The study of the application of crystalline silicone solar cell type for a temporary flood camp

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Abstract. During flood period, most of temporary evacuation shelters in Jakarta are lack in electricity because the local electricity company turned the electricity off to avoid any electrical problem because of the high water level over the flooded area. Whereas, the local electricity or the grid is the main energy source for the lighting and water pump machine, therefore the energy source becomes a significant issue during this period. Currently, the local government has already provided diesel generators to substitute the local grid when it is off, however, the amount of the generators is still limited. This study, therefore, investigated an alternative energy for the electricity, particularly solar energy and this paper presents an analysis of the Jakarta duration of sunshine during rainy seasons in order to investigate which Crystalline Silicone solar cell type that can be implemented optimally for energy supply in the period of flood evacuation as well as for the shelter. A deep analysis on literature review was conducted on the three types of Crystalline Silicone solar cell, Jakarta local weather. Furthermore, the standard of International Federation of Red Cross and Red Crescent Societies (IFRC) was also studied for the shelter design. The results of this study could be used as a reference for the local authority in providing the substitute energy supply in the temporary evacuation area during flood period in which the solar energy source could be also attached on the shelter.

Keywords: energy source alternative, Crystalline silicone, solar cell and temporary flood camp.

1. Introduction

Jakarta is essentially located in a lowland area which is also adjacent to the Jakarta sea as well as in the meeting point of some rivers and canals (Table 1). This condition causes some area of Jakarta is potential to be a flood prone area.

Floods disaster in Jakarta is increasing from year to year. In 1980, about an area of 7.7 km² or about 1% from the total area of Jakarta, was affected, whereas in 2002 and 2007 the flooded area increased significantly to about 13% and 45% from the whole area of Jakarta consecutively [1].
Table 1. The Geographic feature of Jakarta location

| Geographical features | Information                                      |
|-----------------------|--------------------------------------------------|
| The geographic location | Latitude: -6.012  
                          | Longitude: 106048                  |
| Coastal line          | ± 35 km                                          |
| Rivers                | Angke, Pesanggrahan, Monkervart, Grogol, Krukut,  
                          | Cipinang, Sunter, Kalibaru Barat, Jati Kramat, Ciden  
                          | dan Buaran                                    |
| Drainase              | Cakung dan Cengkareng                           |
| Canal                 | East and West Flood Canal                        |
| Altitude              | 7 meters above sea level (60%)  
                          | 1-1.5 meters below sea level (40%)          |

Source: The Jakarta local government, 2015

During the flood period, the people stay at a temporary shelter at some locations which are appointed by the local government. However, there is a significant lack of electricity during at that time as the electricity supply is interrupted by the flood. Based on this condition, the local government has made a plan and regulation for mitigation, namely The Emergency Operation Plan. This plan refers to the Government policy number PP21/2008 which focuses on the provision of electricity. The local government, currently, has provided some diesel generator as the electricity backup, however, the number of generators are not adequate. There are only 66 generators of 124 for 70 flood prone area [1]. Indeed, the electrical energy source become an issue during this period. The issue of energy in a refugee camp also occurs in other countries. However, some countries have applied solar energy to substitute fossil fuel and the use of solar energy for a refugee camp has been reported that it is effective and it also can save million dollars [2].

This study, therefore, investigated the Jakarta sunshine duration in the period of flood in order to know the appropriate solar energy, particularly Crystalline Silicone that can be applied in a temporary camp using the local data provided by the Meteorology, Climatology and Geophysical Institution. Subsequently, the standard of the IFRC was applied in order to finalize the solar cell type that has potential to be integrated on a refugee shelter.

2. Literature review

2.1. Duration of sunshine in Jakarta during rainy seasons

Duration of sunshine, that is calculated in percentage (%), is one of several elements of climatology, and is defined as the power of the sun that exceeds 120 W/m². A short sunshine duration indicates that sunlight is blocked by thick cloud, so that the intensity is less than 120 W/m² [3].

The yearly percentage of the Jakarta sunshine duration is presented in Fig.1. It can be analysed that in rainy seasons, particularly from December to March, the period of the sunshine duration is less than 50%. This number has shown that during the months the sky is mostly cloudy. This condition is significant in order to determine the selection of solar cell. The intensity of light on cloudy day reduces since there is a large amount of water vapour in sky, as according to a study conducted in Singapore, the peak efficiency of a solar cell made from silicon is in the range of between 200 W/m² and 500 W/m² [4].
2.2. Photovoltaic

In general, the ‘photovoltaic effect’, that was first discovered by Edmund Becquerel in 1839, is a direct conversion of sunlight into electricity using solar cells. The sun emits energy, namely ‘photon’, in the form of spectrum or optical frequency of light. Based on the quantum theory, higher frequencies have higher photon energies. The photon energy must exceed the solar cell band gap to be absorbed for electricity generation.

The band gap energy is the amount of energy and is in electron volts (eV). It is required to stimulate an electron that is wedged in its bound state into a free state where it can participate in conduction. The energy level at where an electron can be considered free is named “conduction band”, while, the lower energy level of a semiconductor is called the “valence energy”. Fig. 2 shows the schematic of an electron that can jump from the Valence band to the Conduction band in a semiconductor material. The band gap for solar cell made from crystalline silicon, the widely used material of semiconductor, is 1.1eV (Fig. 3) [5].

Figure 1: The average duration of sunshine in Jakarta last 10 years
Source: Government institution of development supervision and control

Figure 2: The schematic of the energy bands for electrons
Source: http://pveducation.org
In terms of Crystalline Silicone, it has 4 varieties in terms of its level of crystallinity: (1) single crystalline, (2) semi crystalline, (3) poly crystalline, and (4) amorphous (Stephen, 1983). Since the semi crystalline is rare being produced, so that this study only focused on the other three types in order to be discussed to investigated which of the types is the most appropriate to be utilized for a temporary energy supply in the evacuation period in Jakarta particularly in rainy seasons.

2.3. Design standard for shelter by the IFRC

In general, The International Federation of Red Cross and Red Crescent Societies has determined 12 principles in designing shelters, and they are as follows: (1) appropriateness, (2) developing a shelter design brief, (3) relocation, reuse and maintenance, (4) hazards, risk and safety, (5) timelines, and construction speed, (6) life span, (7) size and shape, (8) privacy, security and appropriateness, (9) ventilation and thermal comfort, (10) environment, (11) land, site and service, and (12) cost and budgets [6]. However, since the analysis was only on the selection of the solar cell, therefore, this study only used 5 principles and they are defined as follows:

1. Reuse and maintenance
   Construction made considering the maintenance factor that can support the lives of people who live in refugee camps. This includes the financing of the maintenance as well as predictions for the renewal of its construction.

2. Hazards, risks and safety
   The design minimizes the impact on the destruction of nature and the safety factor of the refugee community. It is included in the selection of materials of construction which are not causing environmental damage, such as the use of materials of natural materials can be minimal.

3. Timeless and constructed speed
   Construction considering the ease in transportation, ease of storage and material supply. Ease in the provision of material should use local materials. In addition is the availability of the factors that can build practically and it takes a long time.

4. Life span
   In planning the design should be expected when construction can be used. Therefore, the design should be recycled or refurbished

5. Size and shape
   Size can be made effective and flexible to be placed in all conditions.
3. Methodology

This study aims to investigate the appropriate crystalline Silicone (Si) solar cell type for a temporary evacuation area, the methodology, therefore, include two methods:

1. The electricity calculation in the evacuation area.
2. The analysis on the crystalline Si solar cell type that meet the local climate and the IFRC standard. This include: safety, cost, number of material and life span.

The selected area of this study was SD Baitul Khair building. The school was a two story school building with an area of about 130 m² and was located on Jalan Kebon Pala I, Kampung Melayu, Jakarta. This area is on a low terrain and is nearby the Ciliwung River (Fig. 4). In rainy seasons, particularly on February, this location is often affected by flood and the level of water was around 1 (one) meter, so that the inhabitants should be moved to the nearby evacuation area and SD Baitul Khair building was one of several building that was appointed by the local government (Fig. 5).

![Figure 4. SD Baitul Khoir location](source: Google Maps)

The evacuee, particularly woman, children and elderly, were placed in the buildings and the men were in the open area. The local government provides a temporary shelter. However, the alternative energy for electricity is still limited and this building does not get the diesel generator.

![Figure 5. SD Baitul Khair](source: Google Maps)
4. Results and discussion

4.1. Crystalline Silicone type and its response to the cloudy weather

The analysis is focused on the study of the three varieties of solar cell made of Crystalline Silicon characteristics in relation to the Jakarta local weather during rainy season. Table 2 shows the analysis on the cell structure and its ability on response to the weather.

| Type of Crystalline Silicon | Type of structure | Type of fabricated | The cell structure form | Response to cloudy weather |
|-----------------------------|-------------------|--------------------|-------------------------|---------------------------|
| Single crystalline          | Ordered crystal structure | Wafer             |                         | The efficiency is significantly affected by cloudy sky [7][9] |
| Poly crystalline            | There is a presence of grain boundaries, so that the ordered crystal structure is become slightly distracted | Wafer             |                         | The efficiency is significantly affected by cloudy sky [8][9] |
| Amorphous crystalline      | The order of the cell is disordered. | Thin film and wafer |                         | Better response to the cloudy day, as this type of cell absorb broader range of light intensity such as UV light and infrared [8][9]. |

It can be seen from the table that amorphous crystalline silicone is the most responsive to the cloudy sky.

4.2. The selection of Crystalline Silicone based on the IFRC standard

The analysis on the IFRC standard was conducted as the selected crystalline Silicone type will be deployed to a shelter design.

| Variabel | Criteria | Single Crystalline (Wafer) | Poly Crystalline (Wafer) | Amorphous (thin film) |
|-----------|----------|---------------------------|--------------------------|-----------------------|
| Reuse and maintenance | Construction made considering the maintenance factor that can support the lives of people who live in refugee camps. This includes the financing of the maintenance as well as predictions for the renewal of its construction. The design minimizes the impact on the destruction of nature and the safety factor of the refugee community. It is included in the | Relatively easy maintenance But expensive | Relatively easy maintenance, but expensive | Relatively easy maintenance, relatively cheaper |
| Hazards, risks and safety | Safe | Safe | Safe |
| Variation | Criteria                                                                 | Single Crystalline (Wafer) | Poly Crystalline (Wafer) | Amorphous (thin film) |
|-----------|---------------------------------------------------------------------------|----------------------------|--------------------------|-----------------------|
| Timeless and constructed speed | Selection of materials of construction which do not cause environmental damage | Slightly difficult for large solar panel | Slightly difficult for large solar panel | Flexible |
| Life span | Construction considering the ease in transportation, ease of storage and material supply. | The design could be recycled or refurbished | The used panel can be used for new shelter or design | The used thin film can be used for new shelter or design, but it is more fragile |
| Size and shape | Size can be made effective and flexible to be placed in all conditions. | Inflexible for a large panel | Inflexible for a large panel | Flexible |

The analysis shows that the three type of crystalline Silicone type are potential to be used for a shelter, however, the amorphous type is cheaper and more flexible than the other two. Therefore, the amorphous type is selected to be deployed in the selected refugee camp.

4.3. Electricity need calculation

The electricity is required mainly for lighting and water pump. Therefore, this study only calculated the amount of electricity for those issues. The selected lamps type is a low energy lamp which the energy specification is around 20 Watts.

**Table 4. The calculation of electricity**

| Name of the area | Quantity | Amount of energy (Watt) | Length of utilization (hour) | Total Energy (Watt hour) |
|------------------|----------|-------------------------|----------------------------|--------------------------|
| Class rooms      | 20       | 20 Watt for each lamp   | 12 (night time only)        | 4800 Watthour            |
| Water pump       | 1        | 300 Watt                | 3 (night and day time)      | 900                      |
| Total            |          |                         |                            | 5700 Watthour            |

As can be seen from the table, the total electricity should be provided is 8.1 KWh. The use of electricity for lamps is assumed only at night time, while, for the water pump is for night and day time.

Based on the calculation above and refer to the previous section (4.2), the required area for the amorphous solar cell can be calculated by a general formula:

\[ P = E \times \eta \times A \]  

where \( P \) is Power (Watt), \( E \) is the Irradiance level (Wm-2), \( \eta \) is the efficiency of the selected cell and \( A \) is the area of the solar cell (m2).

The calculation used assumption as follows:
- The average irradiance level on cloudy days is around 500 Wm-2
- The effective sun hour is 3 hours.
- The efficiency of the cell is 7.9% (based on the available product)
The final results of the required area of the amorphous solar cell is : 48 m². This area is fit with the area of the open space in the selected case study.

5. Conclusion
An analysis on the type of crystalline Silicon solar cell in relation to the local weather during rainy seasons in Jakarta has been conducted as well as the selection analysis on the standard IFRC. There are several concluding remarks, and they are as follows:

- The amorphous type is the most appropriate crystalline Silicone solar cell.
- The required area of the thin film is fit with the required electricity demand and the available open space area of the temporary evacuation camp.

Subsequently, the form of the shelter design when it uses thin film could be an integrated shelter with the thin film or the thin film it could be a solar umbrella that cover the shelter.

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