Energy Technologies in the Marine Environment: Ensuring Coexistence with Marine Life

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Focus: How WavEC has been actively involved in ensuring the co-existence of marine energy projects with marine life.

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Topics addressed

- Marine Energy Technologies & Project Life Cycle
- Circular Economy & Sustainable Designs
- Environmentally Friendly Technology Design
- Nature Inclusive Designs
- Marine Spatial Planning (MSP)
- Multi-Purpose and Co-Location
- Key Innovations for Sustainability based on AI & Digital Twins

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Introduction

Energy Technologies in the Marine Environment: Ensuring Coexistence with Marine Life

Two Key Points:

The growing global need for renewable energy and the unique role of marine energy in meeting that demand.

- As the world transitions toward renewable energy sources to combat climate change and reduce reliance on fossil fuels, the potential of marine energy has become increasingly important

The importance of protecting marine ecosystems while developing these technologies, ensuring that energy production and environmental conservation go hand in hand.

- Marine ecosystems: many species are already under stress from other human activities like shipping, fishing, and pollution.

Therefore, coexistence with marine life is essential for long-term sustainability, regulatory compliance, and social acceptance of marine energy projects.

Marine Energy Technologies

Offshore Wind:
Generation of electricity through wind farms at sea (fixed or floating)

Wave Energy:
when wind blows over the ocean it transmits some of its kinetic energy to the ocean’s surface creating wave energy

Tidal Energy:
makes use of the tidal range – the actual height difference between high and low tide – and harnesses the potential energy.

Tidal Current Energy:
kinetic energy contained in fast-flowing tidal currents, typically found in constrained channels.

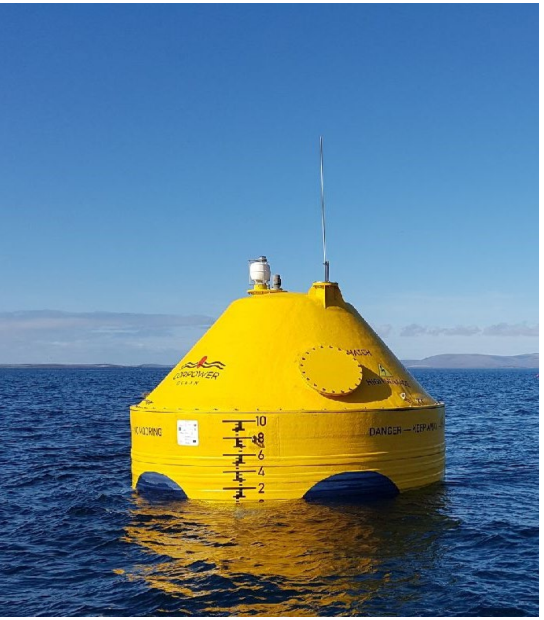
Ocean Current Energy:
Associated with large circulations in the ocean driven by wind, temperature and salinity differences.

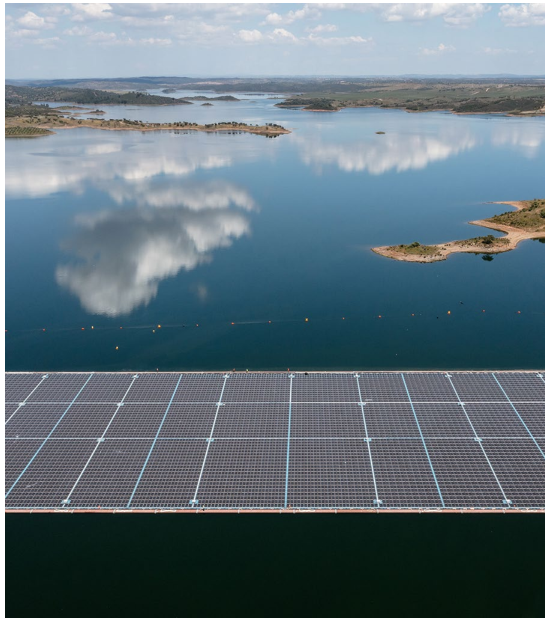
OTEC:
Makes use of the temperature difference between the warm surface and the cold deep-sea layers

Salinity Gradients:
Also known as osmotic energy, makes use of the pressure potential in the difference in the ocean’s salt concentration

Floating Solar
Solar panels mounted on a structure that floats on a body of water.





Stages of Development

Different degrees of development and maturity: some are already very advanced and widely operated worldwide while others are still at research & demonstration level.

Mature technologies benefit from extensive research, established mitigation practices, and regulatory frameworks. Impacts from emerging technologies are still in the process of being understood

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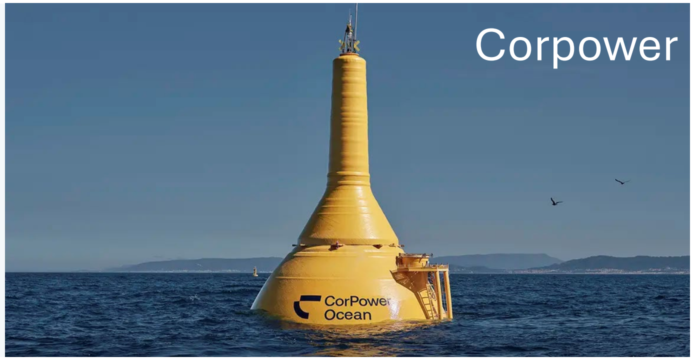
Examples: Improving the current knowledge on environmental impacts of Wave Energy Technologies

WESE
WAVE ENERGY IN SOUTHERN EUROPE

- Develop guidance for planning and consenting procedures to better inform decision-makers and managers on environmental real risks and reduce environmental consenting uncertainty.
- Implement innovative maritime spatial planning (MSP) Decision Support Tools for site selection of WEC projects.

SAFE WAVE

- Improvement of the current knowledge on the environmental effects and risks of WEC through the collection, processing, analysis and sharing of environmental data around devices operating at sea
- Modelling of cumulative impacts of future larger scale WEC deployments.



Marine Renewable Energy Project Life Cycle

Development & geo-technical studies → Fabrication & Construction → Installation → Operation and Maintenance → Decommissioning

Marine energy technologies should be designed with a life-cycle approach:

Policies and standards:

- Ensure that every phase is done in a way that supports the coexistence of energy projects and marine ecosystems
- Environmental Impact Assessments (EIA)
- EU Marine Strategy Framework Directive (MSFD)
- Maritime Spatial Planning EU Directive

Adaptive Management Frameworks:

- To monitor and mitigate environmental impacts throughout the life of the project -> if new risks to marine life emerge, operational practices can be adjusted.
- Requires developers to work closely with regulators, conservation groups, and local stakeholders to ensure that environmental impacts are continually managed.

Circular Economy & Life Cycle Assessment (LCA)

Complementary approaches that promote sustainability:

- **Circular economy** principles helps extend the life of materials and components
- **LCA** ensures that every phase of a marine energy project—from construction to decommissioning—is designed to minimize its environmental footprint.

Sustainable Designs Reduce Impact on Marine Life:

- LCA during the design phase allows developers to choose materials and processes that have a lower environmental impact.
- Examples: **low-toxicity paints, recyclable materials, and environmentally friendly anti-fouling coatings**

A few examples of EU funded projects where WavEC coordinates the LCA Task:

SCARLET Superconducting CAbles foR sustainabLe Energy Transition | MISSION | NauticalSunrise | bamboo | PivotBuoy | MEGA WAVE PTO | LiftWEC | PLOTEC | AQUAWIND | EU-SCORES

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Environmentally friendly technology designs

Design with nature in mind

WavEC ongoing studies on multidisciplinary and holistic design philosophy for marine energy devices

Nature Inclusive Designs (NID)

- Turning marine infrastructures into beneficial elements of the marine environment

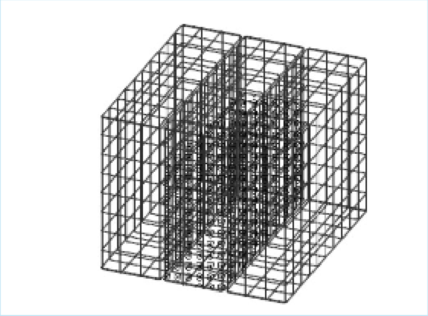
Adding Innovation in Moorings and Foundations

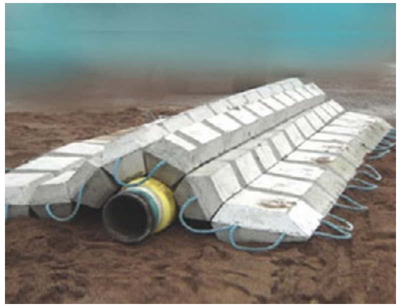
- **Bio-huts:** artificial habitats integrated into mooring or foundation structures
- **Fish hotels:** cage-type structures

Used by fish as shelters, encouraging development of local ecosystems around the installation.

Choose more sustainable materials

- E.g., EcoConcrete more eco-friendly than traditional concrete

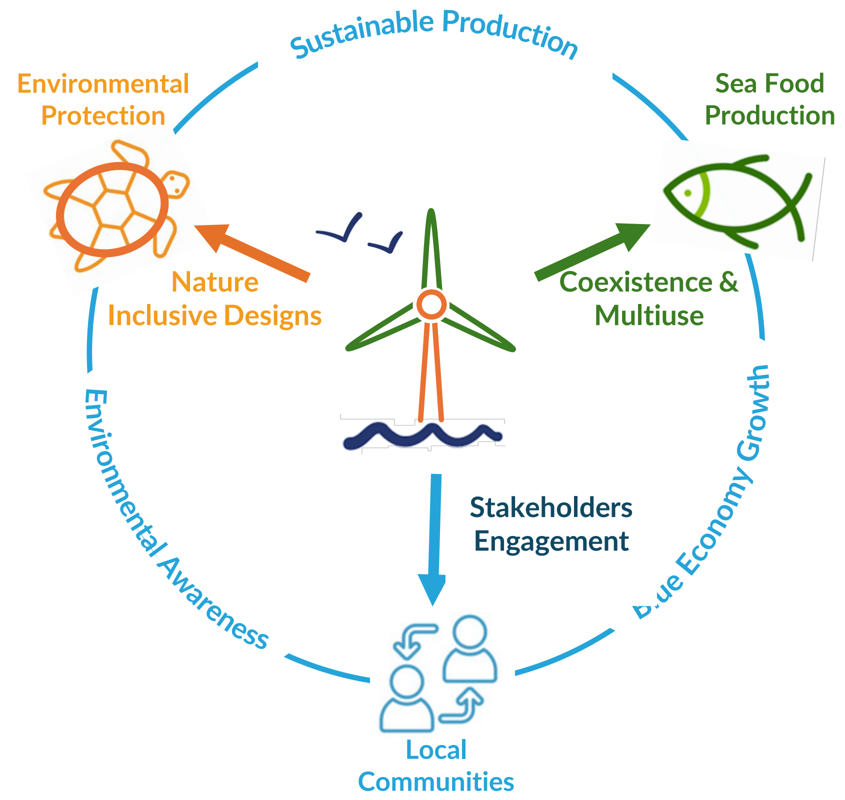




Example: Portuguese Offshore Wind Bid incorporating environmental sustainability criteria

Portuguese Offshore Wind bid Recommendations:

- Ensure that **non-price factors** are transparent using a concise set of criteria.
- Incorporate environmental sustainability criteria through **nature-inclusive designs** that promote the circular economy
- Promote **coexistence with other sectors** of the blue economy, such as offshore aquaculture.
- Consider social and territorial development criteria, **promoting stakeholder engagement.**



This initiative encourages projects to prioritize long-term environmental and social outcomes.

Maritime Spatial Planning

To address the increasing demand for maritime space - from traditional and emerging sectors - while preserving marine ecosystems

Key benefits of MSP include:

- Reduction of conflicts between sectors; synergies between different activities.
- Increased cross-border cooperation between countries
- Early identification of impact and opportunities for multiple use of space
- MSP is not static. Adjusted based on ongoing monitoring of environmental impacts.

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Examples: Multi-purpose and Co-locations

AQUAWIND

2022 – 2025; €1M funding from EMFAF

aquawind.eu

- Multi-purpose platform for floating offshore wind and aquaculture.
- Floating wind technology W2Power + Aquaculture prototype with **tailor-made design fish cage** with novel net materials.
- To demonstrate the technical feasibility, economic viability and environmental sustainability of the multi-use platform.

EU-SCORES
European Scalable Offshore Renewable Energy Sources

2021 – 2025; €35M funding from H2020

euscores.eu

- Offshore solar PV system + bottom fixed windfarm, Belgium
- Wave energy array + floating wind farm, Portugal
- Showcase the benefits of a continuous power output harnessing the complementarity between wind, sun and waves

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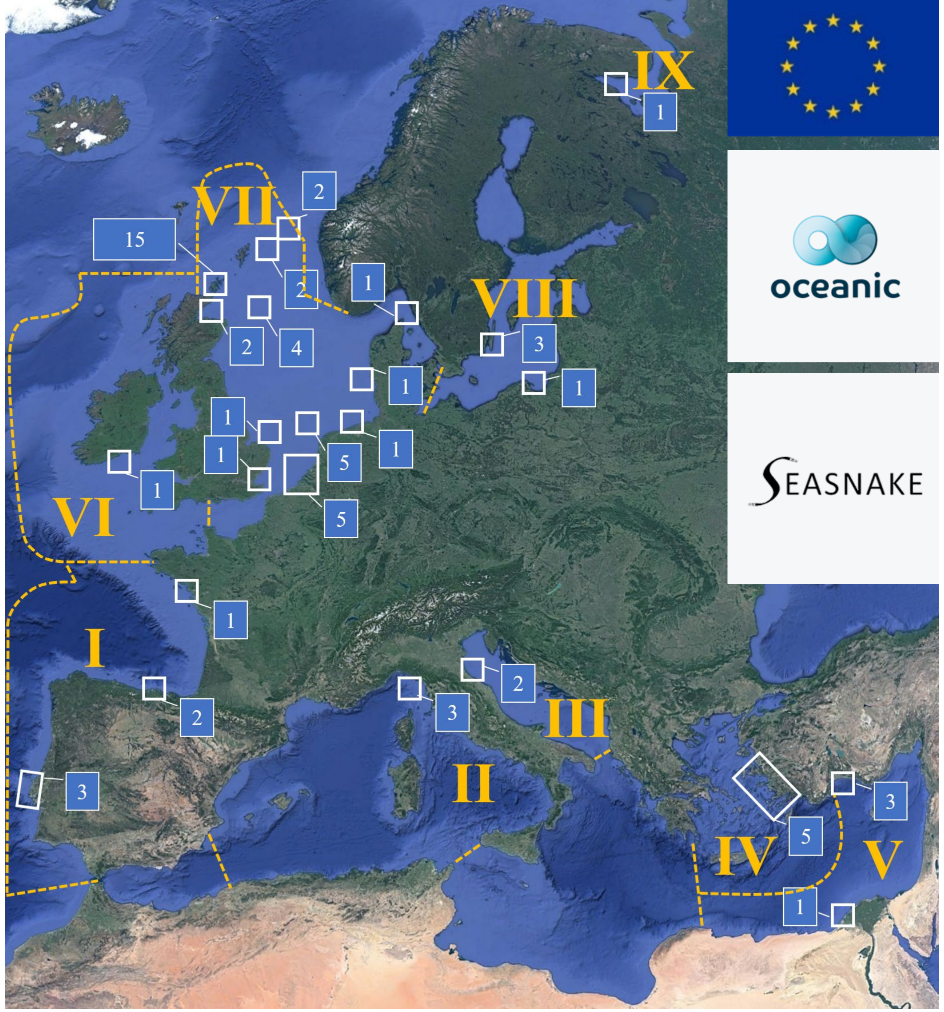
European Biofouling Database

Macrofouling assessment

- Knowledge on biofouling not sufficiently transferred across the ORE sector
- Biofouling is a major problem shared among all maritime sectors
- Information on biofouling composition across geographies is dispersed throughout published papers and consulting reports.
- The database compiles qualitative and quantitative data: aims to aid the sector in understanding which biofouling communities their devices are more susceptible to at a given site.



I – South European Atlantic Shelf; II – Western Mediterranean Sea; III – Adriatic Sea; IV – Aegean Sea; V – Levantine Sea; VI – Celtic Seas; VII – North Sea; VIII – Baltic Sea; IX – White Sea

More informed and quick decision:

- Overview of biofouling in a specific area
- Support site selection, frequency and type of O&M
- Support development of biosecurity risk plans

Vinagre et al., 2020; https://doi.org/10.3390/jmse8070495
https://www.wavec.org/en/services/tools/marine-biofouling-database

Key Innovations for Sustainability

Funded by the Horizon 2020 Framework Programme of the European Union

Key innovations that help minimize environmental impact:

1. AI and Machine Learning
2. Digital Twin of the Ocean

AI and Machine Learning:

Monitoring the State of Marine Ecosystems:

- Machine learning important application of AI for moonitoring and understanding the state of marine ecosystems
- Ability to process vast amounts of data quickly and accurately.

Enhancing Bathymetric Data :

- Essential for planning marine energy infrastructures.
- Spatial resolution can be improved with machine learning - more accurate mapping of the seafloor, including the identification of critical habitats

Detecting and Classifying Marine Species :

- AI models - to track the distribution and behavior of fish species in areas where marine energy installations are being planned or already exist.
- Energy developers can monitor fish populations and adjust operations

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Digital Twins and Environmental Impact Simulation

Digital Twin: virtual replica of a physical system, object, or environment. It can be used to replicate entire ecosystems, and habitats that might be affected by the construction of projects such as offshore wind farms.

Funded by the Horizon 2020 Framework Programme of the European Union

ILIAD Digital Twin of the Ocean (DTO)
International flagship project

How can be used by planners and engineers:

- The Digital Twin can include complex environmental data and allow to understand how the infrastructure might affect these interactions.
- Ability to simulate scenarios over time. The Digital Twin can predict the cumulative and long-term impacts
- Allow developers to test alternative designs before construction begins.
- Continuous Monitoring and Adaptive Management: Sensors and data collected from the actual site feed into the Twin
- Stakeholder Engagement: Digital Twins can be visualized and shared with stakeholders
- **New project:** Digital Toolbox for ecosystem restoration Interoperating with ILIAD

Conclusion

In conclusion, marine energy technologies are a key component of the clean energy transition.

While they do present challenges for marine life, these challenges can be mitigated through innovation, regulation, and collaboration.

By continuing to invest in research and engaging with stakeholders, we can ensure that marine energy contributes to a sustainable future, protecting the ocean ecosystems.

Thank you

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