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FACULTY OF ARCHITECTURE, PLANNING & SURVEYING
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A PROPOSED SOLAR STREETLIGHT DESIGN TOWARDS ENERGY EFFICIENCY FOR UNIVERSITI TUN HUSSEIN ONN MALAYSIA (UTHM)

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Abstract:
Street lighting is an essential public service that provides a safer environment at nighttime to commuters as well as pedestrians. Proper use of street lighting can be considered as a protective method that provides economic and social benefits to the people. However, the conventional streetlight had caused some serious problems. Long periods of wind, rain and sun exposure, low waterproof performance, and poor wire insulation have caused electricity leakage of conventional streetlight that may prove potentially great harm to people. Besides, the conventional street light requires great energy consumption. Therefore, the objectives of this research project are to identify the disadvantages of using conventional streetlights, to compare the energy efficiency, cost and safety of solar streetlights with the conventional streetlights, and to produce a proposed design for solar streetlights. The study location of this project is on the main campus of Universiti Tun Hussein Onn Malaysia (UTHM). In this project, four main processes had been conducted which are data collection process, analysis process, process of comparison, and the design process. With the data collection, an analysis had produced the current practicability of conventional streetlight, and a comparison with solar streetlight was conducted.

Keywords: Solar; Streetlight; Energy; Electrocution

1.0 INTRODUCTION
Every day, the sun radiates an enormous amount of solar energy. The solar energy which the sun radiates in one day is more than the world energy use in one year. The solar energy needs only 8 minutes to travel the 150,000,000 km to Earth (Phys.org, 2017). Solar energy travels at the speed of light, or 300,000 km per second (Phys.org, 2017). Only a small part of the visible radiant energy that the sun emits into space reaches the Earth, but that is more than enough to support the human requirement of energy. Solar energy is considered as a renewable energy source. Solar Streetlight provides light sources that are powered by photovoltaic panels generally mounted on the lighting structure or integrated into the pole itself (Himin Solar Co., Ltd, 2017). The photovoltaic panels charge a rechargeable battery, which powers a LED light bulb during nighttime (Himin Solar Co., Ltd, 2017).

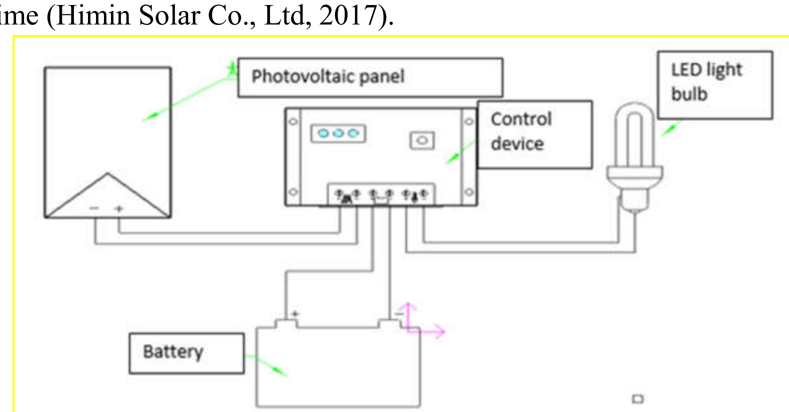


Figure 1: Solar streetlight system (Himin Solar Co., Ltd, 2017)

1.1 Problem Statement

1.1.1 Safety Issues - Hidden Danger of Lamp Leakage

Conventional Streetlight uses the 240V voltage power supply whilst the safe voltage for the human body is 36V. Hence, if any leakage occurs, it will endanger the safety of human life. Streetlights are outdoor lighting, thus their bodies are open to the wind and rain, sun exposure for a long time. The cover plate for the control device and wiring of a streetlight is simple, but if the waterproof performance is poor, ageing line insulation may easily fall off. Ordinary problems difficult to appear, the rainwater flows into them during rainy days, causing the water to carry the charge together, causing great danger to pedestrians.

Once the human gets electric shock, the body has a current through, and thus interfere with the nerve conduction of bioelectricity, making the brain out of control, feel abnormal stimulation, sends the wrong order of muscles and organs (Himin Solar Co., Ltd, 2017). Eventually the current passes through the heart, causing the heart to spasm and stop beating, which leads to dying of suffocation.

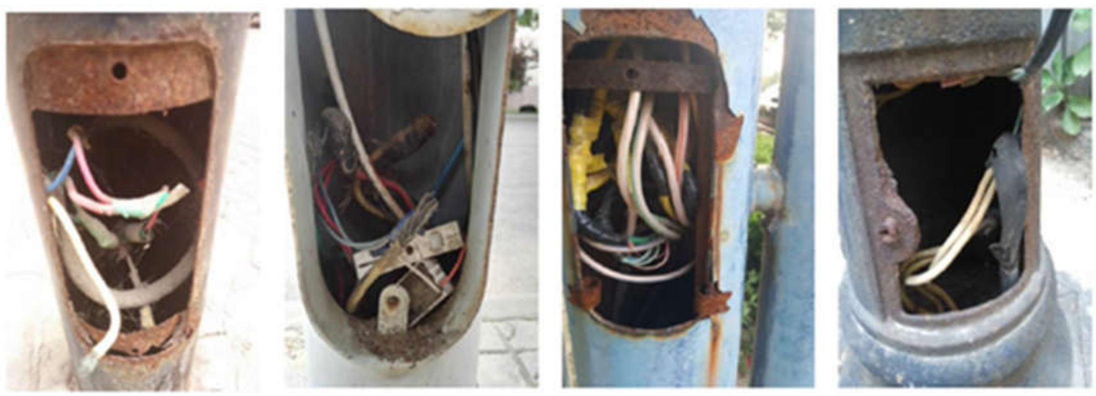


Figure 2: Improper installation of wire in conventional streetlight
(Himin Solar Co., Ltd, 2017)

1.1.2 Low Energy Efficiency

A Conventional Streetlight consumes large amount of electricity to light up the light bulb. The higher the electricity usage, the higher the bills needed to spend. In UTHM, the conventional streetlights are located all around campus, and it is very necessary to secure the safety of all university staff and students. Every month, the university authority must pay to the government with the high-value cost of electricity bills. Excessive use of electricity will increase the environmental problem. This is not because the electricity causes pollution, the fuels used to generate electricity release pollutants during the process.

Table 1: Electricity bills for the years 2016 and 2017 at UTHM main campus

		2017		2016	
No.	Month	kWh	RM	kWh	RM
1	Jan	2256096	996954.75	2376343	1049247.61
2	Feb	2179734	976909.85	2224489	1000706.92
3	Mac	2725830	1176307.20	3012959	1218131.17
4	Apr	2597001	1129176.20	2797192	1216488.09
5	Mei	2826637	1218693.15	3011201	1215024.86
6	Jun	2122300	950575.55	2476527	1078011.16
7	Jul	2275021	984573.10	1936780	861625.83
8	Aug	2044741	900117.55	2163858	950727.71
9	Sep	2104552	941243.31	2444475	1073611.00
10	Oct	2534506	Unknown	2768369	1193367.25

11	Nov	2520687	Unknown	2706516	1104980.80
12	Dec	2324443	Unknown	2502642	1169033.91
	Total	21131912 (without Oct, Nov, Dec)	9274550.66 (without Oct, Nov, Dec)	30421351	13131006.32

Based on Table 1 above, the cost per kWh in 2016 and 2017 were RM0.44 per kWh and RM0.43 per kWh respectively.

Table 2: Simple Calculation of 264 units of Conventional Street Light in UTHM

Unit:	1	264
Operation hours (hours):	12	12
Annual energy usage:	365 x 3 = 1095kWh	365 x 3 x 264 = 289080kWh
Annual cost per kWh:	1095kWh x RM0.44 per kWh = RM481.80	289080kWh x RM0.44 per kWh = RM127195.20

1.2 Objectives

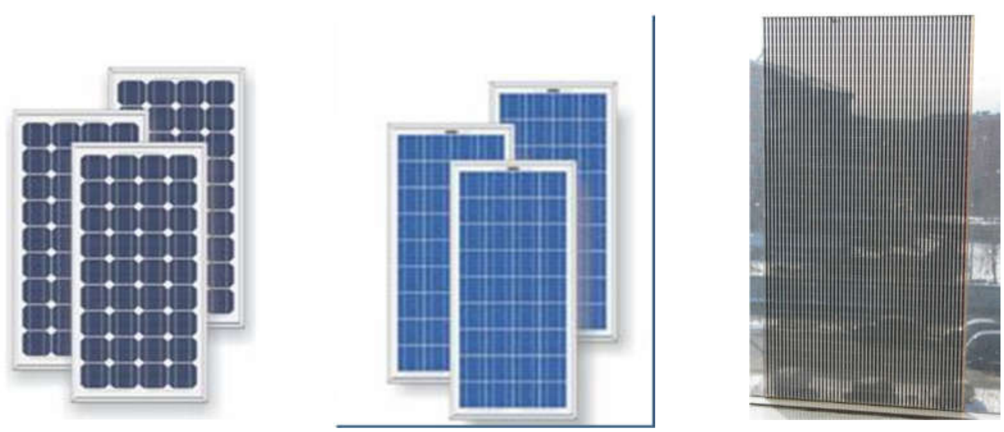
Hence, the objectives of this research are, i) to identify the disadvantages of using conventional streetlights; ii) to compare the energy efficiency, cost and safety of solar streetlights with the conventional streetlights; and iii) to produce a proposed design for solar streetlights.

2.0 LITERATURE REVIEW

2.1 Component of Solar Street Light

2.1.1 Solar Panel

A solar panel is a photovoltaic module using solar radiation from the sun to generate electricity through the photovoltaic effect. The electricity generated is in Direct Current (DC) form. There are three types of solar panel:



Mono-crystalline silicon **Poly-crystalline silicon** **Thin-film (non-crystalline silicon)**

Figure 3: Three types of solar panel
(Himin Solar Co., Ltd, 2017)

2.1.2 Battery

A battery is used to store the electricity generated by the solar panels. The electricity generated at a solar panel during daytime will be transferred through the wiring to charge the battery. The electricity will be used to light up the LED light bulb during night time every day. There are four types of rechargeable batteries, which are:

Lead Acid Battery
(Bhphotovideo.com, 2017)

Gelled Battery
(O'Connor, 2017)

Lithium Battery
(Lithiumion-batteries.com, 2017)

Lead Carbon Battery
(DirectIndustry, 2017)

Figure 4: Four types of rechargeable batteries
(Himin Solar Co., Ltd, 2017)

2.1.3 LED Lamp

LED lamps have lifespans and electrical efficiencies that are several times greater than incandescent lamps. They are also significantly more efficient than most fluorescent lamps, with some chips able to emit more than 300 lumens per watt (Himin Solar Co., Ltd, 2017).The energy efficiency of LED achieves the highest standards worldwide. LED light can contribute between 30% and 50% of electricity savings in buildings (Hidalgo el at., 2017). The advantages of using LED light bulbs are long life span, high luminous efficiency, good colour rendering and uniform light distribution.




Figure 5: LED Lamp (Himin Solar Co., Ltd, 2017)

2.1.4 Controller

A Controller is the core component of solar street lighting system, which prevents overcharge and over discharge of battery, prevents the reverse flow of electricity, and avoids the unnecessary discharge of battery (Himin Solar Co., Ltd, 2017). The Controller controls the flow of electricity from solar panel to battery. Besides, the controller has certain functions such as light control and time control that decide the time for LED to light up. When the battery discharges until 80% of its total volume, the controller will cut off the flow of electricity to the battery to prevent overcharge (Himin Solar Co., Ltd, 2017). Same case when the battery is left with 20% of electricity, the controller will stop the electricity flow to the LED light bulb to prevent over discharge (Himin Solar Co., Ltd, 2017)

Figure 6: Controller of Himin Solar Company China (Himin Solar Co., Ltd, 2017)

2.2 Case Study

Some countries had successfully implemented the solar streetlight system with the response on the application getting good expectations. Some of these are:

- Solar Street Light Bring Safety and Business Back To Somalia March 2016 (U.S. Agency for International Development, 2017)
- First Smart Solar Street Light in Serbia: New Smart City Initiative Belgrade, Serbia (New Smart City initiative, 2017).
- Renewable Energy Law of China (Tsai et al., 2017)
- Graz, Street Light (Radocha & Baumgartner, 2017).

2.3 Accident Cases

The study's problem statement has explained about the importance of ensuring the safety issues of conventional streetlights and their hazards. The real accident cases related to the problem statement are described below:

- 6-year-old boy dies after touching street light pole. (Mendonca, 2018)
- Boy who received electric shock from fallen light pole in Mandurah. (ABC News, 2018)
- Man, 20, Electrocuted Trying to Cut Power to Street Light. (latimes, 2018)
- Call to fix streetlights after children electrocuted. (News24, 2018)
- Youth killed by electric shock after urinating against a street light. (thinkSPAIN, 2018)

3.0 METHODOLOGY

Figure 7 summarise the methodology adopted for this study.

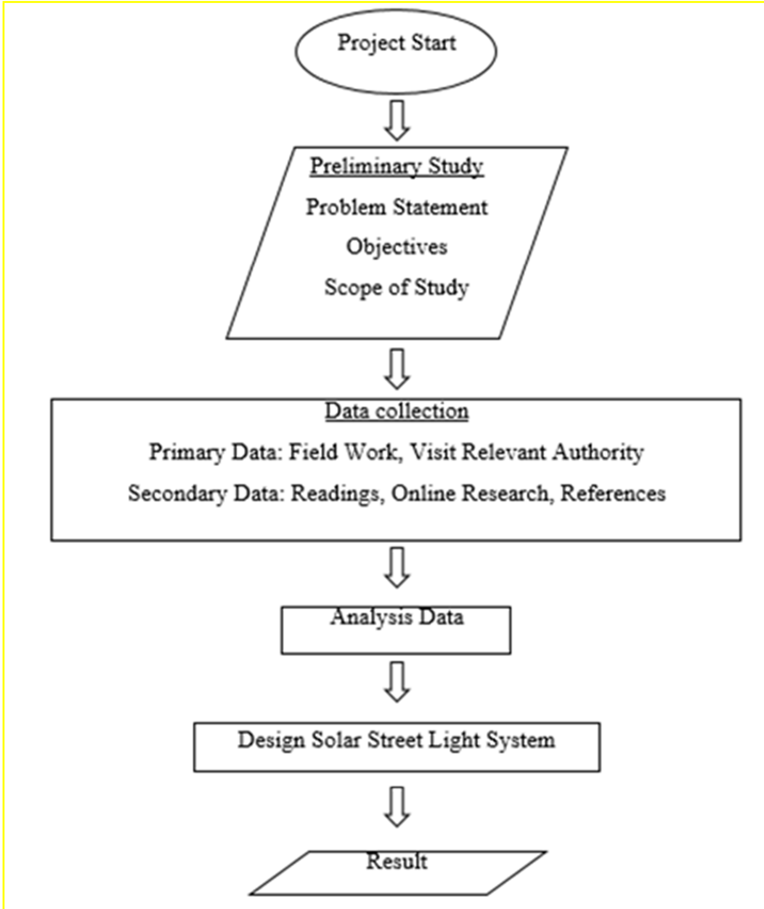


Figure 7: Methodology Scheme

4.0 ANALYSIS OF PRELIMINARY DATA AND FINAL DATA

4.1 Comparison of cost and safety between conventional streetlights and solar streetlights

The conditions are detailed as follows:

- 1km
- 33 streetlights
- 30 meters spacing
- conventional streetlight price = RM1010/set
- Solar streetlight = RM3750/set
- 10 years of service life

All the information and analyses are referred from Himin Solar Company China.

Table 3: Comparison between Solar and Conventional Street Light

Solar Street light	Conventional Street light
Price: RM3750 x 33 = RM123750 Installation fees: RM320 x 33 = RM10560 Packages fees (transportation):RM100 x 33 = RM3300 Maintenance fees:	Price: RM1010 x 33 = RM33330 Installation fees: RM33330 x 10% = RM3333 Packages fees: RM181800 Maintenance fees: Working fees (assume

Change Battery (10 years once) RM320 x 33 = RM10560 Safety issue: Working voltage as DC 12V, safe to human, well stability, don't cause any electric shock accident. Total cost: RM148170	3kWh per day), RM0.44 x 365 x 10 x 33 x 3 = RM158994 Maintenance, RM80 x 3 times x 33 = RM7920 Safety issue: Working voltage as AC 240V, perennial maintenance, there will have electrocution accident during flooding or raining, cause blackout. Total cost: RM382377

4.2 Data Collection

Based on the information from the Global Solar Atlas website (Globalsolaratlas.info, 2018), the solar information is recorded as follows:

Table 4: Data Collection

Location:	Universiti Tun Hussein Onn Malaysia
Photovoltaic electricity output (PVOUT):	3.553 $\frac{kWh}{kWp}$ $\boldsymbol{per\ day}$
Global horizontal irradiation (GHI):	4.597 $\frac{kWh}{m^2}$ $\boldsymbol{per\ day}$
Direct normal irradiation (DNI):	2.551 $\frac{kWh}{m^2}$ $\boldsymbol{per\ day}$
Diffuse horizontal irradiation (DIF):	2.551 $\frac{kWh}{m^2}$ $\boldsymbol{per\ day}$
Global tilted irradiation for fixed systems at optimum angle (GTI):	4.6 $\frac{kWh}{m^2}$ $\boldsymbol{per\ day}$
Optimum angle of PV modules (OPTA):	$\mathbf{2^{\circ}/180^{\circ}}$
Temperature (TEMP):	26.3°C
Elevation (TERRAIN):	7m

4.3 Layout of Conventional Street Light in UTHM

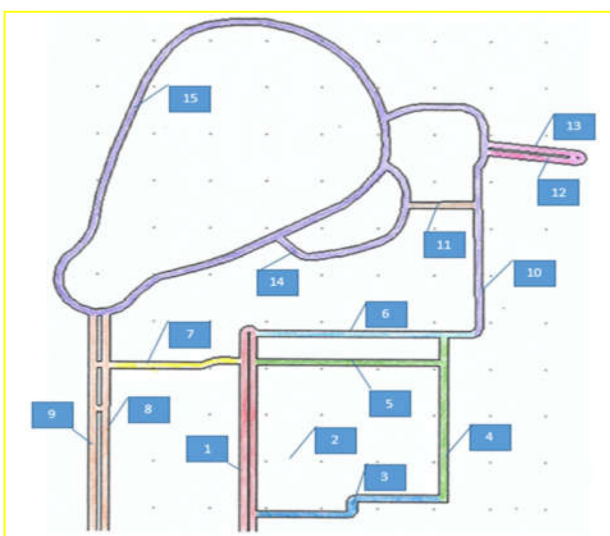
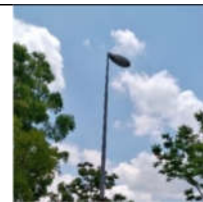
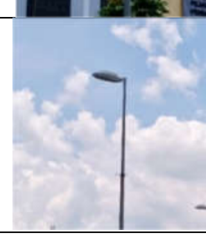
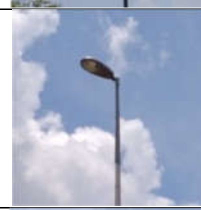
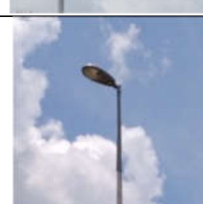
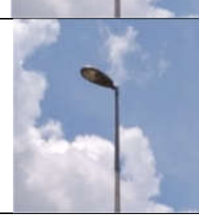


Figure 8: Layout of Conventional Street Light in UTHM

4.4 Detailed Layout Information

Table 5 Detail Layout Information

No.	Distance (km)	Number of Existing Conventional Street light (units)	Picture
1	0.510	19	
2	0.510	19	
3	0.495	14+7	 
4	0.332	14	
5	0.392	16	
6	0.467	15	
7	0.294	11	

8	0.567	16	
9	0.567	16	
10	0.800	22	
11	0.144	4	
12	0.226	7	
13	0.226	8	
14	0.540	12	
15	2.410	64	
	Total :	**264 units**	

5.0 DESIGN PROPOSAL

5.1 Conceptual design

The location of the project is at Universiti Tun Hussein Onn Malaysia, where the type of project is concentrated to Solar Street Light . The light source type: is known as High efficiency LED and the Operation mode is light control. The arrangement of solar street light is shown in Figure 9.

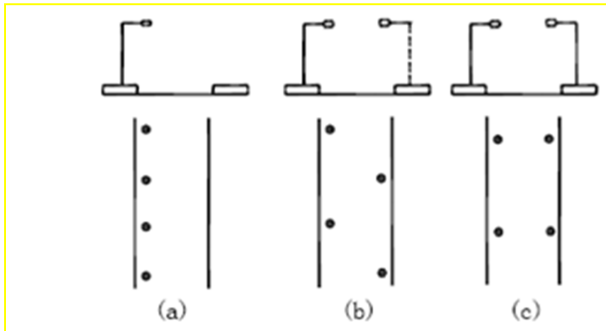


Figure 9: Arrangement of solar streetlights (Himin Solar Co., Ltd, 2017)

Table 6: Arrangement of solar streetlights (Himin Solar Co., Ltd, 2017)

Layout arrangement	Installation Height, H(m)	Separate Distance, S(m)
Unilateral	H ≥ 1.2Weff	S ≤ 3.5H
Double staggered	H ≥ 0.8Weff	S ≤ 3.5H
Bilateral symmetry	H ≥ 0.6Weff	S ≤ 3.5H

Weff = Width of the road.

Table 7 Power of light sources vs Height of streetlights (Himin Solar Co., Ltd, 2017)

Light source type	Height of Solar street light (m)	Power of light source (W)
LED	5 - 6	20 - 40
	7 - 8	60 - 80
	9 - 10	80 - 100
	11 - 13	120 - 150

Arrangement of solar streetlight = unilateral arrangement
Width of the road = 7m
Installation height will be:

H ≥ 1.2 x Weff
H ≥ 1.2 x 7
H ≥ 8.4m (Used: 9m)

Separate distance between each solar street light will be:

S ≤ 3.5H
S ≤ 3.5 x 9
S ≤ 31.5m (Used: 30m)

Base on the Table 7, the power of light source can be set between 80W to 100W.

5.2 Detail Layout Information of Solar Street Light Proposed

Table 9: Number of Solar Street Light Proposed (units), with separate distance of 30m

No.	Distance (km)	Number of Solar Street Light Proposed (units), with separate distance of 30m
1	0.510	17
2	0.510	17
3	0.495	17
4	0.332	11
5	0.392	13
6	0.467	16
7	0.294	10
8	0.567	19
9	0.567	19
10	0.800	27
11	0.144	5
12	0.226	8
13	0.226	8
14	0.540	18
15	2.410	80
	Total :	285 units

5.3 Components of Solar Street Light

5.3.1 Controller

Controller is the device that controls the entire solar street light system. Inside the controller, it is important to design the operation mode. The operation mode can be divided into two types namely light control and time control. Light control system uses light sensor to decide the necessity of streetlight to operate. The important component in light sensor system is the photoresistor, which contains cadmium sulfide that causes the device to conduct or resist electricity current flow in the presence or absence of light. Time control is controlled by the flow of time, which has a serious disadvantage of non-functionality on rainy days during daytime. In this design, only light control system is proposed to Solar Street Light system.

5.3.2 LED Lamp

The height of the solar street light is set at 9 m, and the power of light source can be set between 80W to 100W. Therefore, 90Watt LED lamp is proposed, where 90W/1000 x 12hours = 1.08kWh per day. Hence, the Solar Street Light needs 1.08kWh to light up the place for 12 hours every day.

5.3.3 Rechargeable Battery

The battery needs to be functional for a minimum of 3 days continuously under rainy and dark conditions. Total energy use in 3 days was 3.24kWh. In addition, due to the consideration on the quality of battery, 40% of the total volume must added.

3.24kWh + (40% of total volume) = total volume
Total Volume of Rechargeable Battery = 5.4kWh
The Volume of Rechargeable Battery proposed must be more than 5.4kWh or 5400Wh.

5.3.4 Solar Panel

1 ft^2 of solar panel is able to generate 100 watt. The rechargeable battery must be fully charged before installation. Every day the energy will use out 1.08kWh. Under this condition, 2 square feet of solar panel is proposed.

2ft^2 of solar panel produces 200Watt

200Watt x 7 hours per day (presence of sunlight in Malaysia) = 1.4kWh per day
$2ft^2$ of solar panel produces enough energy to recharge the battery every day.

5.4 Foundation of Solar Street Light

Solar Street Light is an independent element. The foundation of every set of streetlight is very important because it must be able to withstand the wind, climate changes and able to protect the battery from underground moisture. Steps of installation are proposed as below:

- Installation of the Foundation - Dig two areas, Area A is for basic cage of streetlight pole, Area B is for Battery storage. Screw or fix the basic cage to the dug area using four screws. Make sure one side of basic cage is parallel to the roadway. Lean fully C25 concrete into Area A to secure the basic cage.
- Installation of the battery and container - Place the battery into the container and insert into Area B underground about 600mm from surface. Make sure the connection wiring of electricity circuit is properly connected.
- Erect streetlight pole to the correct position. Ensure that the streetlight pole is upright on the bottom plate. Secure it with bolts. Check that all the wiring is connected properly

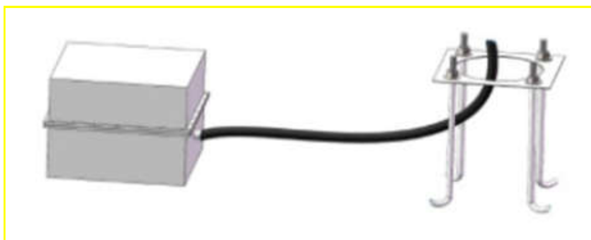


Figure 10: Basic cage and Container (Manufacturer, 2018)

5.5 Proposed Design of Solar Street Light

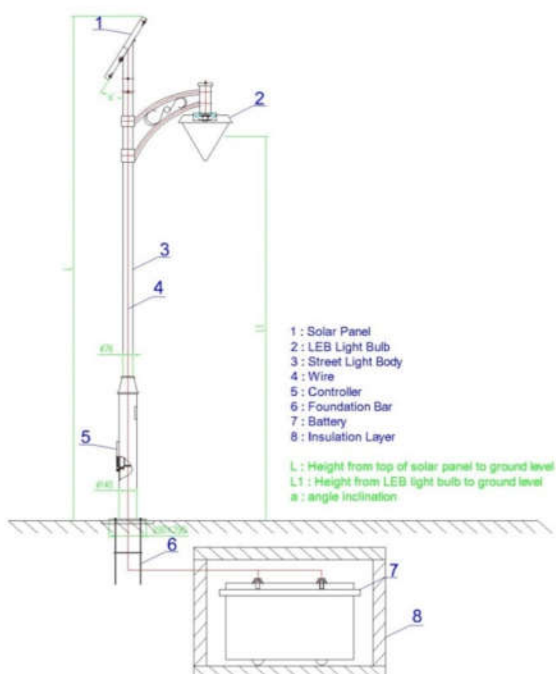


Figure 11: Proposed design of Solar Street Light

6.0 CONCLUSION

Through this research study, it is proved that the solar streetlight is more energy-efficient than the conventional streetlight. Besides, the solar streetlight is much safer than the conventional way. The proposed design of solar streetlight system was elaborated in Chapter 5.0 above. The quality standard of each component in the system was provided.

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