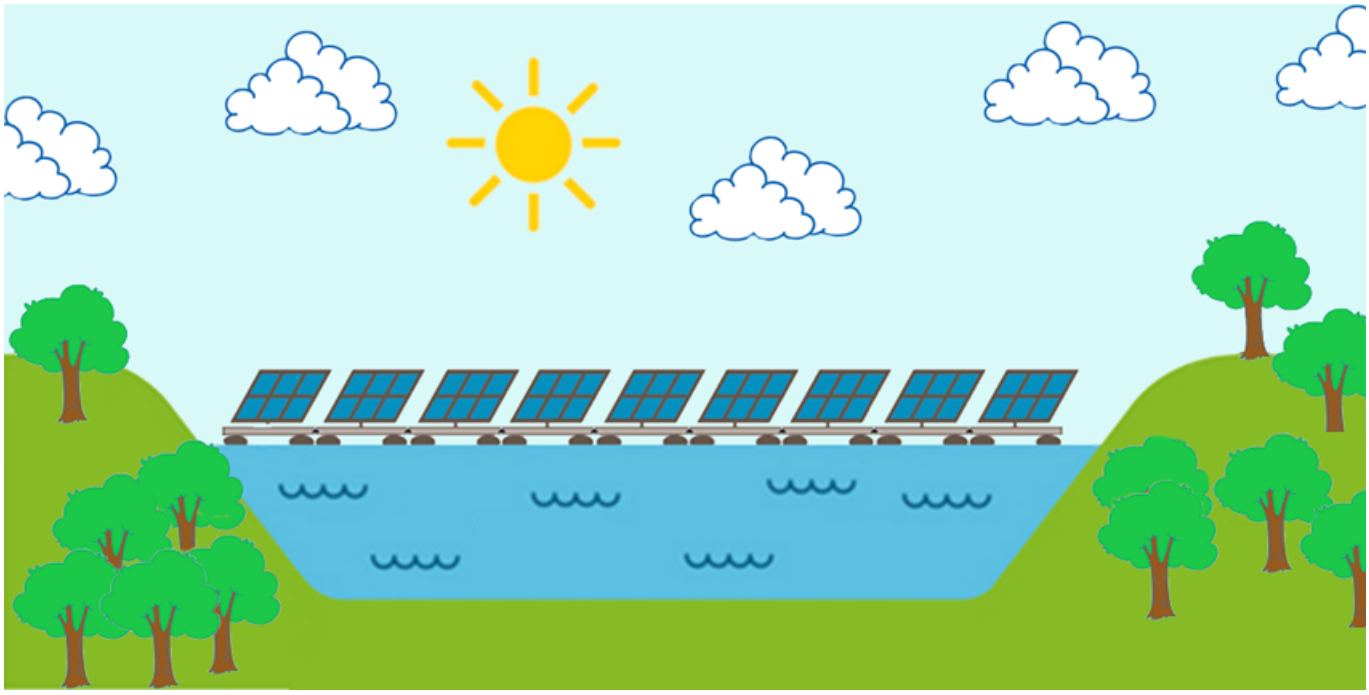

WHY ARE WE INSTALLING SOLAR MODULES ON LAKES?

Leonardo Micheli [1], Giuseppe Marco Tina [2], Girolamo di Francia [3], Diego L. Talavera [4]*

[1] *Dept. of Astronautical, Electrical and Energy Engineering (DIAEE), Sapienza University of Rome, Rome, Italy*

[2] *Department of Electric, Electronic and Computer Engineering, University of Catania, Catania, Italy*

[3] *Research Centre of Portici, ENEA—Italian National Agency for New Technologies, Energy and Sustainable Economic Development, Napoli, Italy*

[4] *Advances in Photovoltaic Technology (AdPVTech), CEACTEMA, University of Jaén, Jaén, Spain*

Photovoltaic modules convert sunlight into electricity, which can be used for various applications, such as charging a mobile phone or lighting a room. Photovoltaic modules do not use fuels, do not emit greenhouse gases, and are very affordable. For these reasons, they are considered one of the main solutions to reduce pollution and fight climate change. However, installing photovoltaic modules requires space, which may be taken from other essential activities, such as growing food. For this reason, many researchers and companies are investigating the possibility of installing photovoltaic modules on water. This solution, called floating photovoltaics, can also help reduce the evaporation of water from lakes, preserving water for drinking or irrigation. However, installing electrical devices, such as photovoltaic modules, on or near water also presents some challenges and risks. This article explains the current use of floating photovoltaic modules and describes their advantages and disadvantages.

PHOTOVOLTAIC MODULE. A device that captures sunlight and turns it into electricity. It doesn't need water to operate.

SOLAR MODULES: ADVANTAGES AND DISADVANTAGES

Photovoltaic modules (Figure 1) are the most common solar energy technology that we can see on the roofs of many buildings in our cities. They capture the particles of energy that make up sunlight,

known as photons. When photons hit the modules, they move tiny particles that are already present in the PV modules and that are called electrons. Instead of remaining inside the PV module, the electrons can be brought outside to generate electrical energy. This can be used for whatever electrical appliance we need (TV, computer, mobile phone, a light bulb...), or can be stored in a battery.

Photovoltaic (PV) modules are considered one of the main solutions to fight climate change because they use renewable energy to generate electricity and do not pollute the environment while doing that. Also, they are not very expensive and can be installed in different ways, from just a few on the roof of a house to thousands spread out in large areas like deserts. However, installing many photovoltaic modules takes up a lot of land, which may be needed for other important activities, such as growing food. Additionally, in some cases, installing photovoltaic modules can destroy animal habitats [1]. For this reason, it is important to ensure that photovoltaic modules are installed in an environmentally friendly way.

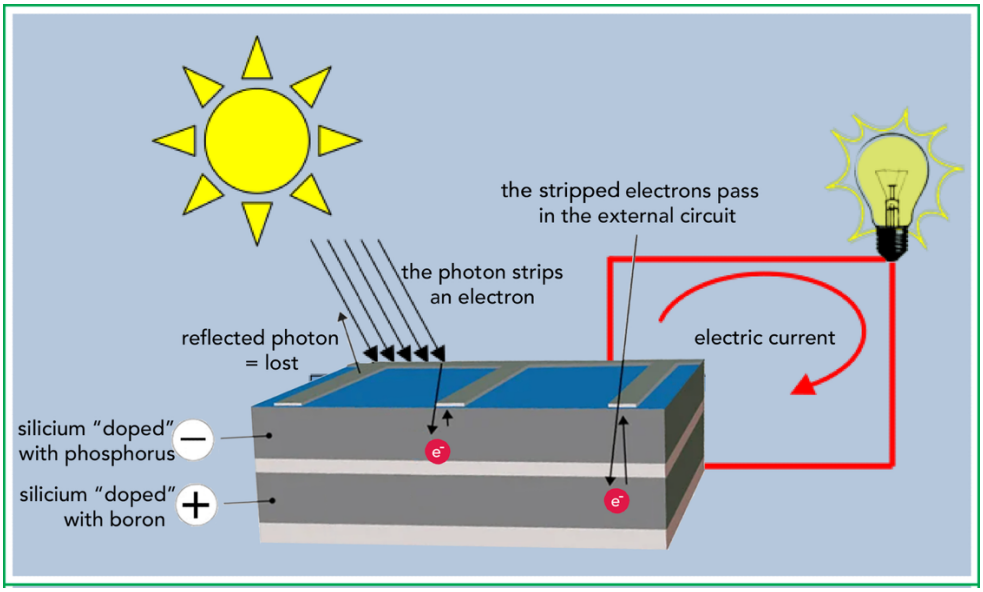

Figure 1. Simplified operation of a photovoltaic cell. The operation of a photovoltaic cell is based on the properties of materials called semiconductors (silicon layers): when photons of sunlight strike them, they strip electrons from these materials. The freed electrons set themselves in motion and are trapped between two layers, one positively "doped" (bottom layer in the dark; silicium "doped" with boron atoms) and the other negatively "doped" (top layer facing the sun; silicium "doped" with phosphorus atoms). This forms a kind of electric battery, creating a flow of electrons (a direct electric current). An anti-reflective layer on the surface of the photovoltaic cell prevents too many photons from being reflected by the cell.

A NEW SOLUTION: FLOATING SOLAR MODULES

Photovoltaic modules can be installed on water bodies, such as natural or artificial lakes, to solve the problem of land usage (Figure 2). This solution is known as Floating PhotoVoltaics (FPV) and is getting the attention of scientists and energy companies in several countries.

PHOTON. A tiny particle of light that carries energy. It doesn't have any weight or electric charge, and it moves very fast… at the speed of light! A beam of light is made of photons.

ELECTRON. Elementary particle that has a negative electric charge. It is, with neutrons and protons, one of the components of an atom.

RENEWABLE ENERGY. Energy produced from natural sources that do not run out, like the sun, wind, and water.

ELECTRICITY. Flow of tiny particles called electrons. It is similar to water flowing through a pipe. This flow of energy is what powers things like lights, computers, and phones.

SILICIUM DOPING. Treatment consisting of inserting a few impurities, in very small quantities, into a material (here silicium). Phosphorus likes to give electrons, boron likes to receive them; the electrons will therefore tend to move from the phosphorus-doped silicium to the boron-doped silicium when the two layers are in contact.

FLOATING PHOTOVOLTAICS. Technology also called floating solar photovoltaics, where solar panels are installed on bodies of water, such as lakes.

FPV modules do not just save land space, but can also save the water of the lakes [2]. Indeed, when water is exposed to sunlight, it evaporates, transforming from liquid to vapor. The shade that the modules produce on the water, like an umbrella, reduces the amount of water that evaporates. This means that more water can become available for drinking, irrigation, or for producing electricity from hydropower plants.

In addition, one must consider that solar modules can get really hot when the sun shines on them. Interestingly, as they become warmer, solar modules produce less electricity, because high temperatures make it more difficult for the tiny electron particles to move smoothly generating electricity. The water underneath FPV modules can help them stay at lower temperature, so they produce more energy than the ones on land [3].

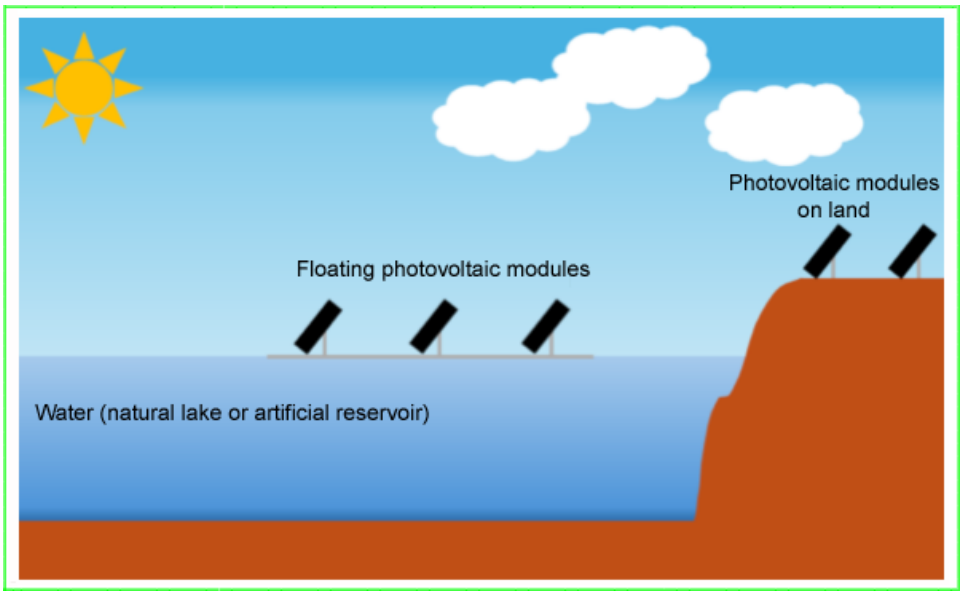

Figure 2. Schematic of a floating photovoltaic system.

However, whether the modules perform better than land ones depend also on several other factors. For example, it depends on how the solar modules are placed, what the local weather is like, and how big or deep the water body is. If the modules are placed flat and touch the water, they stay cooler because their temperature becomes similar to the water's temperature. On the other hand, if the modules are not flat, they can catch more sunlight, but since they are not in contact with water, they don't stay as cool. Also, if the wind is stronger over the water, the modules will be colder. However, if the lake is surrounded by trees or buildings, the wind might be weaker, and the cooling effect will be less. The size and depth of the water body are also important: larger and deeper water bodies tend to stay cooler and provide better cooling for the modules.

In addition, do not forget that FPV modules need special attention because the risk of their failure is higher compared to land. Indeed,

water and electronics don't usually mix well, and water can damage the modules and the other components [2]. Nowadays, the same materials used to realize a PV plant on the land are used for FPV, but better solutions are being studied thanks to the experience we are gaining from existing FPV plants.

HOW MUCH DO FLOATING SOLAR PANELS COST?

An important question that scientists want to answer is: *How much do floating solar modules cost?* Right now, FPV systems are more expensive to set up than land-based solar modules. But even though they cost more, in some places, they are still a good investment [4]. For example, in hot places, such as Türkiye, South of Spain or Italy, FPV systems can work better than solar panels on land because the water underneath helps keep them stay cooler and, being cooler, they can produce more electricity. A number that scientists and engineers use to measure how good an energy system is the *Levelized Cost of Electricity* (LCOE). The LCOE tells us how much it costs to produce electricity from a power system, such as a PV module. The lower its value, the better, because it means that the electricity is cheaper to produce, so it can be sold at lower prices. For floating solar modules, the LCOE is usually higher than on land, but it's still cheaper than burning fossil fuels like gas [4]. This is particularly true in countries where the outdoor temperatures are higher because the lower temperatures of FPV modules can lead to much more energy produced compared to land.

LEVELIZED COST OF ENERGY. Full cost of energy production for a given system (in euros per kWh). It takes into account all the costs of an installation for its entire lifespan: mainly construction, maintenance and renovation costs, and operation.

WHAT'S NEXT FOR FLOATING PHOTOVOLTAIC MODULES?

Even if FPV modules are a relatively new technology, they're growing fast. Right now, FPV systems are most common in countries like China, Japan, and South Korea. In the future, we might see floating solar systems all over the world. If we put floating solar modules on just a tiny part of the world's lakes and reservoirs—about 4%—they could produce all the electricity that we need [5].

But before that happens, scientists are working hard to answer important questions, like how to make the PV modules and floating structure cheaper and how to protect the water ecosystems underneath. For example, we don't know yet if and how FPV modules change the lake's water, or how they affect the animals and plants that live there. So, we need to watch these phenomena very closely. Also, we also need to find new ways to check on these floating modules without having to go out on a boat all the time. At the moment, scientists are working on special technologies that can access the FPV modules from the sky (such as drones and satellites) or underwater (using small submarines or robots, like those shown in Figure 3)

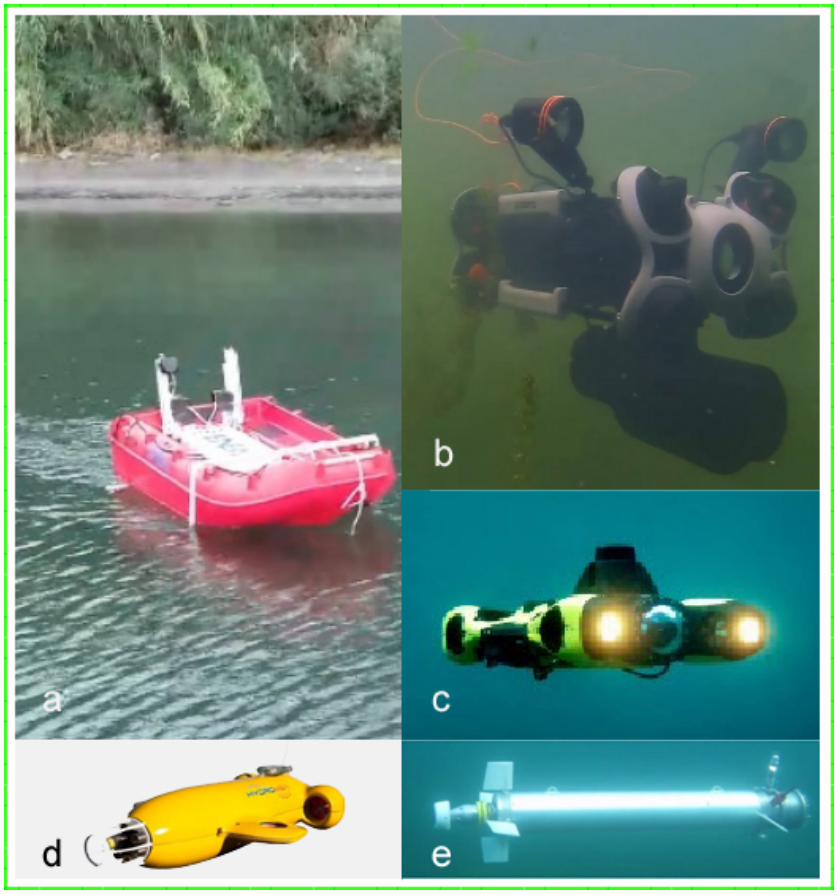

Figure 3. Examples of: (a) autonomous surface vehicle during a mission; (b) and (c) remotely operating vehicles; (d), (e) autonomous underwater vehicles. Adapted from [6].

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SUBMITTED: 11 October 2024; ACCEPTED: 8 April 2025
PUBLISHED ON LINE: 20 September 2025

EDITED BY: Frederic Lemoigno & Catherine Braun-Breton

CITATION: Micheli, L., Tina, G.M., di Francia, G., Talavera, D.L. (2025). Why are we installing solar modules on lakes. https://www.jeunesfrancophonesetlascience.fr/

CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

STELLA, SARAH, NATHAN, MÉLINA, MATHILDE, GABRIEL, CAPUCINE, AUXANNE, ANNOUCK, AGE: 16 - 18
We are French school pupils, studying physics and chemistry in English in a small countryside town in the South of France.

MAISY, AGE: 13
My name is Maisy and I'm 13 years old. I am British and was born in London. My favorite animals are donkeys and bunnies. I am a vegetarian and have two sisters whom I love. I've been playing the piano for six years. Mollie and Eva are my best friends. In the future, I would like to work for my mother's company as a technology integrator.

MOLLIE, AGE: 13
My name is Molly, I'm 13 years old. I am Swedish and was born in Stockholm. I like IKEA, rabbits but don't get along very well with my little brother. Later, I would like to be a veterinarian or another job with animals because I want to help them. IKEA meatballs are my favorite food. Eva and Maisy are my best friends.

EVA, AGE: 13
My name is Eva, I am French, I am 13 years old and I go to the Eridan school in Montpellier. I love my family, my friends, anime manga and I love to draw. Later, I would like to be a doctor. I practice two

competitive sports: aikido and dance. Instant noodles are my favorite food. You probably guessed it, my best friends are Maisy and Mollie!

AUTHORS

LEONARDO MICHELI

Leonardo Micheli is a researcher at Sapienza University of Rome. He is passionate about sustainable energy, especially solar energy! He studies how and why solar panels get dirty and tries to find the best times to clean them, so we can get even more solar energy! After almost 10 years of work, he and his colleagues have made progress but are still searching for the perfect solution. Recently, he has also become curious about floating solar panels, which are installed on water! *leonardo.micheli@uniroma1.it

GIUSEPPE MARCO TINA

I'm an electrical engineer, like a superhero for electricity! After becoming a super-skilled engineer, in 1997 I joined the University of Catania to share my power knowledge. My mission? To understand how cool, clean energy sources like solar power (think sunshine!) work with the giant webs of wires that bring electricity to our homes. I want to make sure everything runs smoothly! By studying how electricity behaves, we can help make sure there's enough power for everyone, all while keeping things clean and green. I'm especially interested in a strange mix: water and solar power! That's why I'm studying solar panels that float on and even go under the water.

GIROLAMO DI FRANCIA

I'm Girolamo Di Francia, an experienced researcher in the Italian National Agency for New Technologies, Energy and Sustainable Economic Development. I like trying to understand how natural things work, including humans. I do this by looking for the traces our activities leave behind: the data. With the help of mathematics and physics, I try to recognize, in these traces, the how and why of things, as well as the similarities between them. I often find myself doing this with energy… but, in the end, isn't it true that everything is energy?

DIEGO L. TALAVERA

Diego L. Talavera is a researcher at the University of Jaén, Spain. His field of study is solar photovoltaic energy. He studies the performance of solar panels and the economic costs and benefits of their implementation. After 20 years of work in this field, he and his collaborators continue researching new technologies and applications of solar panels. Currently, he is also studying solar panels installed on water or placed over land where crops are grown.