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News & Highlights

Will Aquatic Solar Panels Make a Splash?

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Some 6300 km of canals crisscross the US state of California to funnel water to its rich farmland and cities such as Los Angeles [1]. But visitors who travel through California's Central Valley starting in 2024 will see something unusual near the city of Modesto: Solar panel arrays up to 33 m across covering more than 3 km of the canals snaking through the agricultural area (Fig. 1) [2]. The installations are the core of Project Nexus, a 20 million USD pilot study to test the feasibility and performance of canal-mounted solar panels [3–5].

Solar panels are covering other aquatic sites as well. So-called floatovoltaics (Fig. 2), or floating solar power facilities, are proliferating on reservoirs around the globe [6,7]. In addition to becoming more numerous, such arrays are getting larger. When the 72 hm^2, 45 MW facility on the Sirindhorn reservoir in Thailand opened in 2021, it was the world's biggest floatovoltaic [8]. But it is tiny compared with the 1600 hm^2, 2.2 GW project under construction on the island of Batam in Indonesia and scheduled for completion in 2024 [9].

Although floating solar panels currently generate less than 1% of the world's solar power [7], covering just 10% of the world's total reservoir area with such facilities could produce 4000 GW of electricity, as much as all existing fossil fuel-burning plants combined [7]. "The idea that we could power a large percentage of our society with water-based solar arrays is quite realistic," said Joshua Pearce, a professor of electrical and computer engineering at Western University in London, ON, Canada. Siting solar panels on or above water could also increase their efficiency and provide a variety of environmental benefits, such as reducing the amount of farmland and wildlife habitat that might otherwise be needed for solar power facilities [10].

Yet key engineering, economic, and environmental questions about the technology remain unanswered, including its long-term operation in humid locations and its impact on bodies of water that millions of people depend on for food, drinking water, and recreation [7]. The potential of aquatic solar power "is significant, but exploiting that potential will require tradeoffs," said Rafael Almeida, an assistant professor of earth, environmental, and marine sciences at the University of Texas Rio Grande Valley in Edinburg, TX, USA.

According to a 2021 US Department of Energy report, the United States will need to increase its solar generating capacity almost 20-fold to meet its 2050 sustainability goals [11]. That will mean adding up to 61 000 km^2 of solar panels—and finding a corresponding amount of land on which to build them [7]. Other countries with more limited space, such as Japan and the Republic of Korea, will face even bigger challenges as they attempt to boost their use of solar power [7].

Fig. 1. An artist's conception shows what one of the canal-top solar arrays in California's Central Valley might look like after its completion in 2024. This section uses a canal-spanning truss design and will be 33 m across. Credit: Project Nexus (public domain).

Fig. 2. This small-scale floatovoltaic system covers a pond at the Far Niente Winery in Napa Valley, CA, USA. Containing nearly 1000 panels, the array and the land-based panels next to it produce up to 400 kW of power, enough to meet the winery's electricity needs. Credit: SPG Solar (CC BY-SA 3.0).

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Floatovoltaics could help reduce the amount of land needed for solar projects. Such arrays might be able to operate on the ocean, with one Dutch company, for example, testing a 1 MW demonstration model in the North Sea [12]. But several factors make hydropower reservoirs the preferred locations for most existing and planned floatovoltaic projects. The dams holding these bodies of water use turbines to produce hydropower that are already connected to the power grid, so floatovoltaics can feed the electricity they produce into this transmission system without requiring construction of new lines [7]. In addition, some reservoirs emit large amounts of greenhouse gases because of decomposition of the organic material they trap [13]. By generating low-carbon energy, floatovoltaics can help offset this release, said Almeida. Moreover, the ecological disruptions from floatovoltaics may be less severe—or at least less objectionable—for reservoirs than for natural bodies of water. "The argument is that reservoirs are already highly modified environments, so why not use them to generate electricity via floatovoltaics?" said Peter McIntyre, an associate professor of natural resources and the environment at Cornell University in Ithaca, NY, USA.

Waterborne solar panels offer other advantages besides cutting land use. High temperatures reduce the efficiency of photovoltaic cells. Installing panels near or in water can boost their energy yield by keeping them cool [10]. The size of the cooling effect depends on local temperatures and the type of semiconductor material in the photovoltaic panels [1]. However, one field study that compared floating solar panels to their land-based equivalents determined that arrays on water generated 3% more electricity in the Netherlands and 6% more in Singapore [14].

By shielding part of a reservoir's surface from the sun, floating facilities might also curb harmful blooms of algae [6,15] and help reduce water loss from evaporation. How much aquatic solar panels could conserve water by reducing evaporation depends on local conditions such as temperature and humidity, as well as on what percentage of the reservoir is shaded. In a 2020 study, Pearce and colleagues estimated the benefits of installing floating solar panels on Lake Mead, a reservoir in the southwestern United States whose water level has plunged because of drought [16]. They calculated that covering 50% of the lake could prevent the evaporative loss of 6.33×10^9 m^3 of water, enough to meet the yearly needs of more than five million people [17].

Despite these potential upsides, "there are basic engineering and maintenance challenges" with floatovoltaics that do not apply to land-based facilities, said McIntyre. Waves are one such challenge. The greater the distance that wind can blow unimpeded across a water body, the more powerful the waves it generates [18]. So far, most floatovoltaics have been deployed on small, tranquil tropical reservoirs, where the arrays only require mooring lines to remain in position [7]. But the wave energy produced by storms over large reservoirs "could break up practically any floating system, creating added risks to installing panels above water," said McIntyre. Installing floatovoltaics in areas with more severe climates may require sturdier designs to withstand the pressures created by ice formation and heaving, as well as planning for additional maintenance and repair costs, which could reduce the economic attractiveness of floatovoltaics relative to land-based arrays [7,19].

Proximity to water might also pose problems. Damp conditions promote the growth of microbial biofilms, whose accumulation could shade the panels and reduce their efficiency. "The more humid it is, the more such biofilms may thrive," said McIntyre. To remove biofilms and other organic material, the panels may require more frequent and aggressive cleaning than land-based panels, he said.

The environmental costs of covering large areas of fresh water are also unclear. The reservoirs that are potential sites for floatovoltaics serve numerous other functions. As well as storing drinking water, some hydropower reservoirs support fisheries that are important sources of food, and they provide habitat for other wildlife [7]. Shading a large section of a reservoir could disrupt aquatic food webs, alter the mixing patterns that determine the availability of nutrients and oxygen at different depths, and cause other changes. "We do not know what is going to happen if we turn off the lights on a good chunk of a large reservoir," said McIntyre.

One study trying to find out is headed by Steve Grodsky, an assistant unit leader at the United States Geological Survey New York Cooperative Fish and Wildlife Research Unit at Cornell University in Ithaca, NY, USA. The two-year project will gauge how three levels of solar panel coverage—0%, 25%, and 75%—affect aquatic ecosystems in experimental ponds. The researchers will measure a host of variables, including water chemistry, evaporation, microbe diversity, abundance of aquatic vertebrates, and even the ponds' acoustical properties, which are important because fish and aquatic invertebrates often communicate with sound. The study and other research may reveal ways to reduce the impact of floatovoltaic systems, said Grodsky. "Engineering them to account for sociological and ecological variables could make them a more sustainable option," he said.

Solar panel arrays on canals have not progressed as fast as their reservoir-based counterparts. India boasts several canal-top solar projects [20], but Project Nexus is the first to test this approach in the United States. Covering canals with solar panels could provide many of the same benefits as the floating arrays in reservoirs. In a study reported in 2021, Brandi McKuin, a Project Nexus team member and assistant project scientist at the University of California, Merced, CA, USA, and her colleagues estimated the potential payoffs for eight sites in California [1]. The researchers modeled the effects of two designs used on canals in India. In one design, a steel truss holds the solar panels above the canal. In the second, a framework that supports the panels stands in the canal and is anchored by tension cables.

When the scientists considered only the cost of power generation, they found that a standard array built next to the canal would beat both over-canal designs at all eight sites. But that conclusion changed when they factored in the other benefits from covering the canals, including reduced growth of aquatic weeds that would otherwise have to be removed, decreased evaporation, and increased efficiency of panels cooled by the water. At all eight sites, the more complete accounting indicated that the tension cable-based design would provide higher returns than a nearby land-based array, whereas the more expensive truss-based design was superior at only one site [1].

Funded by the California Department of Water Resources, Project Nexus will test whether real canal-covering solar arrays can deliver these benefits [21]. When construction is finished in 2024, two sections of canal stretching more than 3.2 km will feature solar panels. The two-year project will evaluate different array designs, measuring their effect on variables such as aquatic weed growth, water temperature, and evaporation from the canals.

By doubling up on land use, the canal-based solar approach spares agricultural acreage and wildlife habitat, said McKuin. And if Project Nexus determines that the panels are net positive, California may install the arrays on more of its canals [21]. "Projects like this are important to show that we can use the built environment to achieve our energy goals," McKuin said.

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