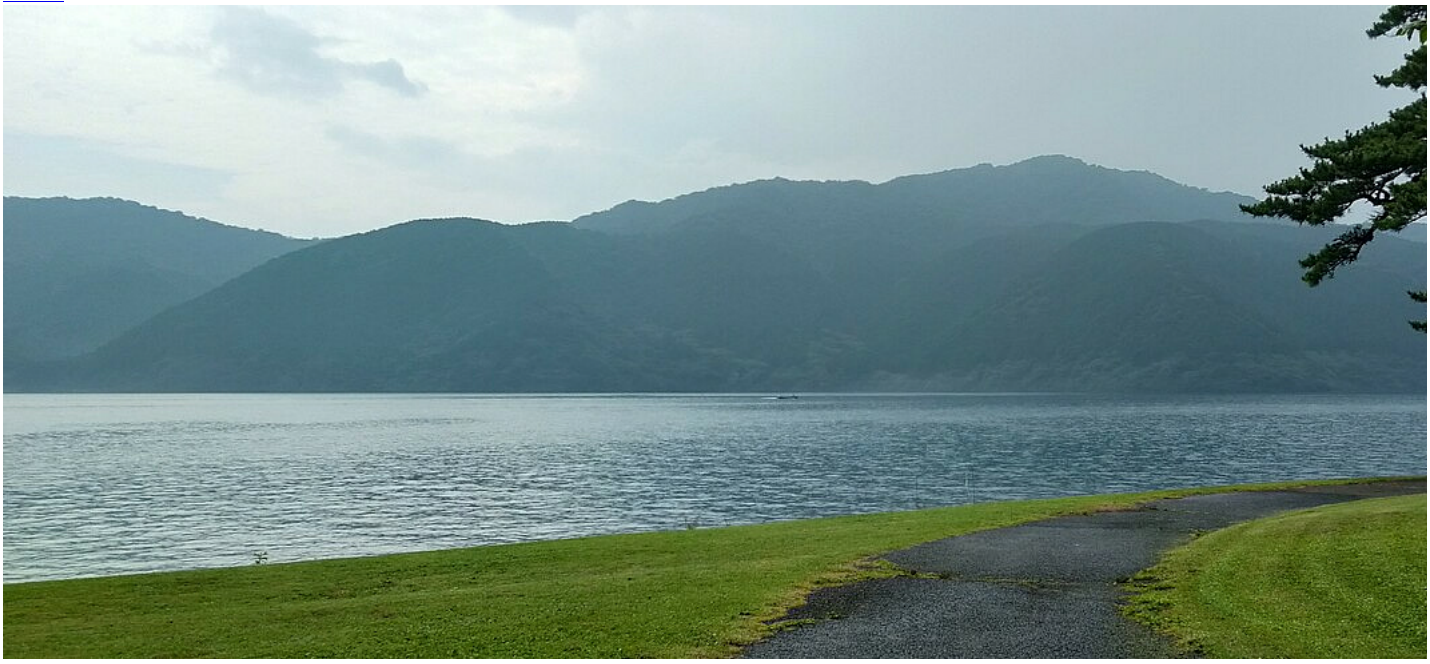
From “Maladaptation” to “Antifragility”: Coastal areas under the combined impact of changing climate and development of ocean renewables

Published Apr 26, 2023

Bahareh Kamranzad
Lecturer & Chancellor's Fellow, University of Strathclyde
Follow



The use of fossil fuels has been widely acknowledged as a significant contributor to both energy crises and climate change. As a result, there has been a growing need for renewable energy sources to provide sustainable energy solutions and support net-zero emission targets. In coastal regions, **ocean renewable energies (OREs)** such as wind, wave, and tidal offer promising alternatives to fossil fuels, which among them wave energy outstands due to its relative advantages such as the highest density among all ocean renewables, predictability, being endless, lower visual and environmental impacts, and broad geographic viability. Moreover, wave energy can be used as a novel method for coastal protection against the increased coastal disasters due to climate change[1]. In contrast with conventional coastal protection schemes, wave farms can be more adaptable to Sea Level Rise (SLR) due to the flexibility in their design. However, the availability of wave energy in the long term is highly affected by climate fluctuation, necessitating a sustainability assessment of this resource at various time scales to determine suitable locations for wave farms with sustainable supply[2,3] (Fig. 1). Additionally, assessing the offshore/coastal climate variability is crucial for future development planning, disaster prevention, and climate mitigation programs.

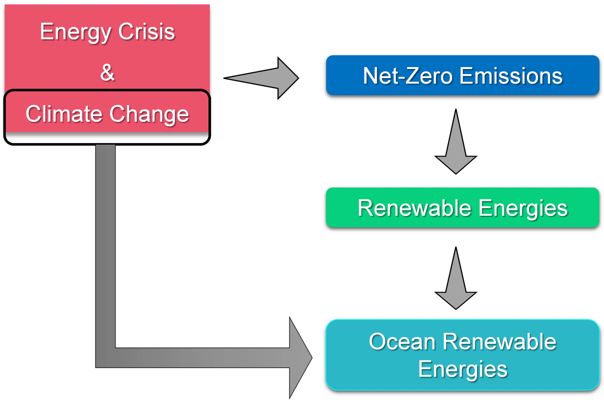


Fig. 1. Impact of climate change on OREs

The investigation of ocean energy under the impact of climate change presents significant challenges due to: **i) uncertainties in ocean simulation and hence, resources assessment**, and **ii) uncertainties in climate change projections**. However, there are opportunities to advance the research frontier despite these challenges. Such opportunities include developing high-resolution regional and local ocean models, innovative downscaling techniques, and wave model development to achieve higher accuracy for complex conditions (to address challenge i), as well as developing high-resolution regional and local climate models, innovative methodologies for generating multi-model ensembles, and utilizing data assimilation methods to reduce uncertainties (to address challenge ii), which highlight the research gap in the area of ocean renewable development in the face of a changing climate in order to establish reliable estimates of ocean resources and their sustainability.

In a previous study, we generated a wave dataset spanning 60 years of wave hindcast to investigate the long-term variability in wave climate and focused on understanding the relationship between the change in wind and wave characteristics (including wave energy) on a global scale. Such a relationship can be used in predicting future changes, without performing long-term and time-consuming modelling for various climate projections, under the assumption that the relationship between wind and wave parameters which is defined by ocean dynamics remains the same. We performed the analysis for both locally generated wind-induced waves (referred to as "Seas") and "Swells," which are wind waves that originate in one location before being transferred to another. Our research indicated that it was possible to predict the changes in global wave power with a high degree of accuracy (91%) based solely on predicted changes in the swell climate. Additionally, without numerical modelling, it was also possible to predict the change in global wave power based on the change in wind speed with 85% accuracy. Through this approach, we were able to redefine suitable coastal regions for wave energy exploitation in line with Sustainable Development Goals (SDGs) by utilizing a novel index that takes into account the available energy and its intra-annual fluctuation and long-term change[4].

One of the primary challenges facing the development of wave energy is the economic justification of the high levelized cost of energy (LCOE) relative to other forms of ORE. However, new approaches are being explored to address this challenge, such as co-locating OREs[5] (e.g., joint wind, wave, and solar farms), as well as exploring the potential for multi-purpose usage of wave farms[6] (e.g., for coastal protection). Incorporating wave energy into existing wind farms can also lead to multi-purpose usage of them. While the multi-purpose usage of wave farms for coastal protection holds promise, coastal engineers are acutely aware that coastal protection efforts can lead to unintended consequences, such as sediment transport and erosion in adjacent coastlines[7]. Such outcomes can be viewed as a form of **maladaptation**, as the removal of sediment from a coastal sediment budget can have negative impacts on neighbouring coastal regions.

Thus, it is of utmost importance to consider the complex impact of climate change and renewable energy development on coastal areas in order to enhance coastal resilience, a subject of growing interest among researchers, developers, and decision-makers. In this context, a relatively novel concept has emerged which holds the potential for maximizing the benefits of ocean renewable energy usage in coastal areas. Introduced in 2013, the concept of "**antifragility**" describes systems that not only withstand stress and uncertainty, but actually thrive and benefit from them[8]. This concept can be applied to technology, allowing systems to become more adaptable and better equipped to handle unpredictable and volatile situations, ultimately enabling them to turn such challenges to their advantage.

It is noteworthy to highlight that the concepts of "**antifragile**" and "**resilient**" have distinct meanings. Resilience refers to the capacity of an entity to withstand and recover from a disruption or shock, and to return to its original state. A resilient entity can endure stress and maintain its function, but it does not necessarily gain any benefits from the stressor, nor does it become stronger from it. In contrast, antifragility describes a property of some systems or entities that actually benefit from stressors or shocks, resulting in increased strength and robustness. An antifragile system does not simply return to its original state, but rather improves and adapts in response to stressors. Thus, while resilience refers to the ability to withstand stress, antifragility refers to the ability to improve due to it.

Given the uncertainties inherent in ocean climate simulation and climate change prediction, addressing the complex and combined impact of climate change and ORE development on coastal areas requires the next generation of interdisciplinary research. Such research may offer novel designs for existing technologies and protection schemes and/or renewed strategies for coastal zone management that allow coastal areas to benefit from the inevitable impacts of climate change.

References:

1. Penalba, M., Ulazia, A., Saénz, J. & Ringwood, J. V. Impact of long-term resource variations on wave energy Farms: The Icelandic case. *Energy* **192**, 116609 (2020).
2. Silva, A. P. *et al.* Climate-induced variability in South Atlantic wave direction over the past three millennia. *Sci Rep* **10**, 18553 (2020).
3. Kamranzad, B. & Takara, K. A climate-dependent sustainability index for wave energy resources in Northeast Asia. *Energy* **209**, (2020).
4. Kamranzad, B., Amarouche, K. & Akpinar, A. Linking the long-term variability in global wave energy to swell climate and redefining suitable coasts for energy exploitation. *Sci Rep* **12**, 14692 (2022).
5. Li, J., Pan, S., Chen, Y., Yao, Y. & Xu, C. Assessment of combined wind and wave energy in the tropical cyclone affected region:An application in China seas. *Energy* **260**, 125020 (2022).
6. Rodriguez-Delgado, C., Bergillos, R. J. & Iglesias, G. Dual wave farms for energy production and coastal protection under sea level rise. *J Clean Prod* **222**, 364–372 (2019).
7. Mangor, K. Shoreline management guidelines. (Horsholm, 2004).
8. Taleb, N. N. *Antifragile: Things that Gain from Disorder*. (Penguin Books, 2013).