WIND AND WAVE ENERGY:

MAXIMISING THE OFFSHORE POTENTIAL

HIE
Highlands and Islands Enterprise
Iomairt na Gàidhealtachd 's nan Eilean

wave energy
SCOTLAND

OBJECTIVE

Wave Energy Scotland (WES) wants to engage with the offshore wind sector to investigate opportunities for a closer collaboration between the wind and wave energy sectors. This document aims to start a conversation between these two sectors by introducing the potential opportunities for wind and wave co-location to maximise the energy harvested offshore.

INTRODUCTION

The UK coastline has the best offshore wind resource potential in Europe. In the past decade, offshore wind power capacity has increased sixfold, with nearly 14 GW installed and 50 GW expected by 2030[1].

In Scottish waters alone, the last ScotWind leasing round pledged 27.6 GW of offshore wind capacity by 2045[2]. However, the expansion of offshore wind power must be carefully balanced with the need to protect ocean ecology, heritage sites, and co-exist with other economic and social activities[3]. This is essential if the blue economy is to be a sustainable part of our shared future[4]. Another resource coinciding with wind is wave energy. Since the wind and waves are physically linked, wave energy can be thought of as a stored version of wind energy, providing a consistent stream of highly dense energy. The UK has the potential for 22 GW of wave energy with 6 GW expected by 2050[5].

Wind and wave resources coincide with one another and coordinated exploitation of these resources off the UK coastline can lead to:

- Optimum usage of the seabed enabling a higher extraction of energy per square kilometre.
- System benefits such as energy security and achieving UK net-zero targets.
- Economic benefits such as the creation of local jobs, local industry development, and supply chain development
- Export opportunities enabling the UK to become a world leader in ocean energy technologies.

WES is leading the conversation with relevant stakeholders to further develop the opportunities to maximise these benefits. The overlapping of these energy extraction methods, with the best resource potential being in deep waters, presents a massive collaboration opportunity between the floating offshore wind and wave energy industries. By combining the benefits of these two technologies, it is possible to create a more reliable, resilient, and sustainable energy supply for the UK. The objective of this document is to develop understanding of the opportunity for integration of wind and wave generation, and to build consensus on the further study, collaboration and engagement required to move forward.

ROUTES TO INTEGRATION OF WIND AND WAVE

The WES program has successfully delivered two proof of concept technologies with clear routes to market: AWS[6] and Mocean Energy[7].

The potential synergy between wind and wave energy designs is huge. There are two possible ways in which wind and wave can collaborate:

- **Utilisation of space between floating offshore wind structures:** This involves placing wave energy converters (WECs) in the spaces between floating offshore wind turbines. With wind turbines getting increasingly larger, so does the space between them. This presents a unique opportunity to harvest wave energy using this space. By sharing infrastructure (e.g., cables and sub-stations) as well as operation and maintenance services, both wind and wave energy can benefit from key cost reductions.
- **Utilisation of a modular versatile platform for wind or wave energy:** The increasing size of wind turbines requires corresponding large floating support structures. The design of these platforms could share supply chain commonalities with a platform for multiple wave energy converters (WECs), leading to cost savings by sharing the supply chain. Such a multi-absorber platform could also share wind farm space.

The sharing of electrical transmission of wind and wave reduces variability and provides a higher base load to the grid. The combination of reduction in capital and operational expenditure, with the added benefit of improving the value of energy produced, makes this collaboration highly desirable.

1. https://www.great.gov.uk/international/content/investment/sectors/offshore-wind/
2. https://www.crownestatescotland.com/scotlands-property/offshore-wind/scotwind-leasing-round
3. Putuhena, Hugo, et al. "Finding space for offshore wind to support net zero: A methodology to assess spatial constraints and future scenarios, illustrated by a UK case study." Renewable and Sustainable Energy Reviews 182 (2023): 113358.
4. https://www.un.org/en/desa/making-waves-blue-economy
5. P. W. Wong, K. Grattan and H. Jeffrey. Ocean Energy and Net Zero: Policy Support for the Cost Effective Delivery of 12GW Wave and Tidal Stream by 2050. Policy and Innovation Group.

A LANDMARK TECHNO-ECONOMIC ASSESSMENT

Several studies[8,9,10] have investigated the techno-economic benefits of combining floating offshore wind and wave systems.

However, these studies have focused on fully integrated hybrid designs. During the high growth period of offshore wind, the perceived risk of adding such additional complexity to an already challenging build-out seems unlikely to be acceptable. Therefore, the goal should be to understand what benefits could be achieved from more palatable sharing scenarios.

WES recently commissioned OWC Ltd. to carry out a technoeconomic study into wind and wave sharing opportunities. The headline figures from the study are a potential Levelised Cost of Energy (LCOE) saving of up to 7% for wind developers and nearly 40% for wave energy developers, resulting in a combined total saving of up to 12%[11]. Most of these savings could be achieved through co-location and simple asset sharing, without the risk of full integration of hybrid platforms.

What was studied?

- **Levelised Cost of Energy (LCOE):** A total of 17 scenarios were evaluated, including baseline separate wind and wave projects. Simple sharing scenarios involved sharing of array resources, development, operation and maintenance as well as supply chain costs. More integrated studies looked at versatile platforms and shared ownership of the whole project.
- **Wider Benefits:** The additional benefits from couplings were reviewed, such as the power profile smoothing from output coupling, load reduction on floating wind devices from strategic WEC placement and control, benefits to supply chain development, and the local socio-economic benefits to Scotland.
- **Economic Impact:** The economic and social benefits to the Scottish economy and social impacts of each scenario were assessed.
- **Feasibility Assessment:** The feasibility of each scenario, in terms of technology, regulatory, and financial constraints, was assessed.

What were the key findings?

From a combined LCOE perspective, the majority of savings were achieved with shared electrical transmission and non-asset-based sharing, which is excellent from a wind energy perspective as the benefits of collaboration can be achieved at a much lower technology risk. Breaking down the components of LCOE, the following observations were seen:

- Development Expenditure: Sharing the site, such as shared consenting, surveys, modelling and seabed lease, can lead to significant reductions in expenditure.
- Capital Expenditure: All sharing scenarios reduce the cost of floating wind, but the best options are achieved with shared assets.
- Operational Expenditure: The cost reduces as the two projects become more shared, with the fully shared option reducing costs the most.

Future work

The findings of the OWC study are very promising, but there is still considerable scope for further analysis. The opportunities for power smoothing to the grid and structural damping of floating wind structures are vast, and should be investigated further in separate, detailed studies. WES wishes to deliver further studies in partnership with other stakeholders.

The combination of these technologies will create new challenges.

These range from simple motivational challenges for the offshore wind sector, to more academic challenges associated with building novel structures and energy systems. From a business perspective, a roadmap for creating investable projects will need to be developed. From a governmental perspective, these projects would need to be enabled by modified leasing, consenting and permitting processes.

Making the case for a wind/wave system to the floating wind sector:

Wave energy is a promising renewable energy source, but it is less developed than wind energy. Therefore, wave energy developers need to demonstrate that their technology can perform at a high level and is cost-competitive. Scottish technology developers, Mocean and AWS have successfully demonstrated large-scale technologies and are on the path to proving the viability of wave energy to other sectors.

Proving the technology is feasible:

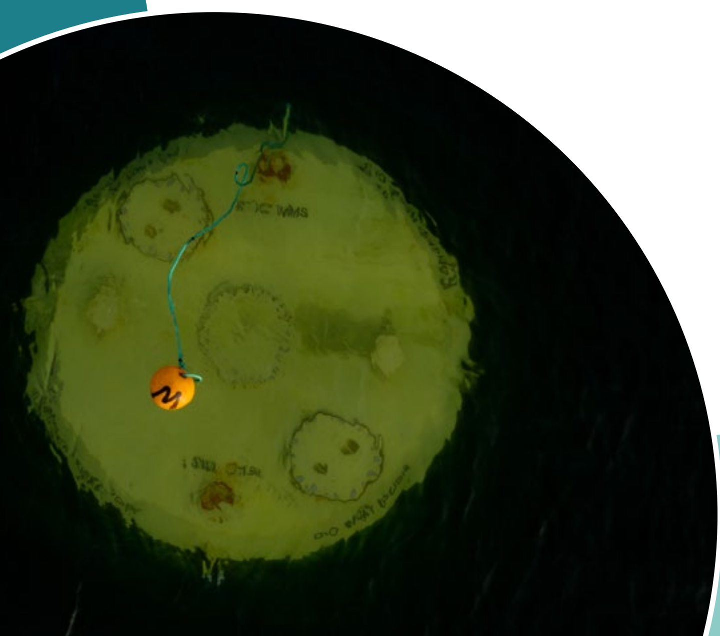
The interaction between the two systems will need to be investigated to determine the spacing requirements for co-location and the design requirements for multi-absorber platforms. A combination of numerical and physical models will need to be developed at different scales to facilitate design decisions that optimise these parameters. Additionally, the linking of electrical systems from two energy systems with different voltage requirements will also require its own analysis.

Business case and deployment opportunity:

Investing in wave energy technologies is economically advantageous because it can help reduce the need for energy storage and make better use of space in the UK's Exclusive Economic Zone (EEZ). There are several support mechanisms in place to encourage investment in wave energy technologies. Contracts for Difference (CfDs) can provide financial certainty to developers of wave energy projects by guaranteeing a fixed price for electricity. The Offshore Wind Sector Deal[12] was a landmark moment for the future development of wind energy, aiming to bring innovation to the market, such as introducing more floating offshore wind, along with the potential for interconnection with wave energy. The deal also has a focus on educational diversity and backgrounds with different jobs in the offshore wind sector. This presents a unique opportunity to develop new supply chains with different jobs for wind and wave to collaborate on. This could allow the UK to become the most competitive supply chain in Europe, with the ability to export novel wind-wave infrastructure technologies.

Consenting and permitting:

Shared projects will require consenting and permitting, which can be a time-consuming process. The Scottish Government has provided guidance on the consenting and licensing process for offshore wind and wave energy applications[13,14]. It involves a number of different steps, including an Environmental Impact Assessment, a Marine Licence, a Seabed Lease, and other licenses and consents. The specific requirements will vary depending on the project, but the overall process is likely to take several years. Some of the existing agreements may need to be reworked for co-location, but this is in line with the Scottish Government's aim of collaborating with other sectors such as green hydrogen, battery energy storage, and aquaculture. A combined consenting process could be more efficient than two separate projects. However, given the relative maturities of the wind and wave energy industries, it is likely that early wind-wave projects would be retrofits, with fully shared projects following in future leasing rounds.



6 https://awsocean.com/archimedes-waveswing/
7 https://www.mocean.energy/
8 Petracca, Ermando, et al. "Design and techno-economic analysis of a novel hybrid offshore wind and wave energy system." Energies 15.8 (2022): 2739.
9 Rönkkö, Jaan, Ali Khosravi, and Sanna Syri. "Techno-Economic Assessment of a Hybrid Offshore Wind–Wave Farm: Case Study in Norway." Energies 16.11 (2023): 4316.
10 Gao, Qiang, et al. "Techno-economic assessment of offshore wind and hybrid wind-wave farms with energy storage systems." Available at SSRN 4358078 (2022).

POTENTIAL STAKEHOLDERS

The stakeholders involved in a co-located wind-wave farm would have different interests and levels of influence.

It is important to keep all stakeholders informed and satisfied in order to avoid conflict and ensure the smooth delivery of wind and wave projects.

Who are the stakeholders and why are they interested?

Project developers have high influence and are responsible for designing, construction, financing, and operation. They are interested due to the potential for cost savings, and improved utilisation of assets.

Technology developers have high influence and offer consultancy and expertise to the project developers. They are interested in the potential to develop new intellectual property and tap into new markets.

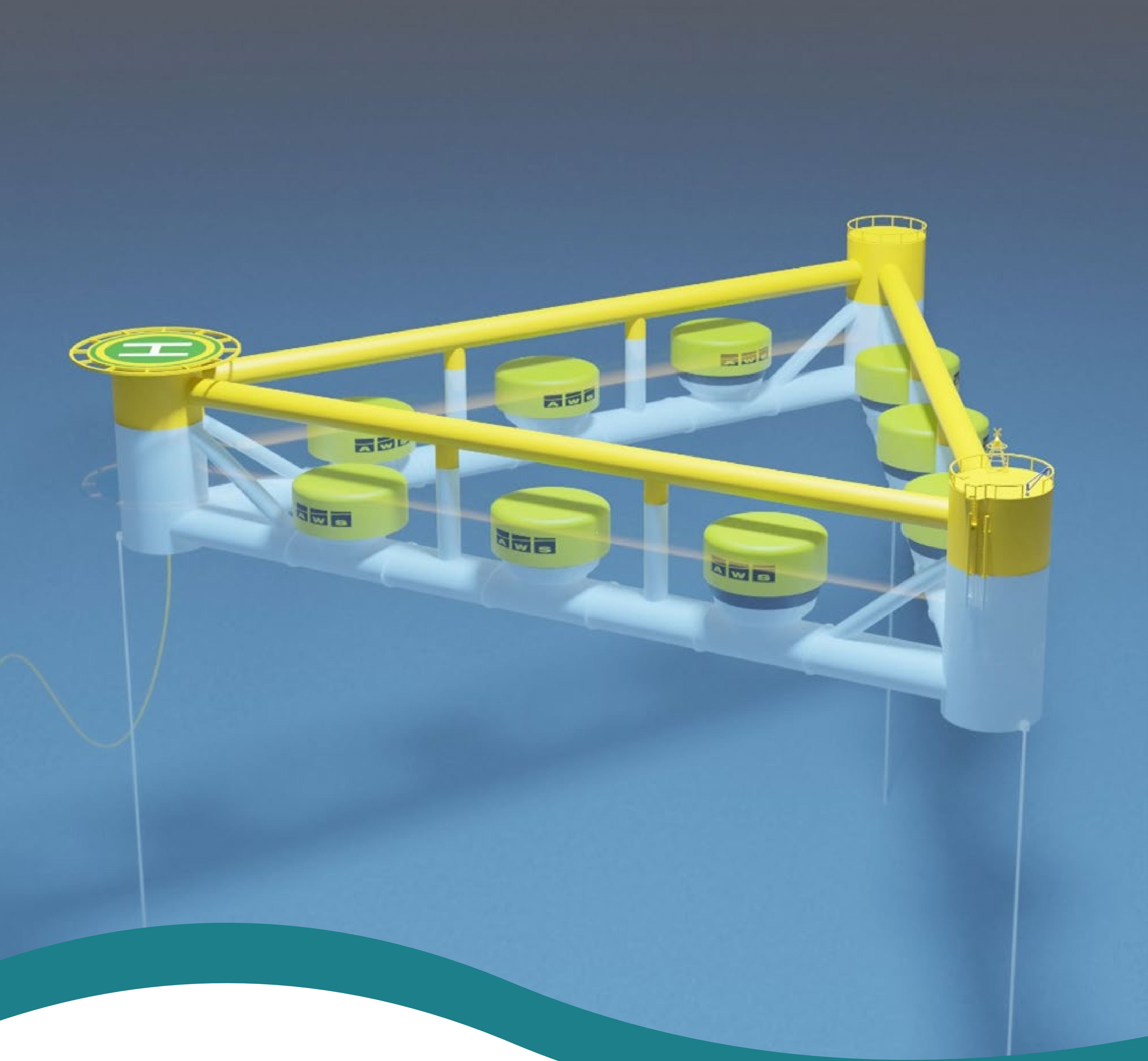
Regulatory, political authorities and landowners ensure the development complies with all relevant regulations. They are interested in the potential to reduce the environmental impact, create jobs, and help the UK meet its climate targets.

Community and environmental groups will be affected by these new developments but will have little power over them. They are interested in local job creation and improvements to the environment from better utilisation of the land and renewable energy resource.

Transmission operators are responsible for transporting electricity from the site to the grid. They are interested in the potential to improve the base load to the grid along with reduced grid pressure and utilisation improvements.

Industry and suppliers provide the materials and services for building and operation. They are interested in the potential to create new jobs, grow the supply chain and the opportunity to develop in the new emerging market of floating wind and wave.

[11] https://www.waveenergyscotland.co.uk/news-events/shared-floating-wind-and-wave-projects-offer-12-combined-lcoe-reduction-to-uk/
[12] https://www.gov.uk/government/publications/offshore-wind-sector-deal
[13] https://www.gov.scot/binaries/content/documents/govscot/publications/advice-and-guidance/2020/02/marine-licensing-applications-and-guidance/documents/guidance/guidance-manual-for-offshore-wind-wave-and-tidal-energy-application/guidance-manual-for-offshore-wind-wave-and-tidal-energy-application/govscot%3Adocument/Guidance%2BManual%2Bfor%2BOffshore%2BWind%252C%2BWave%2Band%2BTidal%2BEnergy%2BApplication.pdf
[14] https://ore.catapult.org.uk/wp-content/uploads/2021/09/FOW-CoE-FOW-Development-and-Consenting-Process-Risks-and-Opportunities-Public-Summary.pdf



NEXT STEPS

WES activity has laid the foundation, we now wish to build constructive engagement between the two sectors.

Once we have agreed on a collaborative way forward, we can design further studies that address the concerns of stakeholders. This will allow us to build a roadmap to exploit this potentially significant opportunity for Scotland.

Over the coming months, WES plans on delivering wind-wave themed workshops to foster this cross-sector engagement.

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