# WAVE ENERGY CONVERTER ARRAY'S IMPACT ON COASTAL PROCESSES AT AGUÇADOURA, PORTUGAL

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## Abstract

As part of the SafeWave project, Hidromod evaluated the impact of wave energy converters (WECs) on coastal processes at the Aguçadoura test site in Portugal. The SNL-SWAN wave model was used to study a farm of HiWave-5 point absorbers from CorPower Ocean. The WEC farm modelled had four groups of seven WEC units each, producing about 10 MW. The farm was located 5.5 km from shore, in an area 40 to 45 m deep. The most significant reduction in the wave energy flux occurred within 250 m of the site, decreasing below 10% further away. The effect gradually diminishes toward the shore, with less than 2% reduction nearshore. Wave direction remains virtually unchanged close to shore.

## Simulating WAves Nearshore (SWAN) and SNL-SWAN

The SWAN wave model computes wind-generated waves in coastal regions and inland waters (further details in https://swanmodel.sourceforge.io/). The SNL-SWAN model, an extension of SWAN, includes a WEC module to account for wave energy converters' power performance and their effects on the wave field. A power matrix provides WEC information, and obstacle implementation influences the transmission coefficient and energy flux between neighbouring grid points.

## CorPower Wave Energy Converter

The equipment simulated at the Aguçadoura test site is the HiWave-5 from CorPower (https://corpowerocean.com/wave-energy-technology/). With the power matrix provided by CorPower, energy production was derived from significant wave height and energy period. Simulations for the power matrix include only conversion chain losses for each WEC unit (e.g., downtime, array interaction losses, electrical farm losses, and auxiliary consumption) and do not account for external system losses. The total system efficiency for each WEC is approximately 86.5% of its rated power.

## Local wave climate

Analysis of data from the Leixões buoy collected over 5 years (2018 to February 2023) shows that the primary incident wave direction is from West to North-northwest, accounting for 91.47% of the registered data. The most frequent significant wave heights range from 0.5 to 5.0 m in this sector. Waves from the West to South-southwest sector represent 5.89% of the records, with the most frequent significant wave heights ranging from 0.5 to 4 m.

Peak periods are predominantly between 8 to 16 seconds (86.51%), associated with significant wave heights from 0.5 to 4.0 m. Higher peak periods have been recorded, but they account for only 1.59% of the data.

## WEC farm modelling

*Modelling domain*

The modelling domain for the simulation must align with the WEC farm size and consider the potential affected area due to the shadowing effect. The generated domain has 8.5 km cross-shore and 7.7 km along-shore. Several grid resolutions and WEC shapes were tested, but the adopted configuration had 9.0 m grid resolution.

*Boundary conditions*

The boundary conditions used for the wave model have a 15-day range and consider typical high-energy events for the Portuguese coast. From the data collected by the Leixões buoy (Figure 1) , it is possible to see that there are four high-energy events (2022/10/15 to 2022/10/25) with significant wave heights above 4.0 m, peak periods ranging from 6 to 15 s, and covering an incoming sector from 200º to 330º. After October 25 (see Figure 1) less energetic wave conditions occur with significant wave heights between 1.0 to 3.0 m, peak periods from 6.0 to 15.0 s, and incoming waves from 220º to 315º. The implementation of these sea states in the wave model was done in the form of wave spectral energy information.

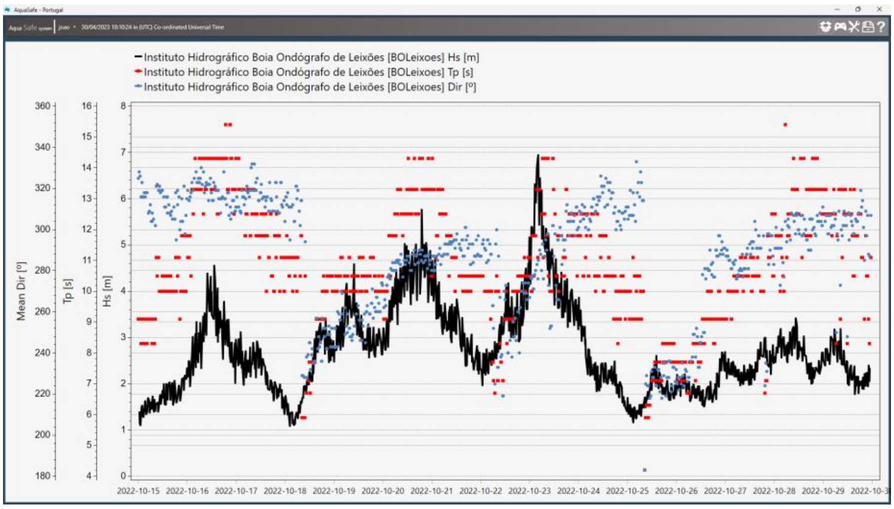


Figure 1 – Collected data from the Leixões buoy.

*WEC farm simulation results*

The whole WEC farm production forecast can be determined by calculating the difference between the energy flux of the WEC and NoWEC scenarios. This is done by extracting a profile immediately to the East along the WEC arrays closest to shore. In the scenario without a WEC farm, the accumulated energy flux along this profile, over the 15-day period, ranges between 14.35 MWh/m and 15.84 MWh/m. However, in the scenario with the WEC farm, the accumulated energy flux along the same profile, for the same time interval, ranges between 6.78 MWh/m and 15.67 MWh/m (Figure 2). Integrating both profiles over the mesh size and calculating the difference between them, a value of 2620.12 MWh is obtained (Figure 2).

When comparing to the theoretical production capacity of the farm, 11.2 MW (400kW times 28 WEC units) for a 15-day period (4032 MWh), this corresponds to a 65% production efficiency for the farm during this period (Table 1). It is essential to keep in mind that the 11.2 MW value is without any energy losses and the 10MW farm includes conversion chain losses as mentioned above.

The range of influence of the WEC farm was analysed by integrating the energy flux data from a 15-day simulation run, in two separate scenarios: one that includes the WEC farm, and another without it.

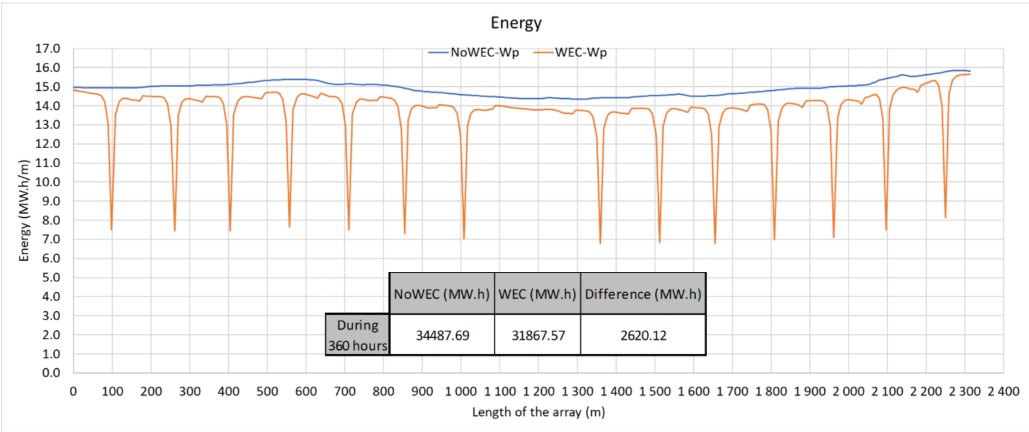


Figure 2 – Energy flux profile for the WEC and no WEC situation and forecasted production.

Table 1 – 15 days energy production estimation.

| | Energy Production (MW.h) | | |
|---|---|---|---|
| | Model | 11.2MW Array | Estimated production |
| During 360 hours (15 days) | 2620.12 | 4032.00 | 65% |

This observation is important because it indicates that while the WEC farm can influence the wave propagation, its impact on the nearshore waves (a critical factor in coastal ecosystems and processes such as sediment transport and beach erosion) is not significant.

The most significant reduction occurs immediately to the lee of the WEC farm, exceeding 1900.0 kW.h/m. Closer to the shore, the reduction in wave energy is progressively reduced, with values lower than 200 kW.h/m.

In Figure 3, the WEC farm's influence in terms of percentage of the energy flux reduction is shown. Roughly within 200m distance from the WEC farm, the reduction is above 10%, while closer to the shore, it ranges between 1% and 4%.

Timeseries of significant wave height and wave power at roughly 700 m to the lee of the WEC farm, show the influence of the WEC farm in the wave field (Figure 4). At this location, a reduction in both significant wave height and wave power can be observed. Although minimal, on the order of centimetres, the significant wave height with the presence of the WEC farm (yellow dots) is smaller than the situation without the WEC farm (black dots). The wave power for the two scenarios shows a clear difference.

## Conclusions

The simulation results of the WEC farm reveals that the most considerable energy reduction takes place within 250 m to the lee of the site. Outside this area, energy extraction decreases below 10%. The shadowing effect gradually diminishes towards the shore, with the reduction nearshore being less than 2%.

Virtual monitoring stations 4.5 km to the lee of the WEC farm show energy reduction ranging from 1% to 4%. The timeseries at these locations indicate that changes in wave power are two orders of magnitude lower than the incident wave power in the shoreline. Changes in wave direction are not observed for the virtual monitoring stations located closest to the shore. This observation is very significant as changes in wave direction nearshore might have a direct impact on sediment transport.

The results achieved with these simulations indicate that a WEC farm located at the Aguçadoura site would not influence the sediment transport at the shore or any other processes.

To accurately assess the extent of the wave farm's influence, large computational domains are required. Additionally, the computational grid must have a resolution capable of simulating the WEC unit. These two factors make the simulation effort very time-consuming and for these reasons future work should address the computational effort in other to simulate longer time periods for larger WEC farms.

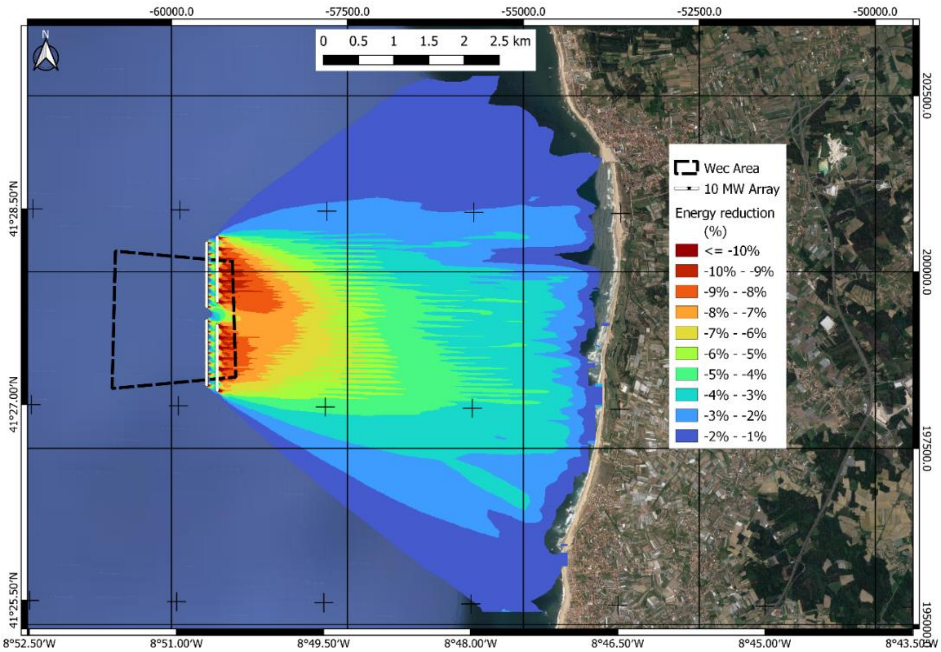


Figure 3 – Percentual energy reduction due to the presence of the WEC farm.

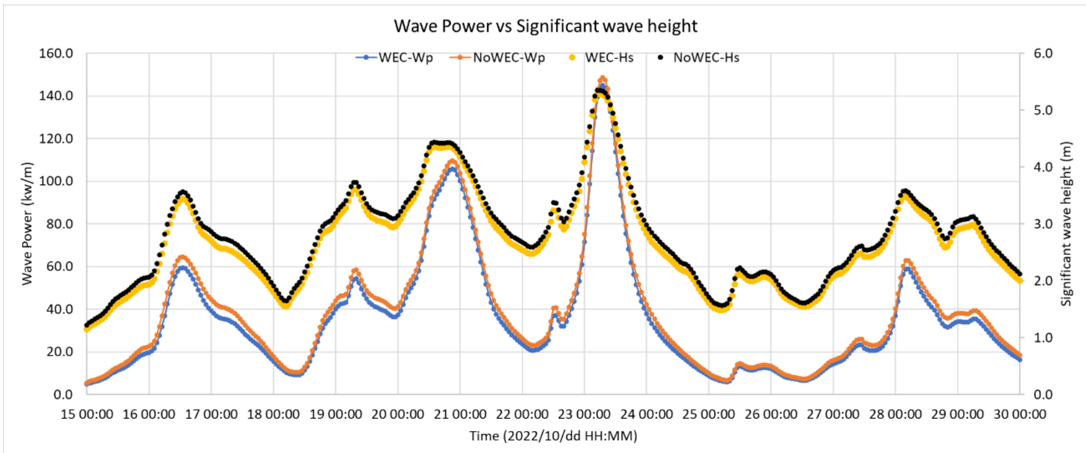


Figure 4 –Comparison between significant wave height and wave power 700 m to the lee of the wave farm.