Riding the wave of solar energy: Why floating solar installations are a positive step for energy generation

Due to its flexibility and performance advantages, the installation of solar on floating platforms is seeing worldwide growth and recognition of its energy generation potential. Besides standard installations on commercial and residential rooftops, and as ground-mount utility parks, reservoirs, lakes and other bodies of water are now becoming valuable and profitable solar commodities.

What is floating PV?

The term floating PV, often also known under the adroit term floatovoltaics, is exactly what the name suggests - an installation of solar panels on a floating platform on a body of water. To achieve this, the solar panels are mounted and fixed to floating supports, which are then joined together to form a larger solar array. This sits on the water surface and is anchored to the shore or water bed. The electricity produced by the installation is routed to inverters, usually stationed on land, and the energy can be fed into the grid or used directly at the site of production with no difference to an installation on dry land.

Img. 1: A 5 kW floating PV system at the University of Central Florida – Orlando, USA, using 20 REC panels and Hydrelio© floats from Ciel & Terre

Why is floating PV a good idea?

By using solar panels in a floating installation, clean energy can be generated while conserving precious land and water, even converting the water surface area to valuable and profitable real estate - indeed analysts believe that 400,000 km² can be unlocked by floating applications and that there is a TW-scale opportunity on freshwater reservoirs alone.[1]

In addition to the optimal use of water surface area, a floating installation with REC panels provides shading to the water, limiting the growth of algae and helping to reduce evaporation, which is of particular benefit in hot climates or where water is scarce. At the same time, water, despite its low albedo, can provide an increase in light reflection from its surface compared to a standard installation surface. All the while, water acts as a natural coolant to the panels for higher efficiencies and improved overall energy yield. With no need for power tools or heavy machinery, solar on water is easy to install and can be deployed quickly.

What are the advantages of a floating PV installation?

There is a wide range of different advantages to the installation of a floating PV system, ranging from improvements in performance to ease of installation:

Use of otherwise redundant areas

A floating system makes use of existing water bodies where there is no competing use (e.g., recreational). 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.

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 land-based 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 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."[3] For utilities, this is lost revenue. Millions is 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. A floating system however, usually covers only a fraction of the water surface meaning 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.

Img. 2: A 108 kW floating PV system at Sungali Labu, Salak, Selagnor, Malaysia using 432 REC panels and Hydrelio© floats from Ciel & Terre

Restricting algae growth

Although algae can be of benefit to the water ecosystem, too much can cause problems. High levels of algae restricts light penetration through the water, limiting the growth of plants and the production of

[1] Igor A Shiklomanov., 1993, "Chapter 2: World Fresh Water Ressources", in: "Water in Crisis", ed. Gleick, Peter H., Oxford University Press

[2] Dr. Thomas Reindl, Dr. Zhao Lu, 2017, "Floating PV Technologies and Singapore's Testbed Experiences, Solar Energy Research Institute of Singapore, National University of Singapore, World Bank Webinar, October 9, 2017

[3] Thomas Reindl., 2018, At the Heart of Floating Solar: Singapore, PV Tech Magazine, www.pv-tech.org

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 more dense than warmer 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 favorable 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.

A reduction in panel soiling

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 never be too far away!

Installation

Dependent on the system chosen and location, a floating PV system compares favorably with the time taken to install a similarly-sized ground-mount installation. Without the need to drill or carry out other groundwork, the total system preparation time can be reduced compared to a terrestrial installation. Conversely, more time is taken with securing each single panel to an individual float. Of course, much is dependent on the platform chosen and how the balance of system (BOS) components are to be installed. Indeed, in the test projects that REC has carried out to date, the installation time for floating systems remains similar to comparably-sized ground-mount installations.

What tests has REC performed to ensure panel safety on water?

To ensure its solar panels are suitable for use on floating installations, REC submitted its panels to a series of extensive tests to replicate the different dynamic stresses seen on water and ensure reliability and durability. The results showed extremely good performance when faced with the demands of a floating system with passes in all tests:

Table 1: The REC testing regime for floating PV applications

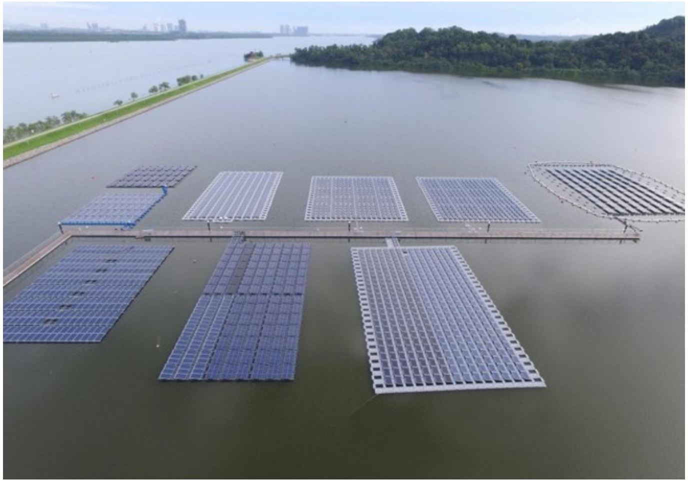
Test	Protocol	Conclusion
Component salt spray	In excess of ISO 9227	• No corrosion • No transmittance reduction
Panel vibration	>324,000 cycles without rubber damping	• Below 2% power loss • No cell cracks in EL • No wet leakage reduction
1 m immersion	In excess of 2 weeks	• Comparable to baseline • Salt water has lower wet leakage resistance than fresh water.
Salinity wet leakage	Up to 65 mS/cm	• No correlation of wet leakage to water salinity
PID	In excess of IEC 62804	• PID resistant
UV Exposure	In excess of IEC 61215	• No color change or mechanical degradation to backsheet

Further to the lab tests, a range of environmental tests were also carried out to ensure suitability for usage on water. During development, REC installed a test system under sheltered coastal water conditions in Singapore. After six months, no power loss attributable to the environment was detected in the panels. With all components monitored, no material degradation was evident and when examined under an electroluminesence camera, no new cell damage was observed. A small amount of soiling was present on the glass, but with a negligible effect on power and comparable to that found on a terrestrial installation.

What results has REC seen from floating PV installations?

Besides a number of small scale test projects, REC has been part of an ongoing large-scale floating PV test installation together with the Solar Energy Research Institute of Singapore (SERIS). First commissioned in January 2017 on the Tengeh fresh water reservoir in the west of the island state, the 1 MW installation compares ten different tier-one solar panel and floating platform types and has seen some striking results.

Img. 3: The 1 MW floating PV system at Tengeh Reservoir, Singapore



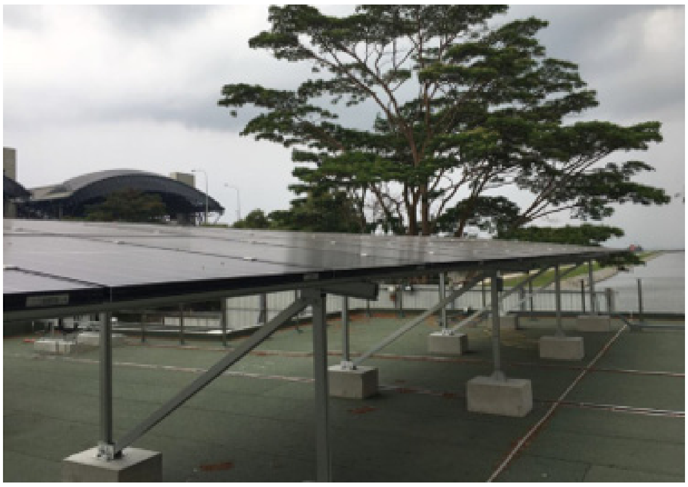
The site has numerous sensors and two meteorological stations, with more than 500 parameters monitored in real time across the complete installation. After the first test period, all systems achieved a performance ratio (PR) within the range of 78% to 94%, with the majority reaching PRs values of well above 80% - something not easy to achieve in the hot and humid climate of Singapore.

Indeed, in its 2017 annual report, SERIS states that, "the heat loss coefficients for floating systems are generally in the range of 40-50 W/m² K, which is about 30-60% higher than the typical values of 30 W/m² K for a well-ventilated rooftop system."[4] However, it also comments on the variations in cooling seen in the different floating platform designs, noting that the greatest cooling is shown by the systems providing the most space between the panels and the water.

Comparison of data to a land-based installation

Next to the Tengeh site, REC also has two roof-mounted systems that enable the direct comparison of system performance. The on-shore systems include a standard rooftop installation and an atypical one where the panels are mounted 1.5m above the rooftop for improved ventilation and heat dispersion. Fig. 1 shows how these systems compare:

Img. 4: The rooftop system close to Tengeh Reservoir, Singapore



[4] SERIS Annual Report 2017, www.seris.sg

Fig. 1: Site comparison of REC installations in Singapore.

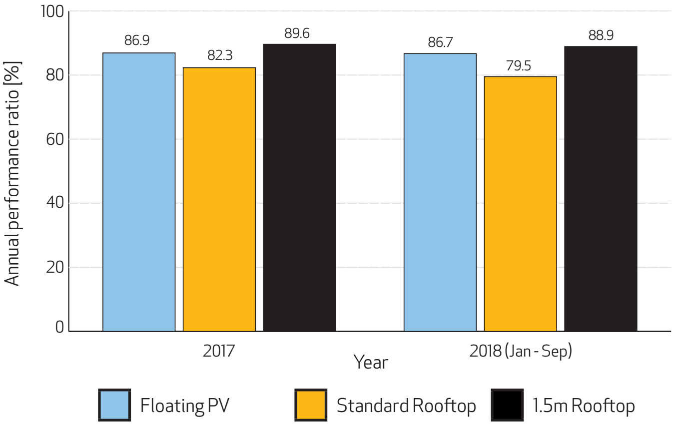


Table 2: Site comparison of REC installations in Singapore.

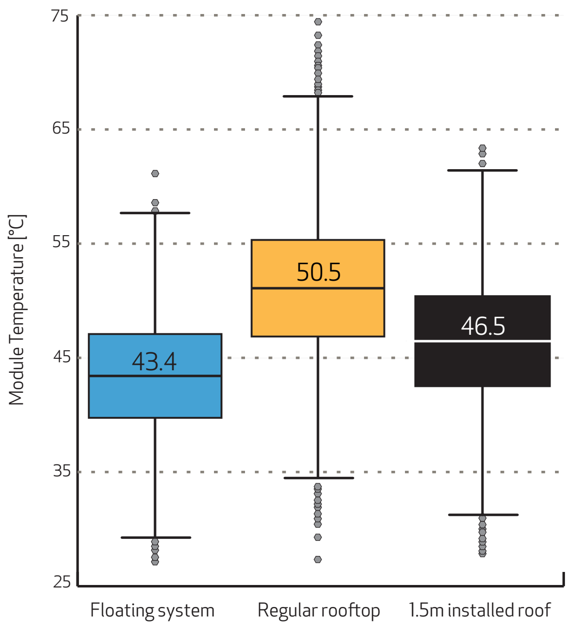
	Floating	Standard Rooftop	1.5 m Rooftop
Module type	REC TwinPeak 280 Wp	REC TwinPeak 280 Wp	REC TwinPeak 280 Wp
System size [kW]	78.4	67	11
Installed	January 2017	October 2016	March 2017
Average PR [%]	86.8	80.9	89.2

The data from the test results above shows that since operation, REC's floating PV systems at Tengeh Reservoir has a performance gain of 7% compared to a typical rooftop system at Singapore.

Lower operating temperatures

This performance gain can be attributed principally to the lower operating temperature of the floating system, where the water acts as a natural coolant, keeping the panel working more efficiently. The Tengeh test systems saw a difference in median operating temperatures of 7°C between land and water, and maximum differences between systems of around 15°C. In fact, a maximum temperature of 70°C was reached on the standard rooftop system compared to only 60°C on the water-based systems, demonstrating the natural refridgeration effect of water. Of course, the impact of the water cooling depends on ambient temperature and humidity, plus the design and footprint of the pontoons, but after almost two years of testing at Tengeh, SERIS had reliable data showing a consistently lower operating temperature on water than on the rooftops. These advantageous conditions were critical to achieving the higher yields for the floating systems versus the standard rooftop system.

Fig. 2: Comparison of module temperatures of REC installations in Singapore, showing the floating section with the lowest operating temperatures.



While fig. 2 clearly shows the cooler conditions experienced by the floating system compared to the rooftop test systems, normally, it would be expected that due to the much improved operating temperature for the floating system, that it would also outperform both rooftop systems (although the 1.5m well ventilated system only by a small margin). What these results show however, is a very similar performance level between the floating and 1.5m systems. This can be explained by the fact that the Tengeh floating systems were heavily affected by the local bird population and suffered regular and heavy soiling. This is obviously a location-specific issue and with a regular and efficient cleaning practice can be easily overcome. Given the close performance of the two systems to date, with improved cleaning, it would be expected that the floating system can produce higher yields and a better performance ratio than the 1.5m rooftop system.

Img. 4: An example of the heavy soiling through bird excrement at the floating test system at Tengeh Reservoir, clearly showing how cell shading can lead to power loss

What challenges are faced by floating PV installations?

Designers of floating systems face unusual challenges such as the selection of anchorage systems, where the exact implementation needs to be known. In certain cases the condition of the water bed will play a role and affect the chosen system, for example, how hard or soft the bed is will affect the type of system required. To investigate this, some evaluation will need to take place, which may involve diving or more involved drilling operations than with a terrestrial system.

One further challenge is the angle of module installation on the floating system is often predetermined in its design and may leave little room for adapting to the best angle for local conditions. Other systems may allow a degree of flexibility. This means that the complete project, including installation time, needs to be weighed up against the angle of installation any associated impact this has on the expected yield and levelized cost of energy.

Are there other important considerations for floating systems?

Safety should always be the primary consideration, as even in layman's terms, electricity and water do not mix! This means more consideration must be given to cable management than on land. Especially if the cables are in contact with the water, they need to be fully impermeable to avoid leakage or performance drop.

One of the primary factors that will be noticed by developers is also the initial capital expenditure. Due to the purchase of the floating platform, early outlay may be more than a terrestrial system, when extra items such as surveys, anchorage, pontoons, and grounding are taken into account. However, as the ground need not be purchased and as civil works and preparation costs are much lower, if the power generation is significantly increased, this initial outlay may be quickly amortized.

Equal thought must then be given to access to the system in the case of Operation and Maintenance (O&M) and how easy is it to replace or repair a panel, or any other component. Even in calm conditions this can be more difficult if access is not considered as part of the design from the beginning of the project.

O&M is certainly an important factor also when it comes to corrosion, especially in more aggressive coastal environments. As well as any effect on the panels, corrosion can affect combiner boxes, inverters, cables and any other metallic supporting structures. Again, both access to such equipment and maintenance needs to be considered before the system can be fully installed.

Img. 5: The REC floating section at the Tengeh Reservoir test bed, showing the floating pontoons and access walkways between rows for easy O&M

Constant movement of the floating platform on the water adds mechanical stress - firstly to the undercontruction with a potential secondary effect on the solar panels and cabling system. This is dependent on pontoon design and how rigid or flexible the mounting structure is. Movement of the pontoon also stresses the mooring system, so this also needs regular checks to ensure optimum safety.

Simply through being placed on water, floating installations are by nature more at risk of moisture-led degradation, for example humidity ingress through the encapsulant, or even Potential Induced Degradation (PID). Even where solar panels are certified PID-free, the increased humidity in the immediate environment can put them at higher risk. Indeed, in terms of certification standards, there are currently no specific requirements related to floating systems other than what exists for standard terrestrial installations.

Due to the high humidity level, it is recommended that floating installations are negatively grounded. This functions as extra protection against moisture-induced drops in system potential.

Isolation faults are another consideration where the insulation resistance (Riso) drops over time for floating PV strings. This is caused by errors due to low Riso, so when the Riso does not meet the preset threshold, inverters do not start and only start working later once the Riso threshold is passed.

Furthermore, the impact of the system on aquatic flora and fauna must be taken into account. A floating installation will usually mean a slight drop in water temperature. Such a change may affect the local wildlife both positively and negatively, although the specific impact is dependent on the system footprint. Each individual site is best examined by a local specialist who will assess the specific impact. Similarly, local fauna may impact on the system, for example, putting a solid structure on the water surface may lead to an increase in bird droppings on the panels -as seen in the Tengeh Reservoir systems - causing shading and power loss, with an increased need for regular cleaning. This is of course dependent on the local bird population and should be taken into account

Does a floating system have any impact on drinking water?

As the solar panels do not come into contact with water, there is limited to no risk of contamination. In fact, the construction of the solar panels protects against any leakage or contact between the current-carrying components and any humidity. Of more immediate relevance is the interaction between the water and the floating system used, as this is the point of constant contact.

Each floating system will need to be assessed to verify the impact on the local environment and quality of drinking water. Some floating pontoon manufacturers have been working on confirming the environmental impact of their systems. Indeed, the French company, Ciel et Terre, has achieved compliancy with the BS 6920:2000 drinking water standards of the Water Quality Association of Great Britain, meaning their floating system is approved for installation on British drinking water reservoirs.[5]

In terms of any potentially harmful substances contained in the floats or their effects on water quality, Thames Water, one of the major water services in the UK, carried out tests on the Ciel et Terre system and approved the use of its high-density polyethylene (HDPE) plastics. HDPE itself is a material used for water pipes, so there should be no extra concerns about the effects of HDPE on drinking water.

What about installations on open and ocean water?

Currently, floating PV installations are primarily designed for inland freshwater water bodies. Some companies are however also developing innovative systems that can cope with the demands of oceanic, off-shore environments. An installation on sea water has further complications than on freshwater and needs to withstand very challenging conditions; these include the increased movement and vibration caused by larger waves, salt water traces on the glass surface of the panel, any extra electrical losses through long cable runs and how to best manage corrosion or degradation to components caused by the aggressive high salt content.

Conclusion

Floating PV is a great use of space and through rigorous testing both internally and with third-party test labs, REC has proven itself as the most suitable panel for such applications. Providing the option of a secondary use of a water body, floating PV enables the water surface to be use to generate income and/or cut electricity payments. Seeing both environmental and commercial benefits, the floating PV sector is now seen as an integral option for clean energy generation.

With testing showing yield gains and improvements in PR of up to 7% more than a rooftop system in tropical climates, the potential for floating PV is exciting and beneficial for system owners worldwide. It has been shown that given the right conditions, a floating PV system can provide more energy that can offset potentially higher operating costs. Unique technical issues need to be resolved, but if addressed early in the design of the system, these present no major obstacle, and costs do not differ significantly from ground-mount installations.

REC is widely recognized for setting industry benchmarks for high product quality and this now extends to installations on water. Having carried out comprehensive lab and real-life testing on floating installations, REC's installation manual already explains the requirements for safe operation on such systems. For floating PV, choosing a high-quality and reliable panel supplier is essential, and with its track record, and thousands of panels already operational in floating installations around the world, REC is truly the leading manufacturer for floating PV applications.

[5] www.floatingsolarpanels.co.uk

NE-18-27, Rev D.2018