CASE STUDY FOR FUTURE WAVE ENERGY EXPLOITABILITY (2020 - 2050) IN THE BELGIAN CONTINENTAL SHELF

Paulino Meneses, Ghent University, Paulino.MenesesGonzalez@ugent.be
Manuel Corrales-Gonzalez, University of Genoa, manuelalejandro.corralesgonzlez@edu.unige.it
Vasiliki Stratigaki, Ghent University, Vasiliki.stratigaki@ugent.be
Edgar Mendoza, Universidad Nacional Autónoma de México, emendozab@iingen.unam.mx
Giovanni Besio, University of Genoa, giovanni.besio@unige.it
Peter Troch, Ghent University, Peter.Troch@ugent.be

WAVE CLIMATE ALONG THE BELGIAN CONTINENTAL SHELF

The wave energy sector aims to reduce the costs and maximize the Wave Energy Converter (WEC) power absorption to reach parity with other renewable energies. Likewise, the continuous change in the local metocean conditions due to several mid and long-term atmospheric and ocean events, and the reduction in air pollution from the extraction of non-renewable energies have prompted a meticulous examination regarding the WEC performance (Lavidas, 2019). Specifically, for the Belgian Continental Shelf (BCS) a performance assessment of several WECs at different locations has been developed. The eleven locations for evaluating the WECs are shown in Figure 1. The wave information at those locations has been estimated through numerical wave modeling by using the Simulation Wave Nearshore (SWAN) model (Booij, et. al., 1996). The numerical model setup consists of three nested meshes with resolutions of 5 x 5 km, 1 x 1 km, and 200 x 200 m. The bathymetry is based on ETOPO-1 (Eakins, et. al., 2010) and Agency for Maritime and Coastal Services (MDK). The model setup was forced with the ERA5-reanalysis (Hersbach, et. al. ,2023) wind database for 11 years (2010 – 2021). Then, the spectral parameters were validated for 2015 with the BVH buoy data (Meetnet Vlaamse Banken, 2023) as shown in Figure 2.

This study will be extended in the time horizon to the period from 2024 to 2050, wherein the wave climate is estimated forcing the numerical setup with CORDEX regional climate model data (Copernicus Climate Change Service, Climate Data Store, 2019) from 2024 to 2050 with a spatial and time resolution of 0.11° x 0.11° and 6 hours, respectively.

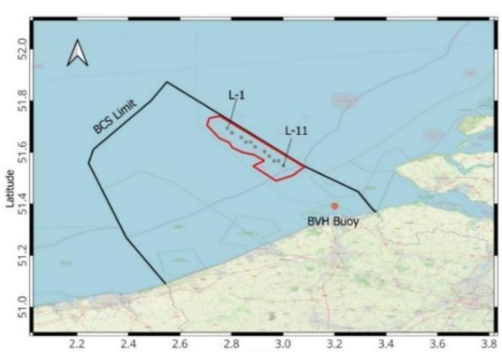

Figure 1 – Studied region: Belgian Continental Shelf (BCS). The red contour corresponds to the zone of marine energy exploitation. The locations are named from L-1 to L-11 in ascendent order, but, for clarity of the image, the names of Locations from 2 to 10 have been omitted.

STUDY ON THE PERFORMANCE OF WAVE ENERGY CONVERTERS

According to the literature, BCS's average annual available wave power ranges from 1.5 – 5 kW/m (Beels C., et al., 2007). The current WEC concepts are incompatible with the BCS wave conditions because, originally, they were designed for high-energy areas. Previous studies have demonstrated that a scaled version of the WEC can be suited to low-energy seas (Babarit, et. al., 2011; Bozzi, et. al., 2018, Corrales-Gonzalez, et. al., 2023). This work studies the performance of nine scaled WECs at the BCS. The scale is carried out through Froude's law, with λ in the range of 0.2 to 2.0. The following results were estimated with the current database, 2010 – 2021, but to understand the variations over time, they will be calculated for the wave conditions projection, 2024 – 2050.

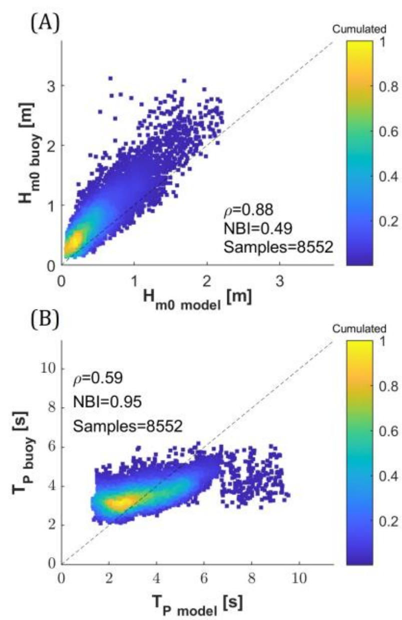

Figure 2 – Comparison of the significant wave height (Hs) in the panel (A), and peak period (Tp) in panel (B) between the simulated and buoy data, year 2015.

Hence, the Capacity factor (CF) of the scaled converter can be re-estimated, and how much its efficiency increases, as shown in Figure 3, which presents in this abstract the results for 4 of the evaluated converters and 4 locations. Once the WEC with the highest CF is chosen, it can be further analyzed by converter performance indexes such as SIWEDTR (Lavidas, 2020), defined as:

$$SIWED_{TR} = \frac{e^{-CoV(H_{m0})}\,CF}{\frac{H_{EVA}}{H_{max}}}, \qquad [1]$$

where CoV(H_{m0}) is the Coefficient of Variation of H_{m0}, CF the capacity factor, H_{EVA} corresponds to the wave height associated with the return period of "TR" years from the extreme value analysis, and H_{max} is the highest wave height along the model data. In Figure 4 it is clearly observed that the scaled converters Sparbuoy (λ=0.5) and AquaBUOY (λ=0.4) produced higher values of SIWED30. These results mean that those converters are suitable to deploy the wave energy extraction at all locations, even considering the survivability of WECs. The other converters do not offer good performance for the wave conditions occurring at the BCS. Furthermore, an economic analysis has been carried out, namely the estimation of the levelized cost of energy (LCOE), the cost of energy (COE), and the payback period (PBP). Then, a more appropriate WEC selection has been done along the evaluated region in the Belgian seas.

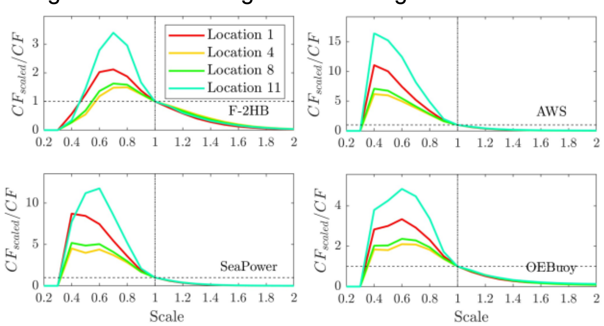

Figure 3 - Capacity factor ratio between the scaled WEC and the prototype one for four WECs at four assessed locations.

The results indicate that a downscaled version of AquaBUOY and Spabuoy can be adapted to the BCS conditions; however, in order to study the feasibility of WEC projects, future scenarios should also be studied.

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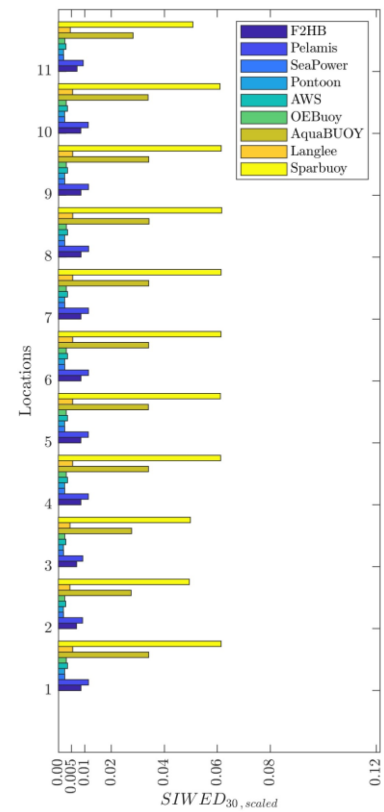

Figure 4 - $SIWED_{30}$ for the all the scaled WEC with the highest CF_{scaled} at the eleven locations.

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