Usage of recycling materials of PVC material in designing of solar panel floaters

ABSTRACT

The purpose of this report is to study the impact of Plywood and PVC materials for the development of Solar Panel Floaters. Solar panels are the world's largest source of renewable energy and are widely regarded as the best solution for replacing fossil fuels. This report contains extensive discussion of two different PVC materials, one of which was chosen to be the floaters for the solar panels.
This study includes a brief introduction to solar panels and solar panel floaters, as well as its background, problem statement, and project limitations. A literature review of seven journal articles related to the topic and methodology was conducted. Upon this review, tests will be selected upon design of experiments to determine whether to determine whether the desired material can withstand the weight of the solar panels and overcome the wind factor, which is always one of the major issues with solar panel floaters. The final results of the tests are discussed in the report's results section. The final comments on the selected material are given during the discussion, as well as how it is a better choice than the other suggested materials.

Keywords: Recycle, PVC, Solar Panel, Floaters

INTRODUCTION

This report focuses on the case study on the effect of recycling materials of PVC and Plywood material in designing of solar panel floaters. The report consists of the introduction, literature review and the methodology on the topic. Fossil fuels are the substances in which hydrocarbon are the main chemical element. The burning of the fossil fuels is known as the non-renewable sources of energy, which means once they are used, they cannot be used again. The fossil fuels were made from the anaerobic decomposition of dead and buried organisms. The burning of the fossil fuels in order to get the energy is being used for many decades now. These methods not only deplete the world's fossil fuels but also creates a huge amount of harmful emission for both humans and environment. the reduction in the layer of Ozone, the global warming and melting of glaciers are just few of the many major disadvantages of the rapid burning of the fossil fuels just for the sake of energy.
Many researchers have done some research work in the calculating and comparing the emissions of the gases between the solar panels and other sources like burning of fossil fuels. It is very important to consider the study of the other researches on this topic because it will help us to understand more the concept of the carbon emission from the **PV** cells. Keeping the top 10 research articles and books under consideration, the literature review of some of those studies are given below:

Case Study 1: Development of solar panel floaters using recyclable materials

by Lu Sheng Chua, Mohd Faizal Fauzan, Mohammad Rhiaz.

This journal article focuses on the designing and manufacturing of the Solar Panel Floaters by using the recyclable material. It can be achieved by optimizing the pontoon design. This will lead to the lower fabrication cost per unit. As the study is taking place for the Solar panel floaters in Malaysia so the structure is being designed to cater with the surrounding environment of the Malaysia. The Ashby method was used to select the PVC and plywood materials. The mass reduction was very important from the original apparatus, so by using the recyclable materials, the total mass reduction of 56.55% was achieved.
The floating structures are referred to as pontoon. The main reason for design the floaters with recyclable materials is to reduce the **L**evelized **C**ost of **E**nergy (**LCOE**), the optimal performance of the pontoon while partially being submerged in to the water.
In the Ashby method of material selection, the function or calculation is used which is derived from the performance **P**. the equation can be represented as below:

$$P = f\ (F, G, M)\text{----------- (1)}$$

Where: F refers to functional requirements; G refers to geometric parameters; M refers to material properties
After the calculation, it was found out that the most suitable materials for the floaters are the class of natural polymers. In the new design all the metals were replaced by the PVC materials due to the heavy weight and rusting of the metals. This is also due to the fact that the PVC are low cost, low density and more moisture resistance than the metals.

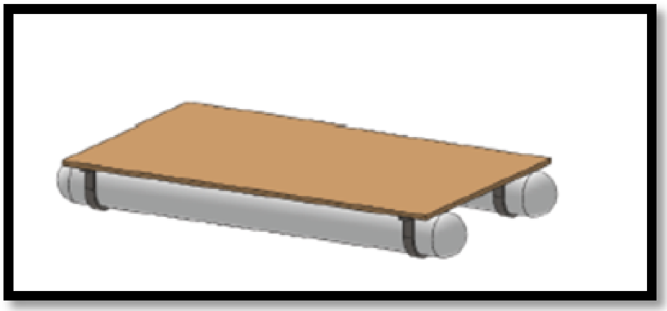

Figure 1. Floater design

To ensure that the floaters can tolerate the weight of the panels and float on the water, the following equation was used to calculate it:

$$V = \frac{M}{\rho} \text{ ------------- } (2)$$

Where: M = Mass of the Floaters; ρ = density of the water (1000 kg/m^3).

After all the calculations, a more suitable design was selected for the floaters, which is given in Figure 2.

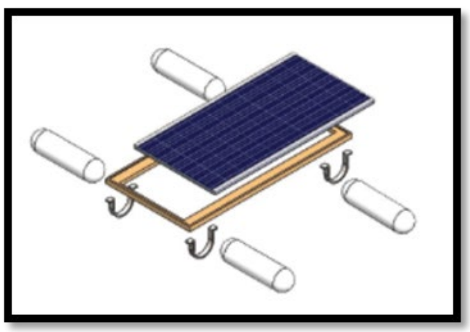

Figure 2. Module Floater

As the cost reduction was also factor kept under the concentration so the Table 1 shows the Mass, volume, Weight tolerating capacity, platform dimension and estimated cost (RM) of the new design.

Table 1. Specification of Proposed floaters

Mass (kg)	Volume (m^3)	Weight Bearing Capacity (kg)	Platform Dimension (mm)	Estimated Cost (RM)
80.75	0.122	127	1200 x 2000 x 50	218.19

The estimated cost of the apparatus is calculated to be 218.19 Malaysian Ringgit (MR), which is much lower than the usual cost of the floaters, which is 425 MR.

Case Study 2: A new photovoltaic floating cover system for water reservoirs by Carlos Ferrer-Gisbert, José J. Ferrán-Gozálvez, Miguel Redón-Santafé, Pablo Ferrer-Gisbert, Francisco j. Sánchez-Romero, Juan Bautista Torregrosa-Soler (2013)

This paper discussed the new PV floating cover system for water reservoir. The researchers used polyethylene-floating modules, which can adapt of many water levels. The floaters covering the river will have many other benefits too, such as:

i. Lowering the filtering cost
ii. Much Longer duration for the algae production
iii. Reduce the slit accumulation.

The design of the floater was calculated to be 1.6x1.0m / 200 Wp panels. In order to get the maximum amount of the radiation from the sun and produce higher energy, the panels are fixed at 30°. As the tilt angle of the panels decreases, it requires a shorter distance between row lines of PV panels to prevent interactive shadows. The lowers angle also prevents the apparatus to face less air resistance on the windy days and have some drifting force.

The new design is technically much feasible and economically viable. The Photovoltaic Floating Cover System (**PFCS**) discussed in this paper is efficient solution to certain agro-energetic policies.

Case Study 3: A Review on Floating Solar Photovoltaic Power Plants by Patil (Desai) Sujay S., Wagh M. M., Shinde N. N. (2017)

This paper discusses the different types of Floating solar power plants and their importance in today's world. The cost of the floating solar power plant is way cheaper than the ones on installed on the land. The area required for the plant on the land effects the cost of the plant as it is more expensive to rent the land. After the studies it is find out that the efficiency of the solar power plant on the water is increased then the ones on land. The air above the panels cools them hence providing with the more efficiency. This paper also presents different types of floating solar power plant around the world. Figure 3 shows the basic setup of the floating solar power plant. Different types of power plants can generate up to 500kWp, medium size power plants can produce up to 500 to 1500kWp and large power plants can generate more than 1500kWp.

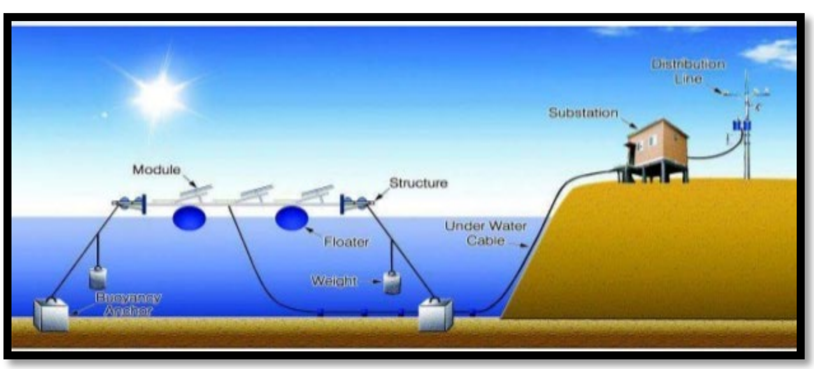

Figure 3. Basic outline for floating PV solar power plant

Figure 4 is the design for the floating solar panels installed in California, which is generating up to 175kWp of power. In this design, the PV panels are fitted on the floater and the angle at which they are installed is calculated to be 8° to get the maximum amount of radiation in order to generate higher energy.

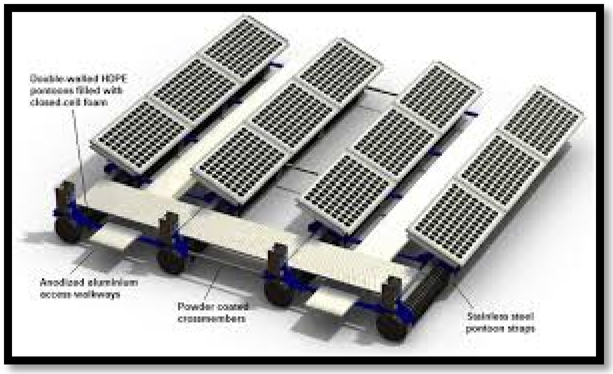

Figure 4. Floatovoltaic Concept at Far Niente, California

Case Study 4: Solar Lanes and Floating Solar PV by Md Wazedur Rahman, Md Sultan Mahmud, Rahate Ahmed, Md Sydur Rahman, Md Zannatul Arif (2017)

This paper discusses the new possibilities of sources of energy in Bangladesh, one of which is the floating solar power plant. It represents a mathematical calculation of the floating solar power plant as shown in Figure 5. As it opens the new avenue for the solar power sector by providing energy through the surface of the water. It covers less area than the ones on land.

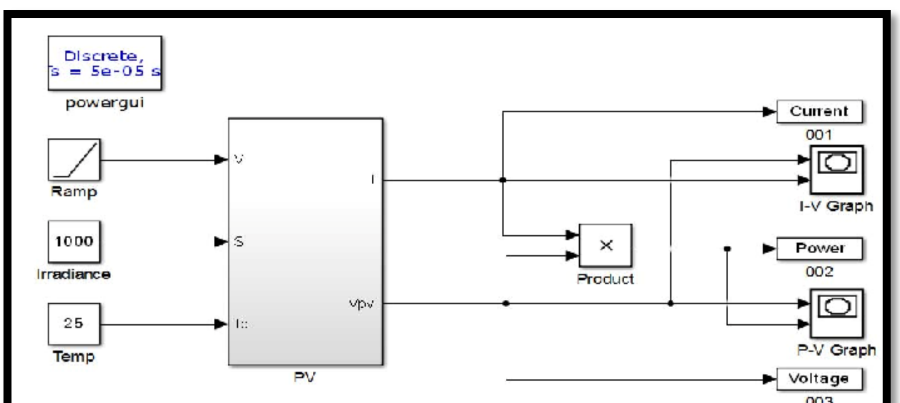

Figure 5. Model developed [20, 21] for solar panel by using data of Sun power E20/435.

The above calculation is done in MATLAB according to the Standard Test Condition (**STC**), which consists solar irradiance to be almost 1000 W/m^2, air mass almost 1.5 and the temperature to be near 25°C. Figure 6 shows a simple graph of voltage over power of the solar panel in temperature of 25°C and 527.7W/m^2. After the calculation, it was found out that the whole Floating Solar Power Plant could generate up to 7.62 MW of electricity. It can be applied to generate 13% of total country's power.

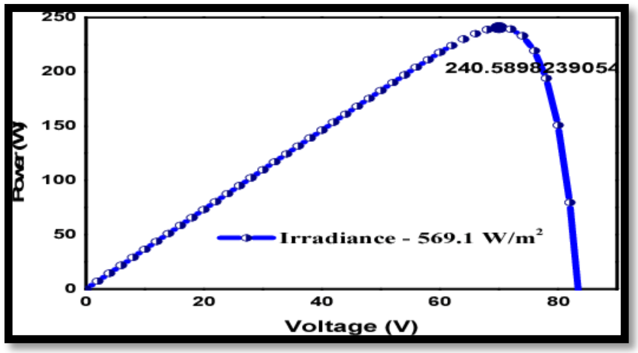

Figure 6. characteristics of solar panel in temperature 25°C & 525.7 W/m^2

Study 5: Design parameters of 10kw floating solar power plant by Paritosh Sharma, Bharat Muni, Debojyoti Sen (2015)

This journal article focuses on the design parameters of the solar panel floaters. In this report, the floaters are discussed. The floaters are made from the PVC material known as Plasticized / Flexible PVC. This is due to the reason that the density of the PVC used in this design is very low which means it will float on the water, which is the main purpose for the solar panel floaters. The reason why these floating solar parks are becoming famous is that they safe a lot of land by setting up on the water where the availability of the large water is accessible. According to the article, the setting up requires many precise connections and requires at least two peoples on the plant to keep it maintained but it is very beneficial by freeing up space on land and setting up on the river.

From Figure 7, it can be seen that the solar panels are fixed on the floaters in such an angle that it gets the maximum radiation from the sun and produces the maximum energy. The floaters are fixed under the structure to keep it floating on the water. The panels are cooled naturally, as the air above has high moisture. By planting the floating solar park, it prevents the evaporation process from the river by 70%. There is less need of the cement structures in it as all the main processes will happen on water. The algae growth in the water can be reduced as the water is mostly covered by the solar panels.

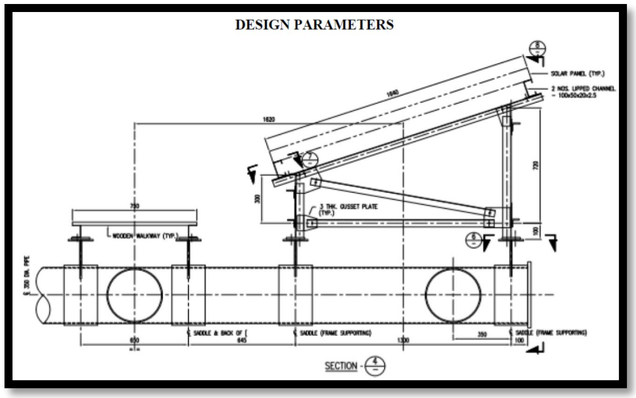

Figure 7. The design parameter of the Solar Panel floater

Study 6: A Study on Power Generation Analysis of Floating PV System Considering Environmental Impact by Young-Kwan Choi. (2014)

In this journal article, the author has proved the superiority of the floating solar power plant by comparing the amount of generation by 2.4kW, 100kW and 500kW. In addition, there were other factors that effects the efficiency of the solar panels such as speed of wind, speed of waves on which the panel's floats were also analyzed. Korea Water Resources Corporation, or K-water, is the governmental agency for comprehensive water resource development. The K-water, Figure 8, has installed 100kW and 500kW Floating solar power plants in Korea in 2011 and 2012 respectively. In the 100kW power plant, the panels are tilted to 33° and it has installed capacity of 99.36Kw. The panels of 500kW power plant are also tilted to 33°C with the installed capacity of 496.8kW.

Fig.8 K-water PV floating plant

For the comparison of the two power plants with different capacities, as shown in Figure 9 "Daily average generation quantity of Haman 935.9kW overland PV system when converted into 99.36kW" Young-Kwan Choi. (2014).

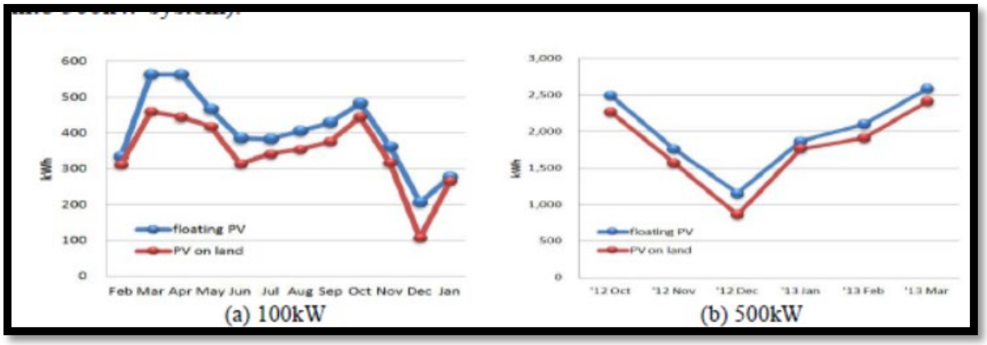

Figure 9. Comparison of daily average generation capacity

According to this journal article, the floating solar power plant is 11% more efficient than the ones installed on Land. The data collected during the experiment is taken in such a way the angles of the panels are being changed in such a way that the wind factor is taken zero. In order to get more efficiency from the power plants, the tilt angle of the panels have to be changed couple of times per day.

Study 7: Energy Pay-Back and Life Cycle CO2 Emissions of the BOS in an Optimized 3.5 MW PV Installation by J.E. Mason, V.M. Fthenakis, T. Hansen and H.C. Kim (2005)

In this article, the study has been done on the **B**alance **o**f **S**ystem (**BOS**) components of the 3.5 MWp multi-crystalline PV. **BOS (B**alance **o**f **S**ystem**)** are the components used in the solar power plants, which includes everything except the photovoltaic panels, which are switches, wires, mounting system, inverters, batteries and battery charger. Other processes such as transportation, installation etc., are also included in **BOS**.

In the Figure 10, it can be seen that the emission of **BOS** are given. The highest emission is from the production of the **BOS** components which is 25 kg CO_2 eq/m^2 and the least emission is by transportation of those parts to the power plant, which is 1 kg CO_2 eq/m^2.

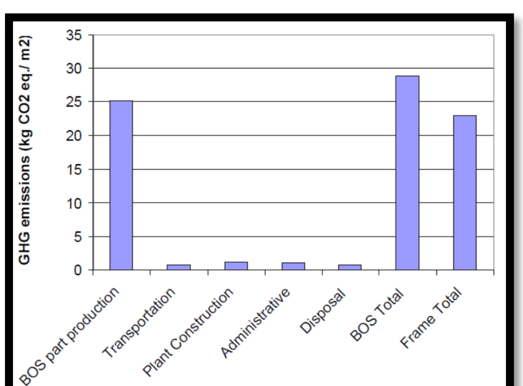

Figure 10. Life-Cycle GHG Emissions of BOS

According to (J.E. Mason, et al 2005) “the total primary energy for the BOS life cycle was estimated, by using different databases and analysts, to be only 526-543 MJ/m2. The GHG emissions during the life cycle of the BOS are 29-31 kg CO2 eq./m2.” This results shows that if the current PV modules are replaced by the new and improved CdTe modules in the Solar Power Plant then it will decrease the amount of GHG.

Methods

Plasticized PVC is flexible in nature and it is usually used as thermoplastics in everyday work. The density of the Plasticized PVC is 1.35 g/cm^3. On the other hand, the un-plasticized PVC is rigid in nature and has density of almost 1.5 g/cm^3. By keeping these qualities in mind, the plasticized PVC are the best option as the floaters for the solar panels as they have less density and are much more flexible than the un-plasticized PVC. This also means that the plasticized PVC can undergo more stress than the other can, which makes it much more favorable material to use in this case.

In order to design the floaters from the recyclable material for the floating solar panels, a simple design is made which is commonly used in most of the floating solar panels, the diagram of which is given in Figure 11:

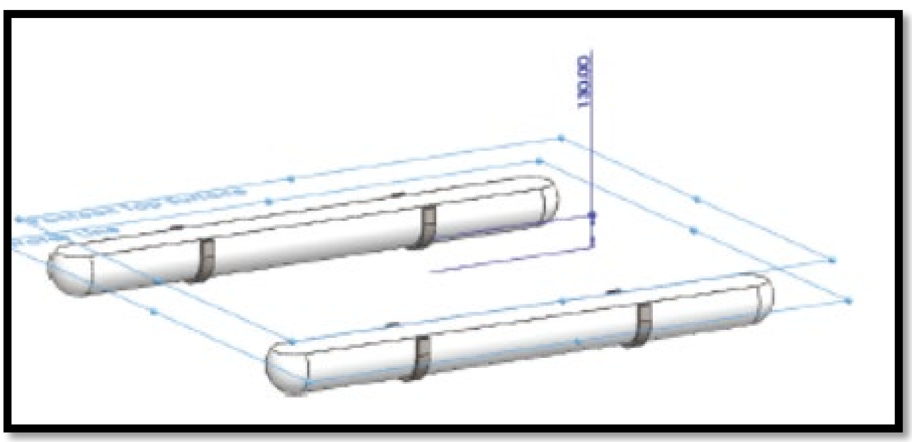

Figure 11. Volume of floaters model beneath the water

After the basic design was completed, a stress analysis was done to find out that how much of weight the floaters could take before completely submerging in the water. This is due to the optimal weight of the panels will be applied on the floaters and see if the floaters can handle that much weight. For this purpose, the **ANSYS workbench** was used. ANSYS is perfect software for calculating the effect of stress on the material. It was used to further refine the basic design. The technique used for the topology optimization of the floater’s design is known as the Optimality Criteria (OC). It solves the optimality conditions by deriving closed form expressions. The sole purpose of the floaters in this case is to just keep the panels float on the surface of the water and keep them from downing. In the ANSYS software, OC method is applied by using a Fully Stressed Design (FSD). It will indicate if the floaters are of minimum weight under its maximum allowable stress. To achieve the FSD, the boundary conditions are applied in the ANSYS. Figure.12 shows the force exerted by the PV panels (a) and hydrostatic pressure acting on the submerged surface (b). It is very important to have more material in the area, which are weak as there are chances of those places to get deformed under the stress of the applied weight. The strain energy in these areas will also be higher than the other places. It was also found out that the main reason for the topology optimization is to reduce the total mass of the floaters by keeping in mind not to effect the performance of the floaters. Figure 13 shows the pontoon design optimization cycle (sheng, Faizal, Rhiaz 2020).

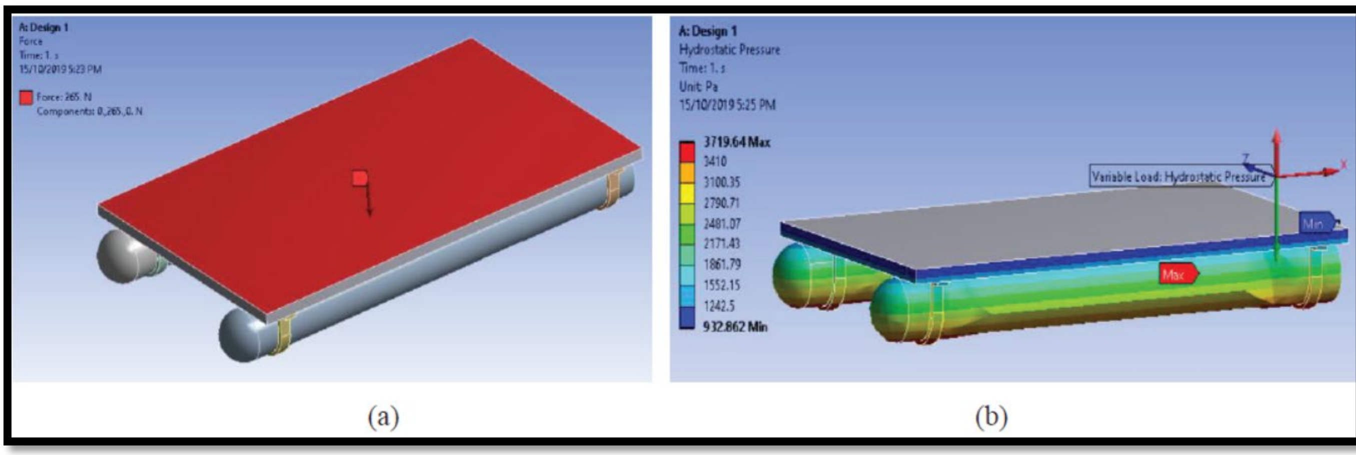

Figure 12. Results from ANSYS

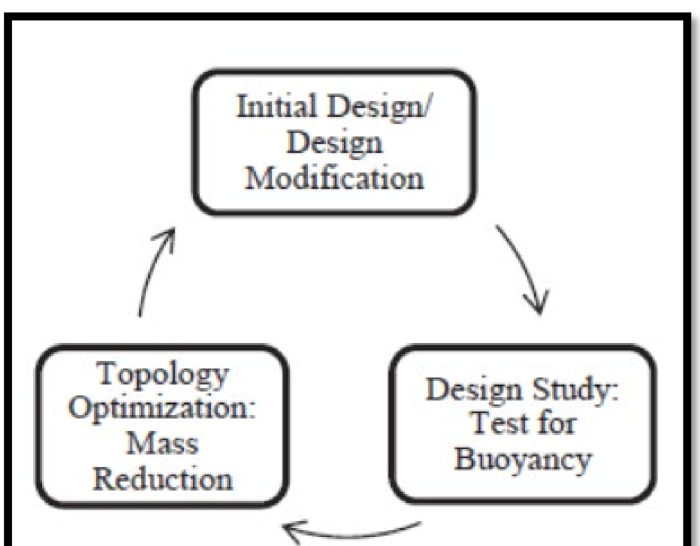

Figure 13. Pontoon Design Optimization Cycle

Results and Discussion

The plasticized PVC and unplasticized PVC are the two final recylced materials that can be used in manufacturing of the Solar panel floaters. The comparision of both is given in Table 2.

Table 2. Difference between PVC and UPVC.

Plasticized PVC	**Unplasticixed PVC**
Flexible and durable	Rigid but less durable then the plasticized PVC
Does contain phthalates	Does not contain phthalates
Does contain **BPA** (Bisphenol A)	Does not contain **BPA** (Bisphenol A)
10 feet of plasticized PVC pipe costs less than 10$	10 feet of unplasticized PVC pipe costs more than (10-15)$

In regards of the table above, it can be seen that Plasticized PVC material is best suitable for the Solar panel floaters as its properties are bit superior than the unplasticized PVC.

Design

After the Pontoon Design Optimization, three final designs come across. The purpose of all three design is same, to make the solar panels stable and in the event of heavy wind, to keep the panels steady. The three designs are shown in Figure 14.

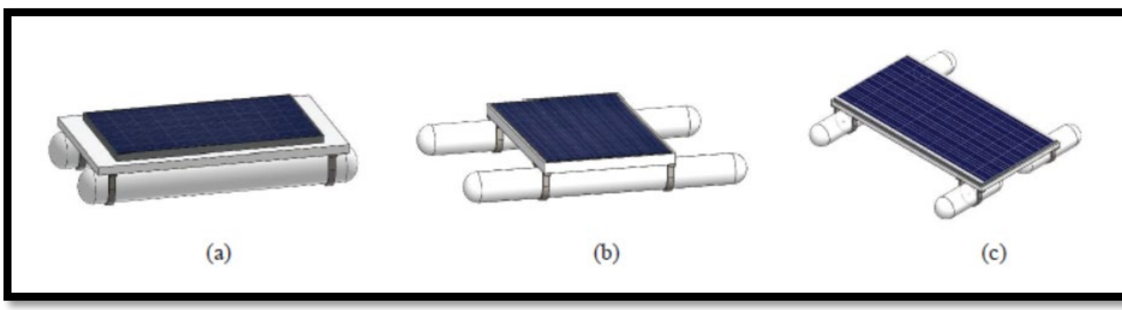

Figure 14. Designs for Solar Panel Floaters

From Figure 15, it can be seen that all three designs are based on the same principal, which is keeping the pipes under the panels and keep them float. Now the figure (b) shows prominent result of keeping off the water from touching the panels as the pipes are bigger in sized and will keep solar panles well above the water level. The other point due to which it is better is that with this design the angle of the panels can also be adjusted in order to get the maximun thermal energy from the sun.

Conclusion

In this report, it was find out that the current model and design of the solar panel floaters have some issues and faults in it, which can affect the efficiency and life span of the solar panels. Which includes High initial cost, Floaters get damaged, Solar Panel corrosion, Carbon Footprint of Solar Panels. The first problem is solved by using the topology optimization which reduces the overall usage of excess material and uses material only necessary for the floating the panels safely. The second problem is overcome by using the new design of the floaters, which is designed, by using Pontoon Design Optimization, which uses more material in the area, which gets effected more by the water. The third problem is solved by the new design of the floaters which prevents the water to overflow on the panels and it doesn't do any corrosion. The fourth problem is overcome by using recycled PVC materials which is best used to reduce the carbon foot print in the world which is very concerning issue. In the end, it is clear that the new design, which is adapted in this report, is safe and economically feasible which are 2 major reason of this report.

Limitations

As this paper was written in the year 2020, the year in which the covid-19 virus spread into the world and due to which all the educational institutes were closed, the were some major limitations in writing the report.

a) Only resources available are the online resources, E-books, articles and MEC's E-Library.
b) There are very few research work done on this topic so it was hard to find many journal articles related to the topic.
c) Solar panels floaters are not installed in the Sultanate of Oman so there is no way of testing the topic in reality.

Unable to use the Laboratory's apparatus for the study

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