Powering Our Lives With the Ocean: From Waves to Electricity

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POWERING OUR LIVES WITH THE OCEAN: FROM WAVES TO ELECTRICITY

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YOUNG REVIEWERS:

LEON
AGE: 13

NIKHIL
AGE: 13

STEPHANIE
AGE: 13

We are surrounded by an incredible amount of energy every day! Energy powers our phones, video games, and even our cars. But where does this energy come from? Did you know it can come from waves? All the waves that you see from the beach carry an enormous amount of clean energy, and we can turn this energy into electricity that powers our days. This is achieved by using devices called wave energy converters. Just like a windmill produces power thanks to the blowing wind, wave energy converters generate electricity by harnessing the energy from incoming waves. Curious to know how it works? Dive into this article and discover the world of wave energy!

WAVES TO POWER YOUR DAY

Would you believe us if we told you that you could charge your phone, power your computer, or run your car (if it is electric) using the very

same waves you see when you go to the beach? Ocean waves can carry a lot of **clean energy**, and you have probably experienced that energy yourself. If you ever used a bodyboard to catch a wave (or even a surfboard, if you are more experienced), you have directly used the energy available in waves to swirl yourself across the ocean. Even when you are simply standing in the sea and a wave approaches, you can feel a force pushing you...sometimes so strong that it makes you fall! As you will find out by reading this article, wave energy can be harnessed to power your daily life. This is the idea behind the world of ocean wave **energy conversion** [1].

CLEAN ENERGY

Energy that comes from sources that do not create pollution or harm the environment, such as sunlight, wind, and water.

ENERGY CONVERSION

The process of changing energy from one form to another.

HOW MUCH ENERGY IS FOUND IN WAVES?

A lot of energy can be found in waves [2]. In fact, let us do a quick estimate together: a single wave, very much like those you ride with your bodyboard, can be used to power your phone more than 4,500 times in a day! (estimation based on the energy available in waves with a 1-meter significant wave height and a 6-s energetic period, per 1 meter of frontage, and the battery capacity from a standard smartphone).

If we consider all the waves in the ocean, that is a lot of power! But where is all this clean energy actually coming from?

Waves result from a combination of two other energy sources that you know very well and experience nearly every day: the sun and the wind. The sun is actually responsible for the wind. Sunlight heats the Earth unevenly, causing warm air to rise and cool air to rush in, creating wind. The wind blows over the surface of the ocean, very much like an invisible hand "pushing" the water forward. At first, the water moves just a little, making tiny ripples, like mini waves. But if the wind keeps blowing, these ripples start mixing and joining together, getting bigger and bigger, creating the waves you see rolling into the shore, crashing against the rocks! Imagine blowing on a glass of water and seeing the ripples and bubbles forming on the surface. When you blow, your breath carries the energy that makes the water move, very much like the wind does on the ocean's surface (Figure 1).

WAVE ENERGY CONVERTER (WEC)

A device that catches wave motion to generate power.

GENERATOR

A machine that converts energy from one form to another. In our case, the energy of the WEC's motion into electrical energy.

MOORING

A device or system, like an anchor, buoy, or cable, that holds a boat or floating structures in place.

TURNING WAVE POWER INTO ELECTRICITY

So far, we have established that waves can be very powerful...but can we turn this power into electricity? And can we do this efficiently? The devices that perform this conversion task are called **wave energy converters (WECs)** [3]. WECs are commonly composed of two main parts: a large body, capable of moving with the waves, and a **generator** (Figure 2). We will discuss both of these key elements in the following paragraphs. But if a floating WEC is hit by big waves, how does it stay in place without drifting away? The secret is the **mooring** system! This

Figure 1

Wave formation process. The sun generates wind by causing warm air to rise and cool air to rush in. The wind forms ocean waves by blowing across the ocean surface, pushing the water.

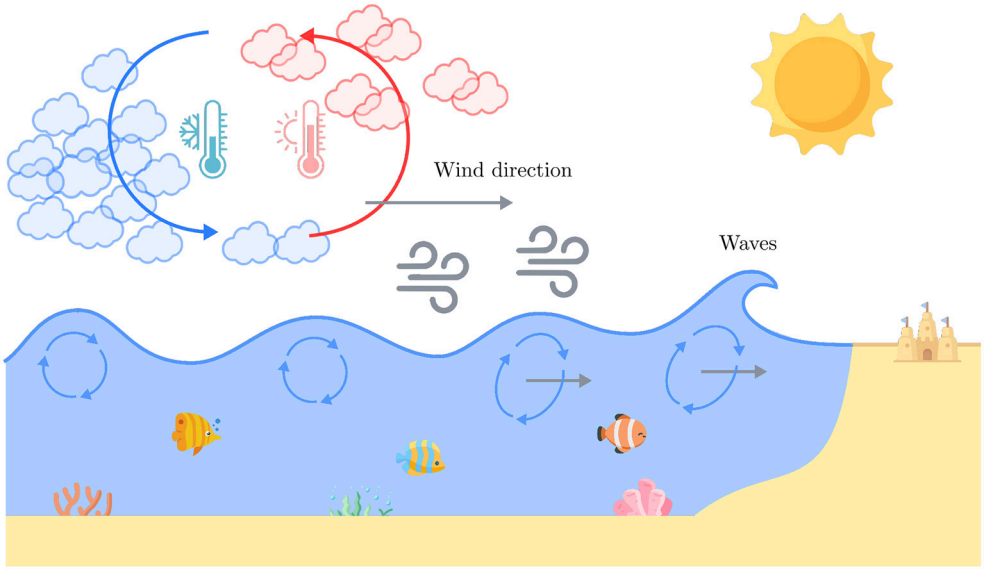

Figure 1

system uses strong chains and ropes, similar to those used to keep ships tied to the docks. These chains and ropes make sure the WEC does not drift away, even when the waves are really strong!

Figure 2

Two main wave energy conversion concepts. **(A)** Point absorber WEC (spherical, in this case) moves up and down due to wave action. **(B)** Terminator type WEC, in particular a flap-like structure, which moves side to side due to wave motion. Both types are connected to generators, which can transform their motion into usable electricity. The difference between the big wave approaching the WEC and the smaller wave leaving it is a measure of the energy the WEC has successfully converted. Researchers make a constant effort to design WECs so that they are harmless for fish and other marine life.

PROTOTYPE

An early model of a device created to test how it works and to make improvements before creating the final version.

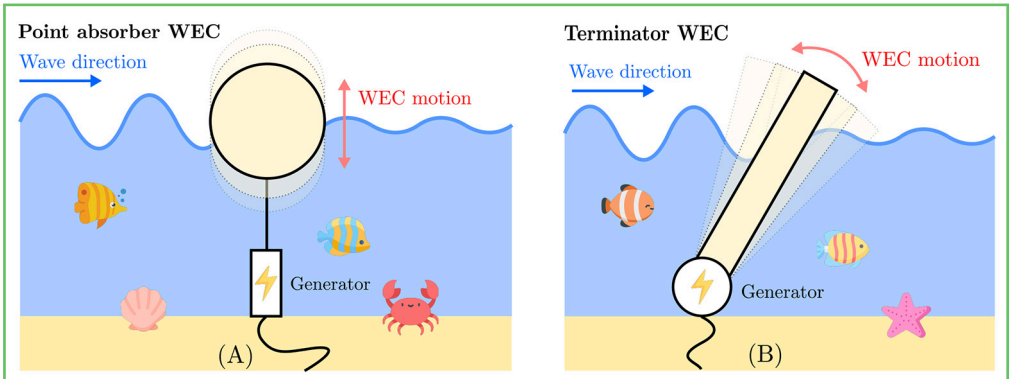

Figure 2

The WEC body moves up and down (Figure 2A), or side to side (Figure 2B), by the action of the waves, which generate a force over the surface of the body. This movement drives a generator, which can transform motion into electricity. Then, the electricity is carried to your house with a long electrical cable. While WECs are not yet widely available, some **prototypes** are already in use around the world, for instance along the coasts of Italy and Scotland. Ultimately, we may see big "farms" of WEC systems, composed of several units close to each other, to improve energy capture from waves.

HOW CAN WE BOOST CONVERSION OF WAVE ENERGY?

As shown in Figure 2, WECs can be based on different principles. But which one absorbs more energy? The answer is not as simple as you may expect. The "best" WEC concept depends on the nature of the waves themselves: although waves might look the same when we admire them from the beach, each location on Earth can have different wave formation characteristics. Some spots can have bigger or longer waves, requiring different technology for their efficient conversion. However, there is a "universal" tool that we can use to improve the efficiency of any WEC, independently of its energy conversion method. This mechanism is called a **controller**.

CONTROLLER

Software that directs the actions of other machines or systems to pursue an objective. In our case, the controller aims to maximize the WEC converted energy.

The controller is like a smart computer program (think of it like one of the apps on your phone) that can tell the generator what to do to improve energy conversion from the waves [4]. The controller helps the WEC at just the right moment. If you observe Figure 2 closely, you will see that the waves approaching the WECs are taller than the waves leaving it. This difference shows how good the WEC is at turning wave energy into the kind of energy we can use, and making that process better is precisely what the controller aims to do!

Earlier, we explained how the generator turns the WEC movement, caused by waves, into usable energy in the form of electricity. More movement means more electricity. With this in mind, the WEC controller does something very similar to what happens when you are on a swing and you want to go higher: it acts just like someone pushing you at exactly the right moment, to help you swing as high as possible! The controller tells the generator when to give a push to the WEC, to increase its movement and therefore boost the energy converted (Figure 3).

WHAT DID WE LEARN?

You now know that the energy contained in ocean waves is almost unlimited and can be used to power our daily lives! Wave energy can be transformed into usable electricity using machines called WECs, which are designed to convert the up-and-down (or side-to-side) motion of a body in the ocean, moved by wave action, into electricity, using a generator. Since waves can be very different across the globe, and we would like to convert ocean energy everywhere, different types of WECs have been developed. To make energy conversion as efficient as possible, controllers come into play, optimizing the amount of electricity WECs can transform from the ocean waves. So, keep your eyes open for these amazing devices—you might see one floating near your favorite beach very soon!

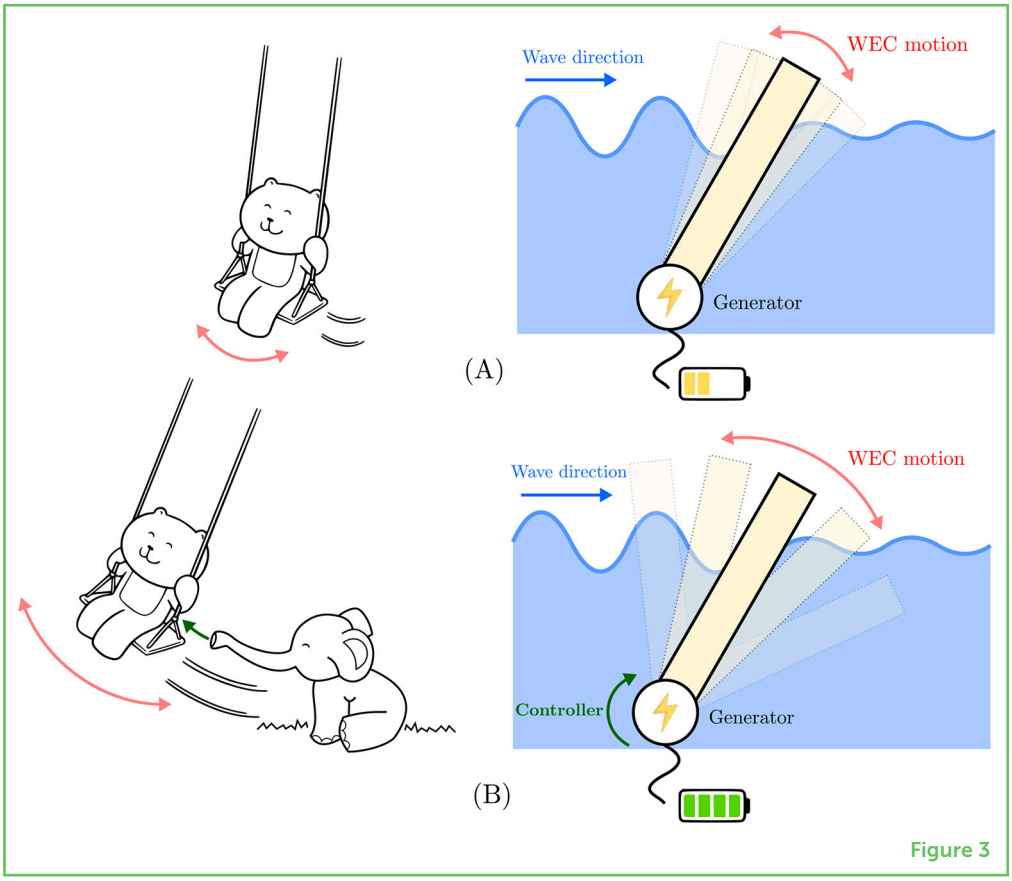

Figure 3

WEC controllers help the WEC to transform energy more efficiently, by giving a force to the WEC at the right moment. You can think of the controller as someone giving you a little push when you are on a swing and you want to go higher. **(A)** If you swing alone, your movement will be always less than if **(B)** someone pushes you at the exact right time, helping you go as high as you can. The WEC controller essentially does the same, by giving a little push to the WEC body at the right moment to maximize its movement.

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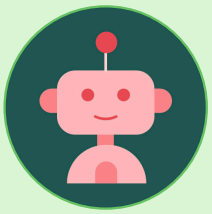
CONFLICT OF INTEREST: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

YOUNG REVIEWERS

LEON, AGE: 13
Leon is a curious 13-year-old with a passion for science, especially astronomy, biology, and physics. He loves exploring science fiction, particularly The Remembrance of Earth's Past Trilogy. Leon enjoys trying new foods from around the world, including Thai, Chinese, Italian, and Japanese cuisines.



NIKHIL, AGE: 13
Nikhil is fascinated by the world of science, specifically astrophysics and microbiology. He is a funny kid who loves goofing around and being silly as well as geeking out on black holes and warp drives in equal measures.

STEPHANIE, AGE: 13
My name is Stephanie and I am 13 years old. I am an eighth grader in middle school and my hobbies include singing, playing tennis, and playing the clarinet. My favorite subject in school is ELA and I enjoy reading and writing mystery and dystopian stories. I have performed for the UniverSoul Circus before and I have been a reviewer for some scientific articles in this journal.

AUTHORS

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Nicolás Faedo comes from Buenos Aires, Argentina (birthplace of the one and only Leo Messi!). He received a degree in automation and control engineering from the National University of Quilmes, Buenos Aires, and a Ph.D. in electronic engineering from the Center for Ocean Energy Research group, Maynooth University, Ireland. Nicolás is a researcher at the Politecnico di Torino, in Italy, working in the field of marine renewable energy systems, addressing efficiency and optimizing energy conversion using control theory. *nicolas.faedo@polito.it

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Bruno Paduano hails from Pompei, Italy (1992). He earned his mechanical engineering degree from Politecnico di Torino, Italy. Currently, on a post-doc journey at the Marine Offshore Renewable Energy Lab, he is delving into wave energy. In 2022, he was a Visiting Researcher at WaveEC Offshore Renewables, Lisbon. His interests span modeling, design and control of offshore devices. Beyond research, Bruno's passion lies in cooking delectable dishes and sharing hearty dinners with friends.

MARIA LUISA CELESTI

Maria Luisa Celesti earned her B.Sc. in Mechanical Engineering from Università degli Studi di Perugia, Italy, and an M.Sc. in the same field at Politecnico di Torino. Her research journey began at the Center for Ocean Energy Research in Ireland, where she developed her master's thesis, immersing herself in the study of renewable energy technologies. Currently, she is pursuing a Ph.D. at the Marine Offshore Renewable Energy Lab at Politecnico di Torino, focusing on energy conversion from waves and wind, focusing on their control. Beyond her academic pursuits, she enjoys trying new sports, traveling, and strumming tunes on the guitar.