Deployment of Offshore Floating Solar System

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Abstract

Floating solar panel platforms were designed by the PUB to allow Singapore to have a renewable energy source without sacrificing precious space on land. PUB first deployed one such platform at Tengeh Reservoir, which cost around $11 million (2016). PUB announced that they would be deploying more of these platforms, some of which would be along the Straits of Johor by 2021 (2019). However, PUB feels that the solar panels would negatively affect marine life. This project is targeted at how these platforms will affect marine life, mainly fully submerged plants, and to come up with a solution to solve this problem. The plants would be subject to testing, either through leaving a gap between the solar panels or adding a bulb below the platform. It was found that having an additional light bulb powered by the panels would not only solve the problem but it allowed the plants to photosynthesize at the most efficient rate. However, more testing is needed to make sure that the amount of energy needed to power the bulb does not entirely use up the amount of power produced by the solar panel.

1. Introduction

Floating solar panels are an initiative given by the HDB and will be deployed by 2021. The solar panels generate a lot of electricity, about 6388 kWh of electricity, capable of powering 1250 4-room flats. The floating solar panels are on a platform connected by connectors. The floating solar panels are initially designed for the reservoirs where the waves and winds are not as strong as the sea, where they will be deployed too. The platform that is going to be deployed to the sea faces several issues. The floating solar panels platform can be affected by biofouling issues. The platform is vulnerable to barnacles and other organisms growing on the underside which may weigh the platform down. Another issue is that the strong waves and winds at sea may damage the connectors, causing them to bream. Lastly, PUB identified that the solar panels platform may affect marine life. The platform covers a very large amount of area and blocks a lot of light that tries to reach the plants at the bottom of the platform. This will affect marine life and this problem needs to be solved. There has been no case study or research done by the HDB and this project is to research about this problem and find a suitable solution.

2. Literature Review

Photovoltaic cells were discovered by Alexandre Edmond Becquerel in 1839 but were very inefficient so they were unfeasible to be used. In 1941, Russell Ohl invented the solar cell which was able to efficiently generate electricity from sunlight. Solar panels are photovoltaic cells that convert light energy to electrical energy but allowing particles of light or photons to knock electrons free from atoms, creating an electric field. (Solar panel history and overview, The Solar Experts)The solar panels make use of the abundant sunlight to generate electricity. The sun is a renewable source of energy. Renewable sources of energy are energy sources that can be replenished easily and is a more eco-friendly alternative to fossil fuels. The solar panels also do not produce any harmful gases or radiation as the sun it relies on is a clean source of energy. Floating solar panels in Singapore was an initiative by HDB that makes use of the open waters around Singapore. It was originally designed for reservoirs but has since expanded to oceans. The solar panels are connected by interlocking platforms inspired by the floating wetlands in Punggol PCN. The first buyer was PUB which placed the solar panels in Tengeh reservoir in 2016 (Straits Times, 2016, October 25).

Improved yield performance

Warm temperatures inhibit a solar panel's ability to work at its most efficient level. The surrounding water has a cooling effect on a floating system of around 5-20% depending on location, local climate and float structure used.2 Combined with advantages in terms of reduced shading and soiling, the lower operating temperatures of a floating system increase its energy generation capacity compared to a landbased installation.

Evaporation control

A floating solar array naturally causes shading of the water surface, and with it, a drop in water temperature. This can be advantageous when employed on reservoirs, as the amount of water lost through evaporation is reduced, although the rate of evaporation is directly linked to the size of the area covered by the floating platform. In a keynote speech to the 2017 International Floating Solar Symposium, Professor Eicke Weber from UC Berkeley and BEARS (Singapore) stated that “more water evaporates from reservoirs than is consumed by humans”. For utilities, this is lost revenue. Millions of dollars are spent pumping and treating water to be sold to customers and any loss through evaporation is lost income. It is clear that reducing evaporation would benefit the local population by saving drinking water and keeping costs down. Of course, shading by the floating system can be compared to other factors such as the coverage of the surface by algae. However, A floating system usually covers only a fraction of the water surface. This means that warmth from sunlight and oxygen continues to be distributed through the water body by its natural convection cycles. Dependent on the footprint of the floating platform, there may also be space between panels where light hits the water, keeping the impact of widespread shading to a minimum.

A floating system makes use of existing water bodies where there are no competing uses. This makes it ideal for use in countries and areas with limited land. In water bodies such as reservoirs, floating PV can also be a secondary use of the water real estate, generating extra income and giving the water body an additional purpose.

Restricting algae growth

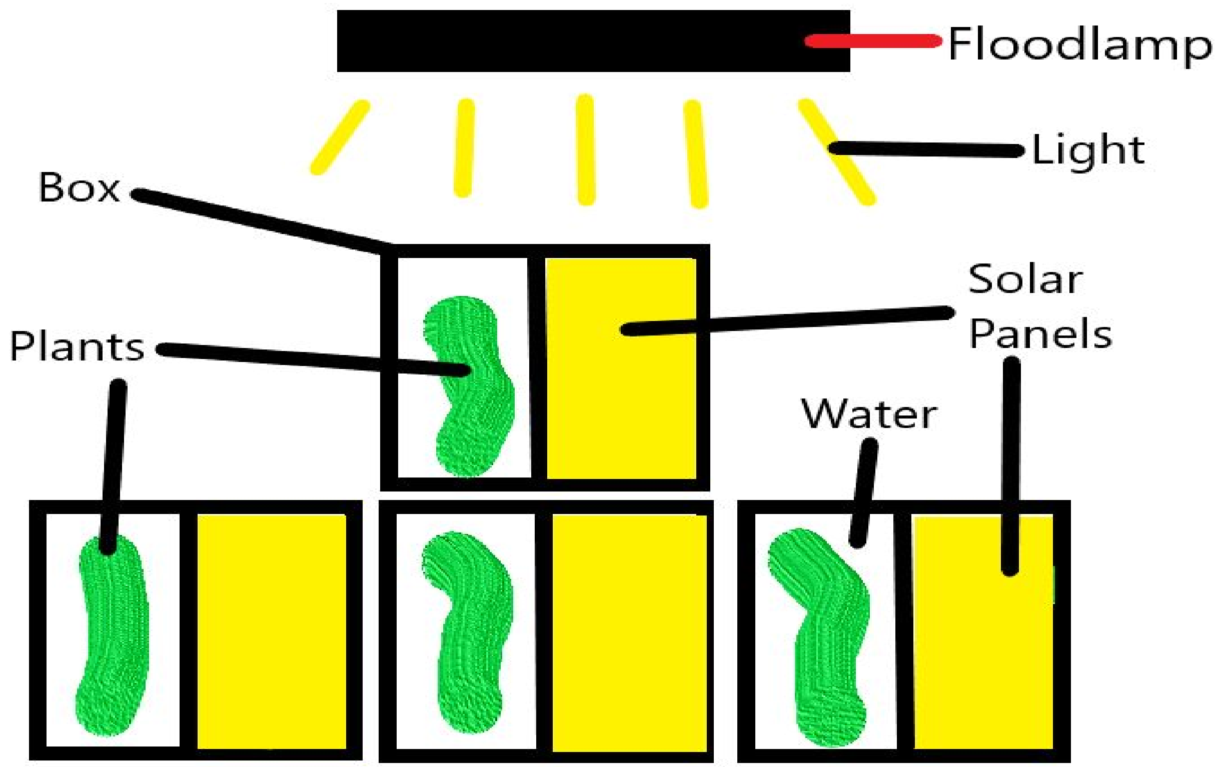
Although algae can be of benefit to the water ecosystem, too much can cause problems. High levels of algae restrict light penetration through the water, limiting the growth of plants and the production of oxygen necessary for fish and other water fauna, as well as impeding the decomposition of organic matter in the water. This becomes something of a vicious circle, as, without the warming effect of sunlight, the water cools. Cold water is denser than warm water, so it sinks and the overall oxygen levels in the water decrease. The low amount of oxygen available then inhibits the continued functioning of the water ecosystem, endangering the aquatic life present in the water body. Reducing algae blooms on the water has further operational benefits in commercial water bodies where filters can rapidly become clogged and require frequent cleaning or replacement. Here, floating solar creates less favourable conditions for the growth of algae blooms, so with less algae present, there is a reduction in the need for maintenance and replacement of parts.

Less prone to external shading
Positioning of the array in the middle of a body of water also situates it further from shade-causing objects such as buildings and trees. This reduces the amount of time that the array is shaded and so increases the array's exposure to sunlight for higher energy yields.

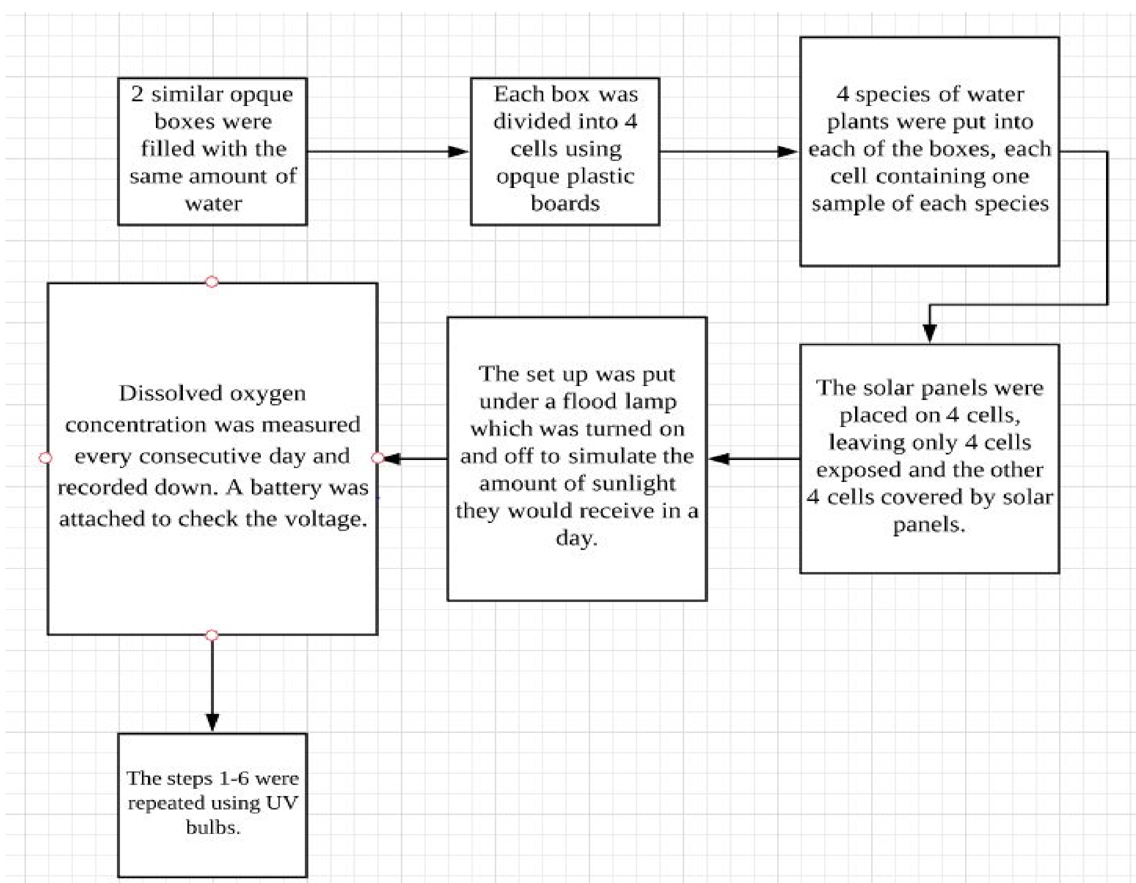
With the solar array situated on the water surface, further from sources of dust and dirt, the installation sees a reduction in soiling. Especially in dry and dusty areas, the increased distance from land means that dust and dirt are not so easily trapped by the panel, reducing the need for surface cleaning. Indeed, on such installations, a plentiful supply of water for cleaning the panel surface should be available around the panel. (Benefits, Splash Floating Solar)

3. Materials and Method

To test the solutions, 4 species of underwater plants were used to test the effects of the solution on various species of plants. The 4 species of plants were Cabomba, Hydrilla, Twisted Vallisneria and Peacock Fern. 2 opaque boxes were filled with tap water with a dissolved oxygen concentration of 8.26 mg. These boxes were divided into 4 parts using black opaque plastic corrugated boards. The plants were put into these cells, where the source of light used was a flood lamp installed above, which was placed between the boxes. 8 3-volt solar panels were used in the experiment, to charge a 3-volt battery attached to each solar panel platform. The solar panels were all connected in parallel to ensure that there is a constant power supply to charge the appliances attached to the solar panels. In a different setup, we attached UV light bulbs to the circuit to test if attaching light below the platform was helpful for the plant's growth.


Floodlamp
Light
Box
Solar
Panels
Plants
Water

4. Procedure


2 similar opque boxes were filled with the same amount of water
Each box was divided into 4 cells using opque plastic boards
4 species of water plants were put into each of the boxes, each cell containing one sample of each species
The solar panels were placed on 4 cells, leaving only 4 cells exposed and the other 4 cells covered by solar panels.
The set up was put under a flood lamp which was turned on and off to simulate the amount of sunlight they would receive in a day.
Dissolved oxygen concentration was measured every consecutive day and recorded down. A battery was attached to check the voltage.
The steps 1-6 were repeated using UV bulbs.

Independent Variable: Type of solution used
Dependent Variable: Concentration of dissolved oxygen
Controlled Variable: Species of plants in the set up, type of water, intensity of light, voltage of solar panel

5. Solution Design

One solution is to place an underwater LED light on the underside of the floating solar panels platform. The underwater light is energy efficient and will only be powered by a small portion of the electricity produced by the solar panels, still allowing the electricity produced by the solar panels to power other things. The lights will illuminate the water underneath the solar panels and allow the water plants at the seabed to receive light. Although the light is artificial, it allows the plants to photosynthesize and thrive underneath the solar panels, preventing a dark wasteland underneath. One limitation of this solution is that the bulb might fuse if powered for long periods. We can solve this by implementing time intervals for the light bulbs to be turned off to cool down.

Another method is to rearrange the solar panels such that light can pass between the individual solar panels. This will sacrifice some of the compactness and increase the space taken up by the solar panels, but it will allow plants on the seabed below to survive. Some shapes we can rearrange the solar panels are squares or triangles, but squares warp easily and triangles are the structurally strongest shape so the choice is clear. The increased structural integrity may also be a solution to stress placed on the connectors by waves, another problem faced by the offshore floating solar panels.

Another solution is to make use of the recently developed transparent solar panels. Previously this was not possible as a transparent material could not absorb light needed for the photovoltaic cells to produce electricity, but a breakthrough achieved by the Michigan State University has now made it possible.
The scientists there used a mixture of organic salts to alter the material to only absorb specific wavelengths of light outside the visible spectrum of light to human eyes, like ultraviolet light. So the material does not absorb visible sunlight, making it viable to be placed in windows or screens. If this technology is advanced further, we will be able to make this into a reality, installing solar panels as windows and eliminating the need to place develop offshore floating solar panels. However, one limitation of this newly developed solar panels is that the efficiency of the transparent solar panel is only 1% with an estimated potential of 5% while conventional solar panels have a 15% efficiency so a larger area of solar panels is needed to generate the same amount of energy. The transparent solar panels are still extremely new on the market and their costs will be very high, making it not feasible to be bought in large amounts. It has not

gone through many tests and it is unclear if the transparent material will be able to withstand the stress of constant expansion and contraction underneath the sun.

6. Results and Discussion

Table showing the concentrations of dissolved oxygen in the control set-up

	Trial 1	Trial 2	Trial 3
Peacock Fern	8.53	9.12	8.37
Vallisneria	8.48	9.01	8.34
Cabomba	8.65	9.78	8.49
Hydrilla	8.27	8.84	7.92

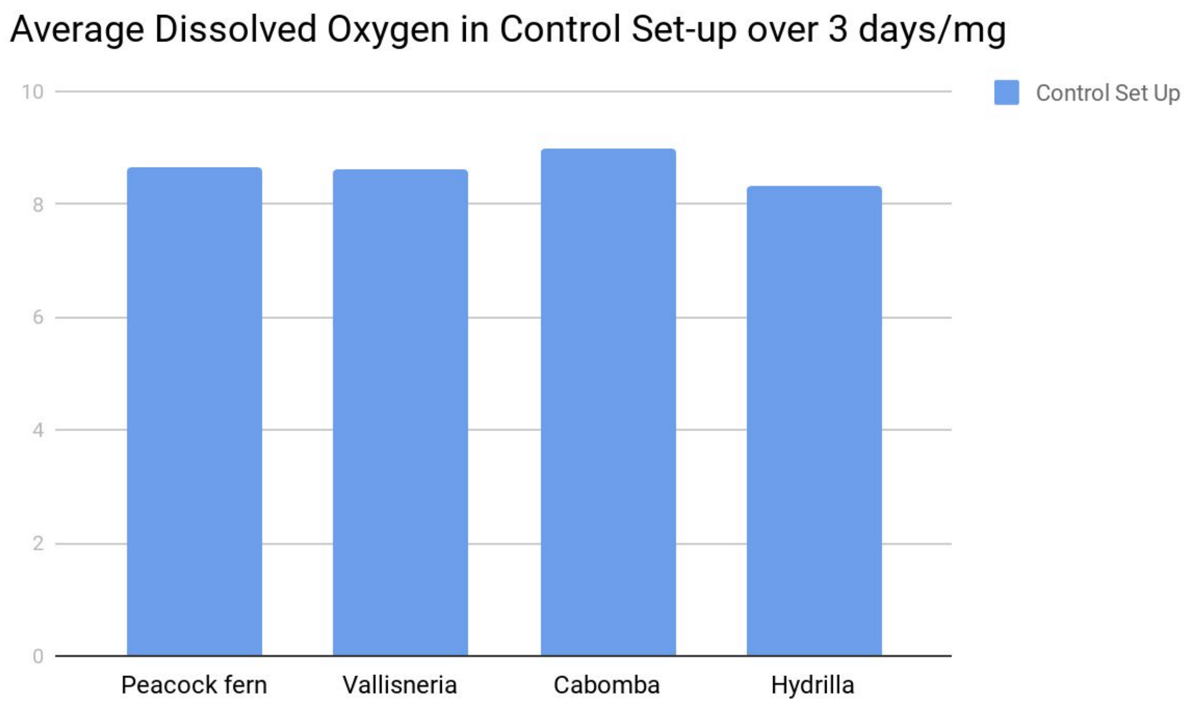


Table showing the average concentration of dissolved oxygen in the set-up with gaps in between solar panels

	Trial 1	Trial 2	Trial 3

Peacock Fern	**8.29**	**8.54**	**8.15**
Vallisneria	**8.26**	**8.52**	**8.09**
Cabomba	**8.34**	**8.68**	**8.19**
Hydrilla	**8.07**	**8.73**	**7.84**

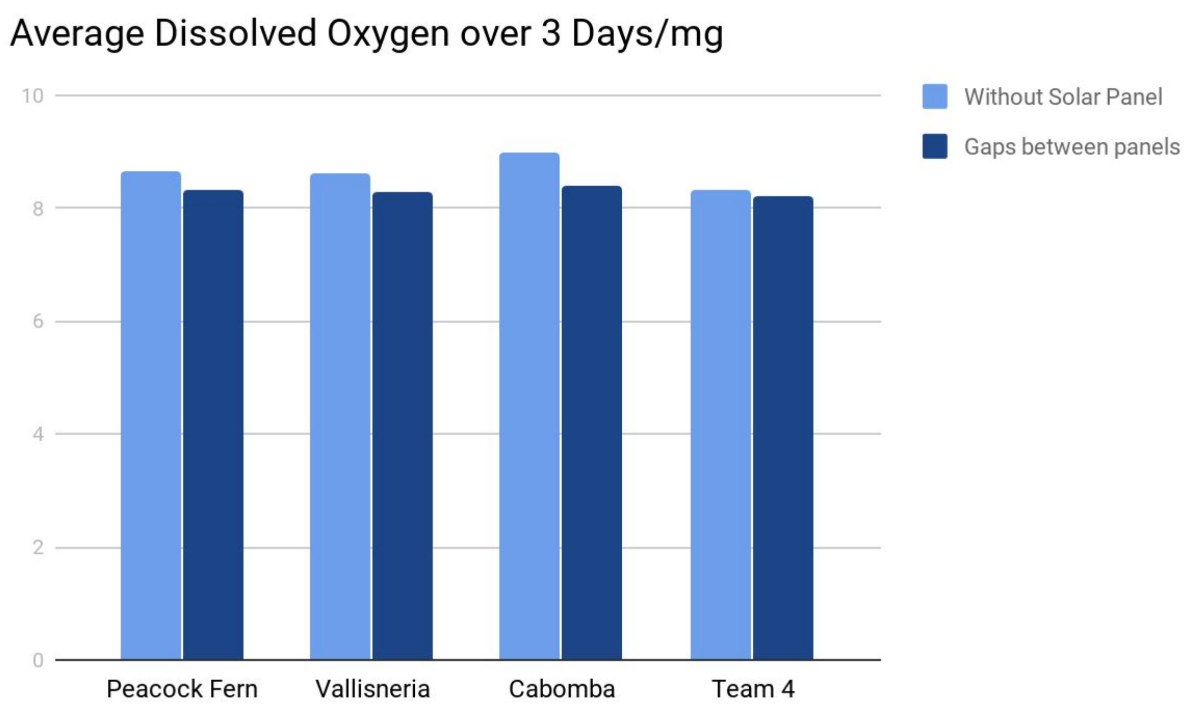
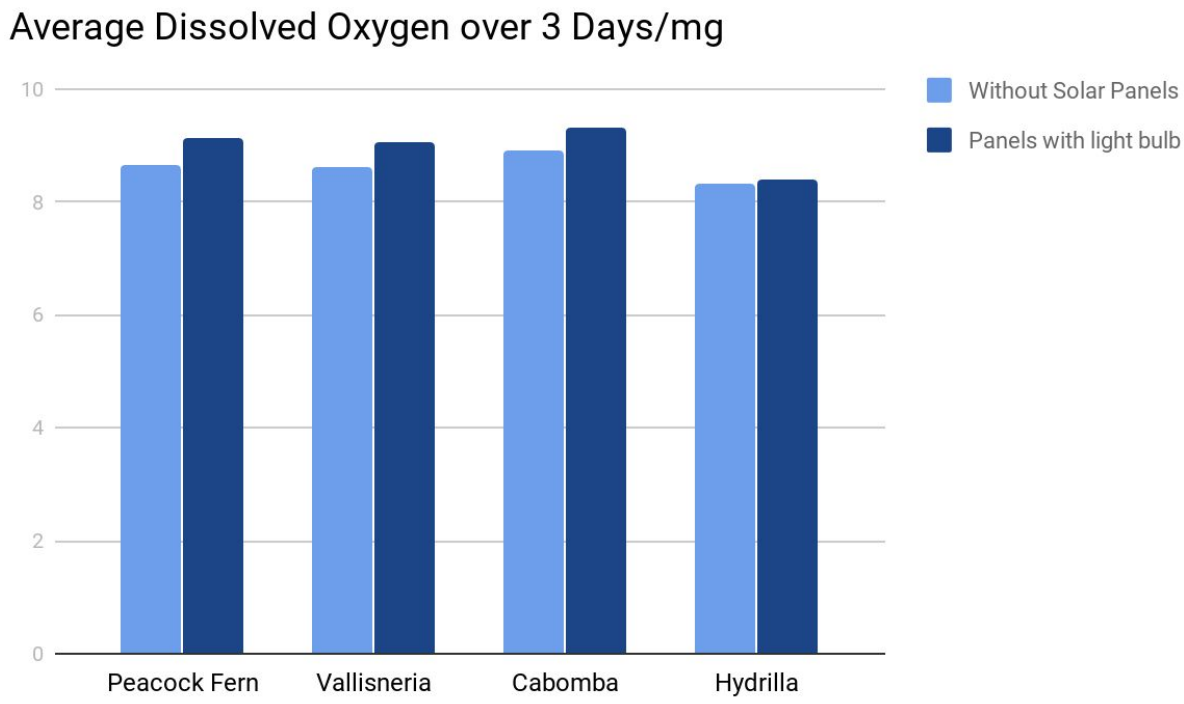
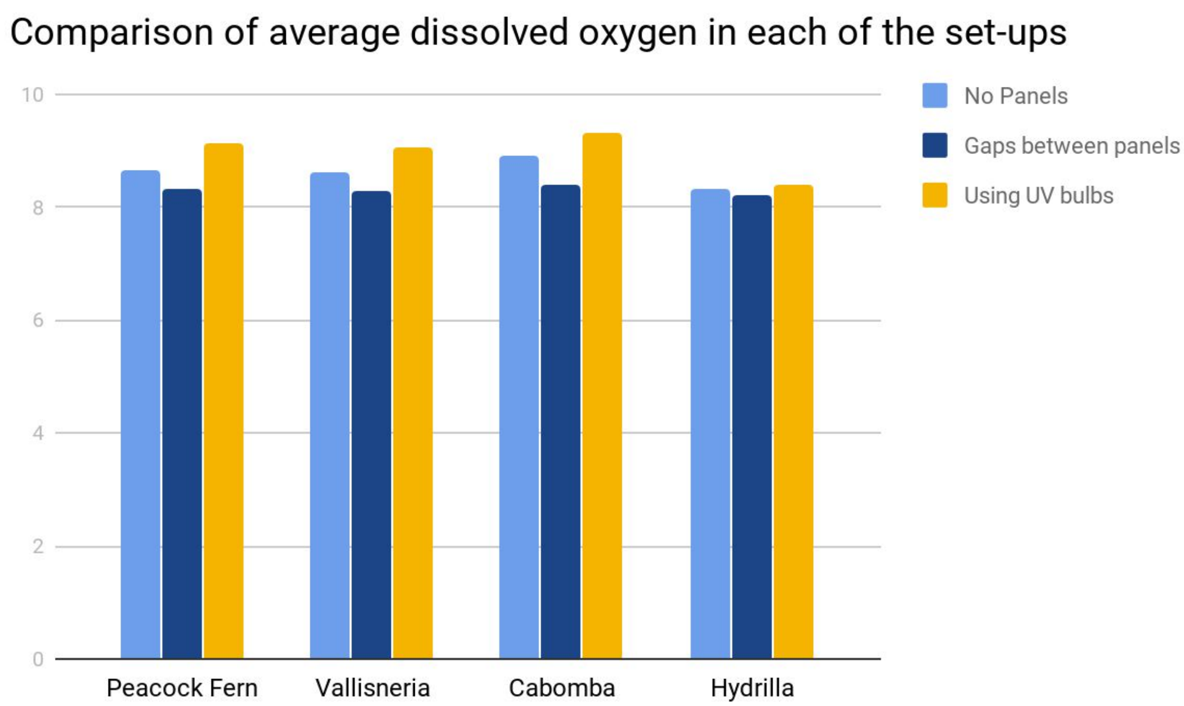


Table showing the average concentration of dissolved oxygen in the set-up with the UV light bulb

	Trial 1	**Trial 2**	**Trial 3**
Peacock Fern	**8.75**	**10.09**	**8.60**
Vallisneria	**8.72**	**9.96**	**8.54**
Cabomba	**8.85**	**10.41**	**8.66**
Hydrilla	**8.41**	**8.51**	**8.26**





As seen by the results above, it is visibly clear that the rate of photosynthesis is different among plant species, but the effects were still similar between each other. The method of creating gaps between solar cells was ineffective at boosting the rate of photosynthesis of the plants, but rather affected it slightly. The addition of bulbs, however, increased the rate of photosynthesis such that it was higher than that of the control set-up, showing that it is possible to implement such a method for commercial uses.

7. Conclusion

Out of the possible solutions that the group had, they feel that solution 2, placing UV lights underneath the solar panels is the best. This solution is not only effective in illuminating the water below, but it also does not largely affect the amount of electricity generated as it is powered by a small percentage of the electricity generated. It is the most cost-efficient as it only requires a UV light bulb for each solar panel and rewiring of circuits. It also does not require a redesign of the existing layout, compared to sacrificing space to create gaps between the platforms or spending a lot of money to buy new technology that has not been thoroughly tested and certified.

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