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Marine Renewable Energy: Opportunities, Challenges and Potential for Integration in Aquaculture Farms

Rosa-Santos P[1,2]*, Clemente D[1,2] and Taveira-Pinto F[1,2]

[1]Department of Civil Engineering, Faculty of Engineering of the University of Porto, Portugal

[2]CIIMAR, Interdisciplinary Centre of Marine and Environmental Research of the University of Porto, Portugal

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***Corresponding author:** Paulo Rosa-Santos, Faculty of Engineering of the University of Porto, Department of Civil Engineering, Rua Dr. Roberto Frias S/N, 4200-465, Porto, Portugal, Tel: (+351) 225081965; Email: pjrsantos@fe.up.pt

Abstract

All European strategies on energy agree that Marine Renewable Energy (MRE) will play an important role mitigating problems associated to the greenhouse emissions and air pollution, as well as strengthening the security of energy supply. Besides this, MRE also presents a high potential for offshore and remote facilities, such as offshore aquaculture farms. This manuscript presents the potential of MRE and briefly describes some of the technologies available to harness it, with a special focus in wave energy harvesting. The present challenges and opportunities are discussed, namely the integration of MRE as a source of energy for offshore aquaculture farms.

Keyword: Offshore facilities; Wave energy; Wave energy converters

Marine Renewable Energy

The Marine Renewable Energy (MRE) comprises the energy of waves, tides, ocean currents, osmotic gradients and thermal gradients (i.e., ocean renewable energy), as well as the offshore wind and the marine biomass (micro and macro algae). The solar energy captured offshore may also be included since, such as the offshore wind, it makes use of the ocean space.

The potential of MRE is of upmost relevance, given the challenges of energy production, distribution and security that modern societies face. By considering only the contributions of waves, tides, ocean currents and gradients (salinity and temperature), the theoretical potential of ocean energy can reach a value of about 151 300 TWh/yr [1]. Although estimates may vary with the source, the ocean energy theoretical potential may be divided as follows: waves - 32 000TWh/yr [2]; tidal amplitude and tidal currents - 22 000 TWh/yr [3]; ocean currents - 6000 TWh/yr [4]; salinity gradients - 30 000 TW h/yr [5], temperature gradients/ocean thermal energy conversion - 61 300 TW h/yr [6].

Nevertheless, a distinction should be made between the theoretical and the technical potential, which takes into account the efficiency of the available technologies to harness the MRE and, therefore, may change with their future development. In spite of the estimates' variability, if the offshore wind resource is included [7], the potential of MRE production increases to values above the present world electricity consumption and the total primary energy supply that were estimated to be 18 900 TWh/yr and 155 500 TW h/yr in 2012, respectively [8].

The current estimates for wave power, in particular, vary globally, with authors such as Mørk, et al. [9] pointing towards a theoretical resource of about 3.7 TW and others to roughly 2.11 TW [10]. However, one must also account for the fact that not all of the energy is convertible, due to efficiency limitations and energy losses that, while mitigated, are always present to some extent. On the other hand, there are also limitations regarding the possible deployment sites, since the use of some areas is restricted, namely near shipping routes or in protected sites (fishing activities, submarine cables, natural reserves, exploration of hydrocarbons, among others).

Furthermore, the resource also varies regionally and from offshore to nearshore. Along the Atlantic European Coast the mean seasonal values of wave power per metre of wave front range from 3.03 to 7.66 kW/m in the Summer and from 6.76 to 28.98 kW/m in the Winter, depending on the national coastline of interest, Guedes Soares, et al. [11]. In the United States, a study conducted by Lenee-Bluhm, et al. [12] provided insight into the US Pacific Northwest wave energy resource, where the ratio of mean wave power available between the winter and summer months was found to be of about 7. Other regions of interest, such as the East China and South China Sea or the Northwest of Sardinia have also been studied by Zheng, et al. [13] and Vicinanza, et al. [14], respectively, amongst many other areas where MRE can have a significant impact and relevance in the future.

Opportunities and Challenges

There are many opportunities and challenges that the MRE sector must account for to become a key contributor to the global energy market, which vary with the energy resource and the Technology Readiness Level (TRL) of the harnessing technology. For example, while the commercial harnessing of tidal energy (tidal barrage) dates back to 1966 [15], with the first large scale tidal power station built in La Rance, France, the wave energy technologies are less mature and in an early stage of development.

Nowadays, there are hundreds of different energy converters [16]. Amongst these are the wave energy converters (WEC), the ocean thermal energy converters (OTEC) or even the ocean thermo-electric generators (OTEG). All those converters are based on different working principles, control strategies and are at different stages of Technical Readiness Level (TRL). For instance, the wave energy converters can be classified in the following main categories based on their working principles [17]: oscillating water columns [18]; overtopping devices [19,20] and oscillating bodies [21,22].

Most of the MRE technologies face common challenges, such as cost reduction, lack of maturity in comparison to other renewable energy technologies [23] and survivability in the harsh marine environment [24], as well as unique obstacles, inherent to the technologies themselves. On the other hand, and in general, the MRE resource is vast and has a high power density, being regarded as a clean source of energy that received considerable interest from both public and private entities, which have invested a large amount of resources in R&D and also in the development of supporting policies and legislation, as pointed out by Dalton and Ó Gallachóir [25]. Moreover, there is an interesting potential for synergies with other developing areas and offshore activities, namely concerning the use of ocean wave energy for water desalination purposes [26]. It was estimated that such a complementary project could yield a yearly production of 0.9 millions of m3 of fresh water, considering an array of 25 surge WECs, which is enough to meet the demands of 30000 persons and therefore could cut down thousands of tons of CO_2 emissions.

Some subjects may provide a dual perspective towards the development and application of marine renewable energy converters, with challenges that can become opportunities and vice-versa. An example of these reports to the environmental impacts, as these can either be positive or negative. The study of these impacts on marine ecosystems has been made by Riefolo, et al. [27] concerning the physical and biological factors for the installation of WEC devices. Issues such as underwater noise, electromagnetic fields, collision risk and changes in benthos and sediment transport have been monitored and analysed for several WEC sites, from which it was concluded that there is a need for adapting the environmental impact analysis (EIA) to coastal ecosystems, update the current legislation and conduct further monitoring studies on the subject. A complementary study that also considers tidal energy converters has been made by Frid, et al. [28], which also points out important changes in the local habitats and migration routes for the local fauna communities.

Even so, there are positive impacts, as explained earlier, which are developed by regarding the use of marine renewable energy installations (MREI) as artificial reefs and aggregation systems for fishes. They may also act as "marine-protected" areas (MPA) where certain activities, such as fishing, are restricted [29]. Another topic worthy of discussion is the influence that a MRE converter might have on the wave conditions itself, as its presence may impose changes, for instance, on the significant wave height profile from offshore to the nearshore. This topic has been addressed in some works through the application of numerical models such as SWAN, as those conducted by Iglesias and Carballo [30] for farms of WECs based on the Wavecat concept [31]. It was found that the presence of a wave farm, the spacing between WEC devices and its distance to the shoreline influence the profile of the significant wave height as it propagates from offshore to nearshore. Even at a distance of 2 to 4 km, there is a reduction of the significant wave height that should not be neglected. These impacts also depend on several other factors, including the WEC type and its spatial distribution and may be positive in regions with a highly energetic wave climate, by reducing the wave power levels that reach the coastal zone or any offshore facility located in their sheltered area (behind the wave farm).

Perspectives for Aquaculture Farms

The food and agriculture sector will face very important challenges in the coming decades due to the increase of word population that should reach 9 billion by 2050. Fisheries and aquaculture are expected to address many of those challenges, since the impressive grown rates observed in recent years should have continuity in the future, especially in the Aquaculture sector. In fact, during the last three decades, capture fisheries production increased from 69 to 93 million tons and the world aquaculture production increased from 5 to 63 million tons [32].

Aquaculture farms vary significantly in size, characteristics and location (inland, coastal, nearshore and offshore), consuming relevant sums of energy in their pumping, lighting, grader, purification and aeration systems, among others. The electricity consumption may vary significantly from one farm to the other, for example, the Aquaculture Initiative [33-34] analysed three case studies with the daily maximum load varying from 9.3 to 90.5kW. In these cases studies, the electricity costs may easily reach thousands of euros per year, stressing the need for efficient systems design and good planning.

It should also be taken into account that the cost of the consumed electricity may be significantly different in remote offshore installations, which are expected to be more usual in the future, as the nearshore locations available for the installation of new farms reduce. The difference in the electricity cost is mainly due to accessibility and transport issues. This creates a unique opportunity to all the marine renewable energies, since they are present at site and readily available to be harnessed.

Conclusions

The harsh marine environment and the variability of the marine energetic resources pose several challenges to the development of energy conversation technologies. However, the amount of untapped energy in the ocean is huge, justifying the investments in the development of novel and already existing technologies to reach a higher level of efficiency and reliability and also to reduce the electricity production costs. Offshore installations, such as aquaculture facilities, may be a valuable end user of MRE, due to the availability of the resource offshore and the difficulty associated to the transport of energy from shore.

References

1. Taveira-Pinto F, Iglesias G, Rosa-Santos P, Deng ZD (2015) Preface to Special Topic: Marine Renewable Energy. J Renew Sustain Energy 7(6): 1-5.

2. Lewis A, Estefen S, Huckerby J, Musial W, Pontes T, et al. (2011) Ocean energy. In IPCC Special Report on Renewable Energy Sources and Climate Change Mitigation. Edited by Edenhofer O, Pichs-Madruga R, Sokona Y, Seyboth K, Matschoss P(Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA.

3. Hermann WA (2006) Quantifying global exergy resources. Energy 31(12): 1685-1702.

4. Turkenburg WC, Arent DJ, Bertani R, Faaij A, Hand M, et al. (2012) Chapter 11 - Renewable Energy. In Global Energy Assessment - Toward a Sustainable Future, Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria, pp: 761-900.

5. Rogner HH, Aguilera RF, Archer C, Bertani R, Bhattacharya SC (2012) Chapter 7 - Energy Resources and Potentials. In Global Energy Assessment - Toward a Sustainable Future, Cambridge University Press, Cambridge, UK and New York, NY, USA and the International Institute for Applied Systems Analysis, Laxenburg, Austria, pp: 423-512.

6. Rajagopalan K, Nihous GC (2013) Estimates of global ocean thermal energy conversion (OTEC) resources using an ocean general circulation model. Renewable Energy 50: 532-540.

7. Arent D, Sullivan P, Heimiller D, Lopez A, Eurek K, et al. (2012) Improved offshore wind resource assessment in global climate stabilization scenarios. National Renewable Energy Laboratory, pp: 1-29.

8. (2014) Key world energy statistics. International Energy Agency (IEA), pp: 80.

9. Mørk G , Barstow S, Kabuth A, Pontes MT (2010) Assessing the Global Wave Energy Potential. ASME, pp: 447-454.

10. Gunn K, Stock-Williams C (2012) Quantifying the global wave power resource. Renew Energy 44: 296-304.

11. Guedes Soares C, Bento AR, Gonçalves M, Silva D, Martinho P (2014) Numerical evaluation of the wave energy resource along the Atlantic European coast. Comput Geosci 71: 37-49.

12. Lenee-Bluhm P, Paasch R, Özkan-Haller HT (2011) Characterizing the wave energy resource of the US Pacific Northwest. Renew Energy 36: 2106-2119.

13. Zheng C, Zhuang H, Li Xin, Li XunQiang (2012) Wind energy and wave energy resources assessment in the East China Sea and South China Sea. Sci China Technol Sci 55(1): 163-173.

14. Vicinanza D, Contestabile P, Ferrante V (2013) Wave energy potential in the north-west of Sardinia (Italy). Renew. Energy 50: 506-521.

15. Frau JP (1993) Tidal energy: promising projects: La Rance, a successful industrial-scale experiment. IEEE Transactions on Energy Conversion 8(3): 552-558.

16. Khan N, Kalair A, Abas N, Haider A (2017) Review of ocean tidal, wave and thermal energy technologies. Renew. Sustain. Energy Rev 72: 590-604.

17. Falcão A (2010) Wave energy utilization: A review of the technologies. Renewable and Sustainable Energy Reviews 14(3): 899-918.

18. López I, Pereiras B, Castro F, Iglesias G (2014) Optimisation of turbine-induced damping for an OWC wave energy converter using a RANS-VOF numerical model. Applied Energy 127: 105-114.

19. Oliveira P, Taveira-Pinto F, Morais T, Rosa-Santos P (2016) Experimental evaluation of the effect of wave focusing walls on the performance of the Sea-wave Slot-cone Generator. Energy Conversion and Management 110: 165-175.

20. Fernandez H, Iglesias G, Carballo R, Castro A, Fraguela JA, et al. (2012) The new wave energy converter Wave Cat: concept and laboratory tests. Marine Structures Journal 29(1): 58-70.

21. López M, Taveira-Pinto F, Rosa-Santos P (2017) Influence of the power take-off characteristics on the performance of CECO wave energy converter. Energy 120: 686-697.

22. Rosa-Santos P, Taveira-Pinto F, Teixeira L, Ribeiro J (2015) CECO wave energy converter: experimental proof of concept. Journal of Renewable and Sustainable Energy 7(6): 14.

23. Astariz S, Iglesias G (2015) The economics of wave energy: A review. Renew Sustain Energy Rev 45: 397-408.

24. Tiron R, Mallon F, Dias F, Reynaud EG (2015) The challenging life of wave energy devices at sea: A few points to consider. Renew Sustain Energy Rev 43: 1263-1272.

25. Dalton G, Ó Gallachóir BP (2010) Building a wave energy policy focusing on innovation, manufacturing and deployment. Renew Sustain Energy Rev 14(8): 2339-2358.

26. Ramudu E (2011) Ocean Wave Energy-Driven Desalination Systems for Off-grid Coastal Communities in Developing Countries. IEEE, pp: 287-289.

27. Riefolo L, Lanfredi C, Azzellino A, Vicinanza D (2015) Environmental Impact Assessment of Wave Energy Converters: A Review.

28. Frid C, Andonegi E, Depestele J, Judd A, Rihan D, et al. (2012) The environmental interactions of tidal and wave energy generation devices. Environ Impact Assess Rev 32(1): 133-139.

29. Inger R, Attrill MJ, Bearhop S, Broderick AC, James Grecian W, et al. (2009) Marine renewable energy: potential benefits to biodiversity? An urgent call for research. J Appl Ecol 46(6): 1145-1153.

30. Iglesias G, Carballo R (2014) Wave farm impact: The role of farm-to-coast distance. Renew Energy 69: 375-385.

31. Carballo R, Iglesias G (2013) Wave farm impact based on realistic wave-WEC interaction. Energy 51: 216-229.

32. Word Bank (2013) Fish to 2030 - Prospects for Fisheries and Aquaculture. World Bank report nº 83177-GLB. International Bank for Reconstruction and Development / International Development Association, pp: 80

33. Aquaculture Initiative (2002) The Potential for Renewable Energy Usage in Aquaculture. Damien Toner, Resource Development Section. AI Resource Development Section and BIM Environment & Quality Section, pp: 1-61.

34. Dinakaran MR (2017) Aquaculture in India, the Second Largest Producer of Farmed Fish. Int J Oceanogr Aquac 1(3): 1-2.