Investigating the impacts of floating solar on the water environment

Floating PV | Despite the growing popularity of floating solar installations, relatively little is known about their environmental impacts on water bodies. Ian Jones and Alona Armstrong are leading a research progamme to understand more about how the environmental benefits of floating PV can be harnessed and the downsides minimised

We are aware that as energy needs escalate alongside the simultaneous pressure to de-carbonise supply, the world has increasingly been exploring alternative means of low carbon electricity production. This has led to fast-paced deployment of solar photovoltaics (PV), a large proportion of which has been ground-mounted. Land, however, is useful for many things, so ground-mounted PV systems need to compete against economic gains which could be generated by other land-uses. The Far Niente Winery in California, for example, realised that deploying solar panels on their land would displace vines, resulting in a revenue loss of US$150,000 annually [1]. They hit on the idea that the pond on their land was a fallow area of no use for growing vines, but which could, nevertheless, be used for electricity production by using floating solar panels.

Thus, the first commercial 'floatovoltaic' array was deployed. From this expedient beginning floatovoltaic deployments have gathered pace across the world. Capacity doubled from 2016 to 2017, and now exceeds 198MW world-wide, with individual installation capacities of up to tens of MW [2]. Floatovoltaics have been deployed in several countries, not only in sunny locations such as arid California, but also in temperate regions such as the cloudy, drizzle-soaked, north-west of England.

The deployment of a floatovoltaic system in the north-west of England stimulated us, scientists at Lancaster University and at the Centre for Ecology & Hydrology, to think whether there were other impacts to floatovoltaics beyond the direct benefits of low carbon energy provision and averted land-use change. In terms of energy system benefits, judicious siting of deployments can enable electricity production to be co-located with demand, such as at reservoir water treatment plants. Similarly, co-locating on hydroelectric power reservoirs would enable the use of the same grid connection, potentially enabling a better power curve [3, 4]. There are efficiency benefits to floating PV panels on water too, as the cooler environment of the water surface increases electricity production [3]. What, though, would the impacts be on the water body itself?

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Understanding any beneficial or detrimental environmental impacts is crucial as water bodies are vital ecosystems and provide many essential goods, for example drinking water, and services, such as playing a role in the global carbon cycle, on which societies rely for their financial prosperity and wellbeing. Placing floatovoltaics on water bodies may alter fundamental physical, chemical and biological properties and processes. Installation, for example, effectively puts a lid on the water body and will, therefore, inhibit evaporation of the water, making floatovoltaics particularly attractive in regions of restricted water availability. Other effects could include changes to water temperature, nutrient concentrations and algal populations.

Research is underway to understand more about the positive and negative environmental impacts of floating PV

The significant uncertainty associated with the likelihood and extent of beneficial and detrimental water quality effects gives pause for thought, lest an unwanted impact proves more economically or environmentally costly than the benefits gained. A full understanding of the ramifications of deployment on the water body could, though, enable promotion of a range of costless additional benefits. Currently, little research has been carried out on the impact of floatovoltaics to the water environment, prompting the need for researchers, regulators and industry to collaborate to develop industry standards ensuring deployments lead to additional gains and not losses.

Why are water bodies important?

Water bodies – lakes, ponds and reservoirs – are hugely interesting, ever-changing parts of our planet, with every one unique. For many people, a water body is just a water body; a feature in the landscape. Water bodies are, though, much, much more, providing public goods and services with resulting economic benefits. They provide drinking water, a fundamental need for our existence. In many places fisheries on water bodies are key sources of food. Some water bodies are used for electricity or heat production through hydroelectric schemes or heat pumps. Others contribute to flood control. Many are go-to places for recreation and have considerable economic potential to the tourist industry. They are inspirations for swathes of artists and poets such as Wordsworth and Coleridge who drew on the natural beauty of the English Lake District to create lasting pieces of verse. They are a source of biodiversity containing countless types of fish, macroinvertebrates, zooplankton, phytoplankton, macrophytes, bacteria and more. A lesser known service that water bodies supply, of particular relevance to those interested in low carbon electricity production, is climate change regulation through processing of the carbon which enters a lake from inflowing streams or from the atmosphere. In order for this vast array of benefits from water bodies to be realised it is of critical importance that we understand the changes that the deployment of floatovoltaics could impose on our water bodies.

Will floatovoltaics be good or bad for the water environment?

Simply put, we do not know, but we do need to know. The technology is so recent and the deployments so new that very little research work has been carried out. That said, research starts with theory and it is possible to hypothesise how floatovoltaics might influence the functioning of the water body and the benefits that it provides to society (Figure 1). As a water body is heavily influenced by the weather at the surface we can be confident that interfering with the air-water interface (as deploying a floatovoltaic would do) will have a large impact on the water body, and the greater the proportion of surface covered, the greater the influence.

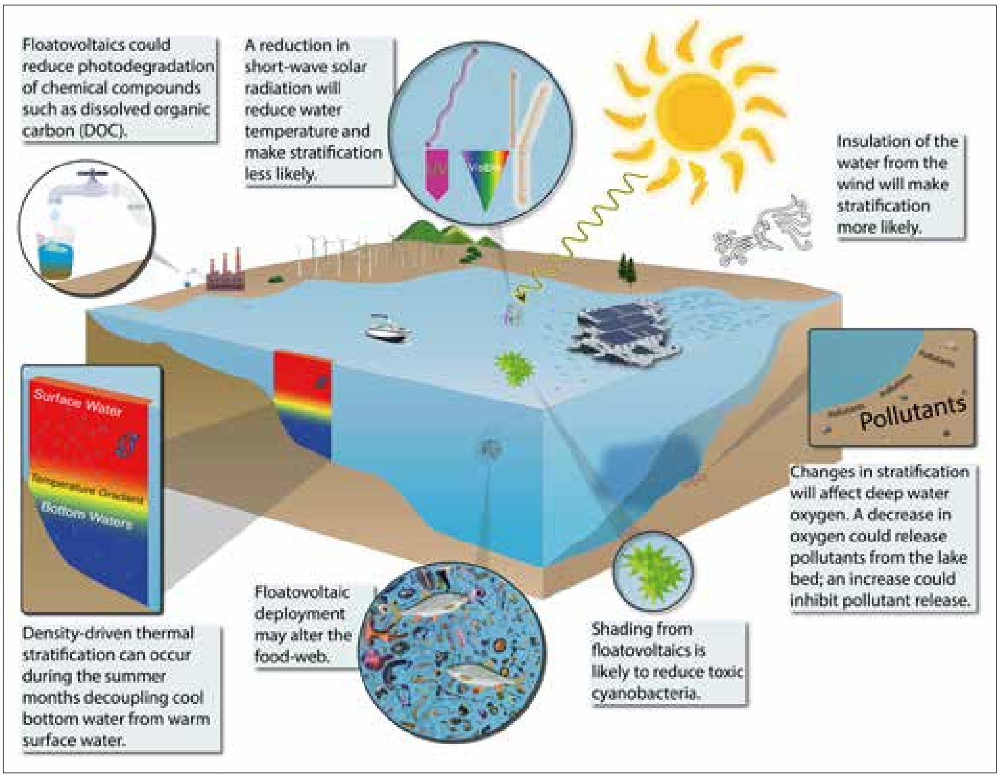

Figure 1. Schematic diagram of the range of impacts floatovoltaics may have on the water body. Figure courtesy of Giles Exley, PhD student at Lancaster University and the Centre for Ecology & Hydrology

Understanding effects of floatovoltaics on water temperature, stratification, oxygen content and sunlight receipts is fundamental in determining the impacts on key environmental aspects such as water quality, species diversity and nutrient status. Water temperature, which affects the rate of many important chemical and biological processes, is determined by several surface processes by which water bodies are heated and cooled. These processes are surprisingly complex, each varying differently through the day, through the seasons and with the location of the water body. Wind speed, air temperature, humidity and cloud cover all play a role. We would, though, expect that the presence of floatovoltaics will generally reduce water body temperature, primarily by reducing the heating effect of the sun. This will slow the rate of many fundamental water body processes, such as productivity. To corroborate this and to determine the conditions in which this does or does not occur and the scale of effect, requires data collection and scientific analysis.

During colder periods of the year it is common for water bodies to have the same temperature throughout, enabling the water to freely circulate from top to bottom under the influence of the wind. For some water bodies, though, summertime heating leads to water nearer the surface warming substantially whilst the bottom waters remain cool, the accompanying density difference inhibiting vertical mixing of water. Arguably the extent to which this stratification occurs is even more important to the water body environment than the temperature itself. The depth of stratification, the strength of the variation in temperature with depth, and the duration of the stratification all significantly impact the way a water body functions. While the likely impact of floatovoltaics is to reduce the heat coming into a water body, and thereby make stratification less likely, the expected effect on the wind is to reduce mixing, making stratification more likely. Consequently, it is difficult a priori to unpick the net impact of floatovoltaics on stratification. Almost certainly the answer will also depend on other factors, such as where the water body is located, the size of the water body, and the percentage of floatovoltaic coverage on the water body, as all these influences will shift the odds for or against stratification becoming more or less likely.

When a water body stratifies, the top and bottom become very different as nutrients, microscopic algae, and gases, such as oxygen, can no longer be mixed. Oxygen plays a crucial role in the water body, entering from the atmosphere or through photosynthesis from algae and other aquatic plants near the surface and being consumed by biological and chemical activity. From an anthropogenic viewpoint, oxygen is good: the more of it that gets into the deep waters of a water body the better. Without oxygen, fish habitats will shrink, nutrients and heavy metals will be released from the bed sediment and more of the potent greenhouse gas, methane, will be produced. If floatovoltaic deployment leads to an increase in stratification and a reduction in oxygen at depth, the environmental consequences could be severe and costly. Conversely, if natural stratification is reduced, then floatovoltaics could provide the happy side-effect of offsetting some of the predicted unfavourable impacts of global warming on water bodies.

A further, predictable consequence of capping a reservoir with floatovoltaics will be the reduction in the wavelengths of sunlight which aquatic plants use to grow, particularly the microscopic phytoplankton which form the base of the food-web. If the primary concern is producing clear, clean water this could be a positive impact, but if there was more interest in food supply or biodiversity this could be a negative impact.

More subtly, but no less important, would be the different impact on the many varied types of phytoplankton. Typically toxic cyanobacteria thrive in warm, sunlit waters, so floatovoltaic deployment could be a neat way of reducing this costly environmental problem. Other types of phytoplankton, such as silica-rich diatoms, however, thrive in lower light and the associated cooler and well-mixed waters. Many of these diatoms are noted for their filamentous structure, useful for absorbing dwindling light but also capable of clogging up filters used on reservoir intakes, adding substantial costs to treatment. Currently, we do not know how floatovoltaic deployment would impact the phytoplankton community, so whether the costs of maintaining water quality after deployment, either through treatment processes or reservoir management, would go up or down remains an unknown. Where they are deployed and which designs are chosen will likely influence the net outcome on water quality and treatment costs as well as which water quality management strategies are most appropriate.

Floatovoltaics may alter the chemical composition of the water as sunlight can break down compounds such as dissolved organic carbon (DOC), a key concern for some water companies. By reducing the sunlight reaching the water, floatovoltaics may, therefore, inhibit a free service, with implications for water treatability and cost. Intriguingly, water bodies also play a part in the global carbon cycle and there are several ways in which floatovoltaics could impact how much carbon the water body stores and releases. Deployments may therefore alter the extent the water body contributes to, or mitigates, climate change. If floatovoltaic deployment can be undertaken in a way which leads to increases in water body storage of carbon rather than release, this would increase their appeal over other means of PV deployment.

How can the full environmental benefits of floatovoltaics be realised?

There remains enormous scope for choice in the deployment of floatovoltaics. How can they be deployed in a way which maximises the myriad potential benefits to the water body while simultaneously removing or minimising any disadvantages? How much of a water body should be covered? Where on the water body should they be put? What size of water body should they be deployed on? Which geographical locations are best? How should the floats and the PV panels be designed for maximum environmental benefit?

Questions such as these were raised at a recent floatovoltaic stakeholder workshop, and are the focus of preliminary research at Lancaster University and at the Centre for Ecology & Hydrology (Figure 1). Answering these questions is the key to understanding how floatovoltaics can be best deployed to increase any beneficial impacts and reduce any detrimental impacts. Demonstrating robust additional benefits beyond low carbon electricity provision will enhance opportunities and support business cases.

Fortunately, although the deployment of floatovoltaics is new, scientists have been studying water bodies for years and have developed numerous tools which will aid answering these questions. These range from the ability to deploy automated in situ sensors collecting data on unprecedented scales, to the development of computer models capable of simulating the water body environment.

The vast array of factors which are likely to affect exactly how floatovoltaic deployment impacts water bodies should be seen as a boon. The range of possible positive and negative environmental impacts means that there is much potential for optimising deployments for additive environmental benefits. Situations which could have net uneconomic or unpleasant environmental consequences can be avoided while those replete with additional environmental benefits can be identified. The key to unlocking this potential is the understanding which scientific research can provide; research which will have global relevance given the increasing number of countries investing in floatovoltaics.

The joint pressures of increasing energy usage, increasing pressure on land and the need to mitigate climate change are driving the desire for inventive and environmentally friendly solutions to electricity production to be found. Stakeholders in the community now have the opportunity to demonstrate how floatovoltaics can be one of these solutions. Researchers, regulators and industry share a common goal of developing industry standards which maximise the additional benefits of floatovoltaic deployment. The beauty or ugliness of floatovoltaics is all in the eye of the beholder, but whether they are good or bad for the water environment is within our gift to determine. ■

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