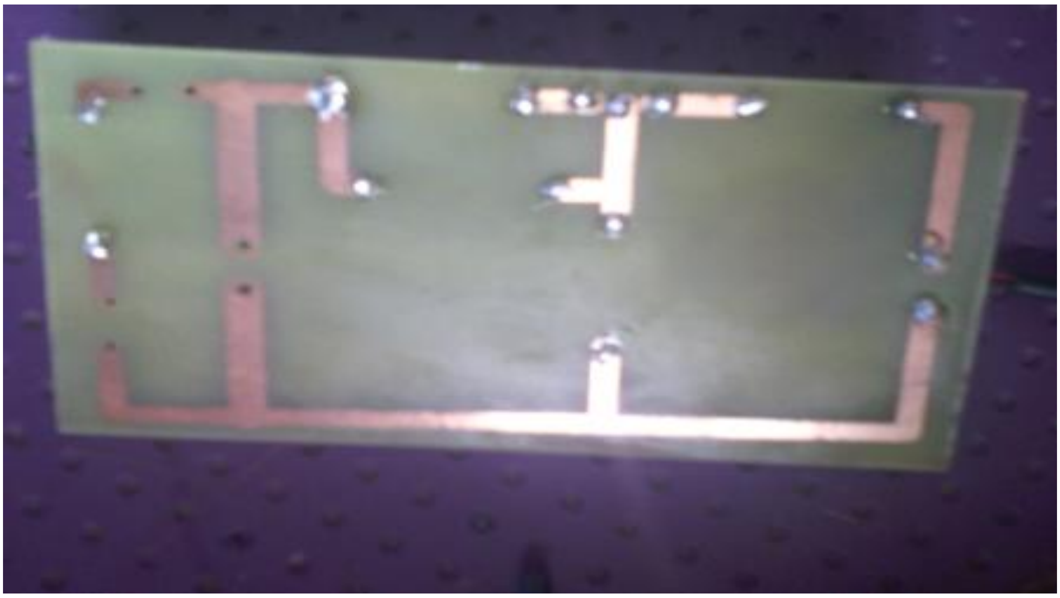
Appendix C1: painting with paraffin to make transparent the printed-out circuit design

Appendix C2: Printing the circuit board on photosensitive material

Appendix C3: Drilling The PCB

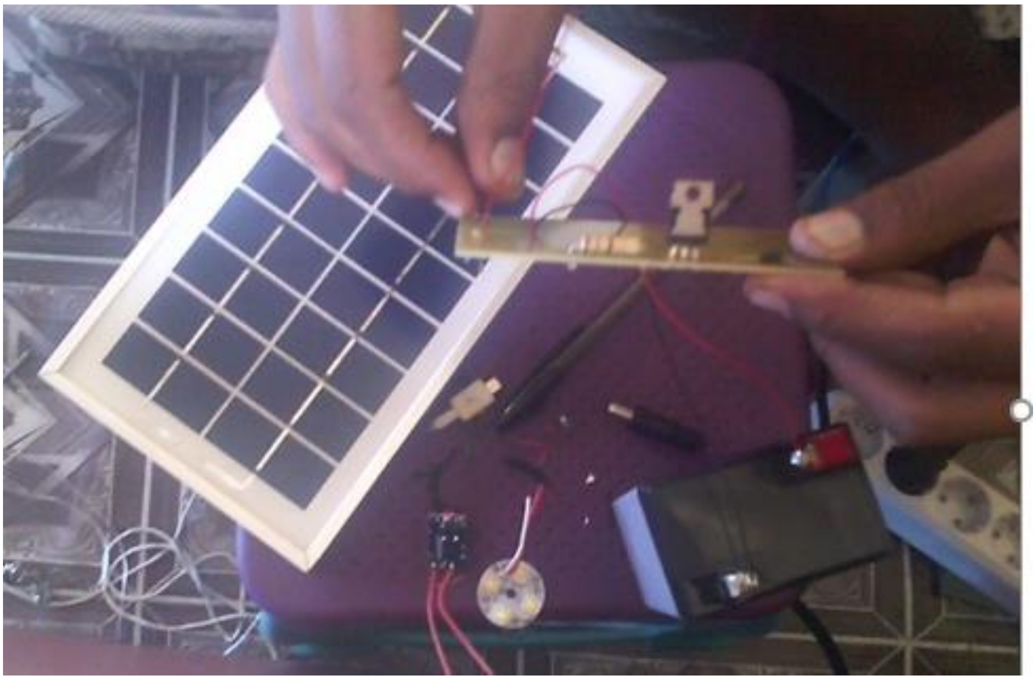


Appendix C4: Soldering the circuit Components

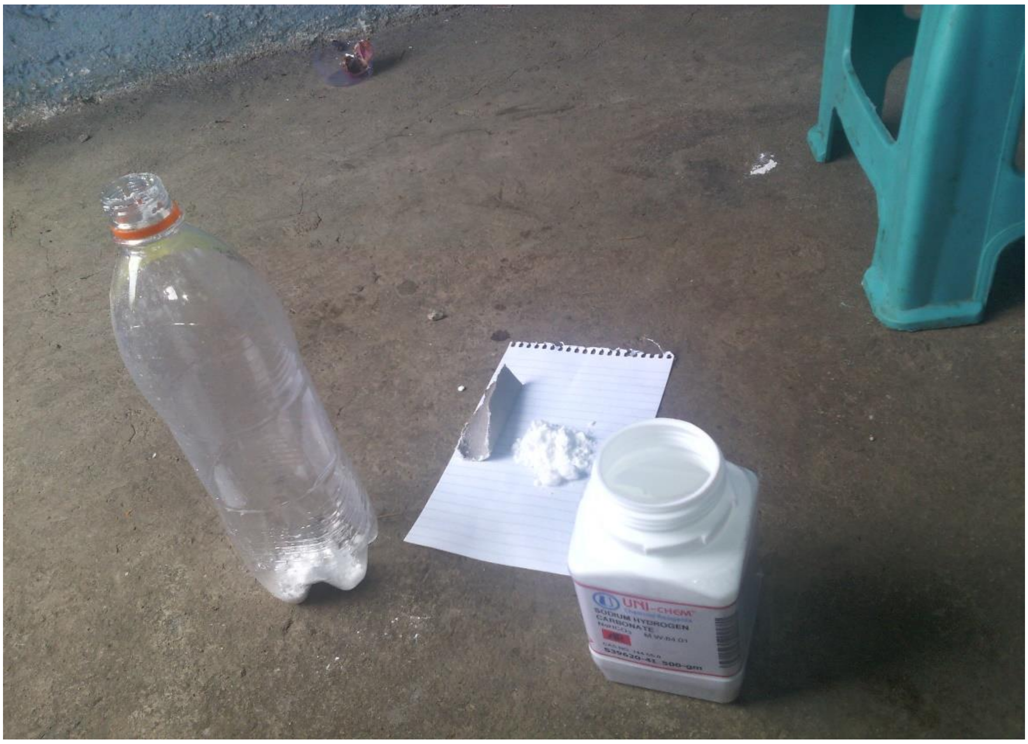


Appendix C5: Connecting with Battery

Appendix C6: Connecting with solar panel



Appendix C7: Preparing Solutions



Appendix C8: Testing in my house

Appendix C9: Alpha power 7Watt emergency light

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