Technology Collaboration Programme
by IEA

ANNUAL REPORT

AN OVERVIEW OF OCEAN ENERGY ACTIVITIES IN 2024

OES OCEAN ENERGY SYSTEMS

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O2 turbine off the Orkney coast. © Orbital Marine Power

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Mocean Energy Blue X device at EMEC. ©Mocean Energy

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With a PhD in Chemical Engineering from Delft University of Technology, he began his career at the Netherlands' Ministry of Economic Affairs. Since 2008, he has been with the European Commission's DG Research and Innovation. He is a member of the IEA REWP and since 2021 co-lead and Mission Director for the MI Clean Hydrogen Mission.

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Since 2005, he has been with the U.S. Department of Energy (DOE) and currently serves as the Program Manager for the Water Power Technologies Office's Marine Energy Program, leading the Program's efforts to conduct R&D on Marine Energy applications. He holds a Bachelor of Science in Chemical Engineering from Ohio University.

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Professor at the University of Western Australia in Perth. He founded Marine Energy Research Australia, supporting innovative offshore renewable energy technologies. Currently, he also directs the UWA Oceans Institute, a research hub with 250+ members specializing in marine biology, ocean science, engineering, and more.

SECRETARY

Dr. Ana Brito e Melo

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Civil Engineer with a PhD in Mechanical Engineering, she began her career with the wave energy team at Instituto Superior Técnico, University of Lisbon. She joined WavEC in 2003 and currently serves as the Chief Operating Officer. Additionally, she has held the role of Executive Secretary of the IEA-OES since 2002.

CHAIRMAN'S MESSAGE

Matthijs Soede, European Commission
IEA-OES Chairman (2023-2025)

In the past year, the OES has achieved significant milestones that we are proud to highlight. These achievements have made impact on both policy and technological progress in the ocean energy sector.

Dear all,

In the past year, the OES has achieved significant milestones that we are proud to highlight. These achievements have made impact on both policy and technological progress in the ocean energy sector. First of all, I would like to highlight our International Roadmap for Ocean Energy. The roadmap was presented in 2023, but in 2024 I can see that there is an understanding that if we would like to bring ocean energy technologies to the market, we shouldn't improve only the technology but also think about market incentives, the creation of the necessary infrastructure, and the establishment of the right regulatory environment. This Annual Report is presenting the progress so far in our sector and I would encourage everyone to read it carefully. There is still a lot of work to be done, but I see that our member countries are working on this.

Last year, we also welcomed the OES-Environmental 2024 State of the Science Report which has been prepared by the IEA OES Task 4 members. Building on the 2020 edition, this updated and expanded report summarizes the latest research on the environmental effects of ocean energy development. It demonstrates our commitment to ensuring that ocean energy is developed responsibly, with a strong focus on mitigating potential environmental impacts, which has been very important in building public trust and confidence in the ocean energy sector.

One of the things which made me very happy last year, was the **10th International Conference on Ocean Energy** led by IEA-OES and hosted for the first time by the Australian Blue Economy CRC in Melbourne Australia. It was the first time that the conference was organised on the southern hemisphere. There was a very good representation from Countries from Asia and Oceania, showing that there is a global interest to harvest the energies from the seas and oceans. The ICOE conference is ultimately a place to meet, to exchange experiences, and discuss the next steps towards bringing the different ocean energy technologies to the market at commercial scale. For everybody who couldn't attend last year, the next ICOE will be in 2026 in The Hague, The Netherlands. I am already looking forward to it and it would be great to meet you there (again)!

The IEA OES Technology Collaboration Programme started officially in 2001, which means the TCP will celebrate its 25th anniversary in 2026. It will be a time to reflect on what has been realized but also to look forward. I would like to invite you to share your thoughts about main achievements and future perspectives with us. We are considering preparing a special report to present it at our anniversary and your contributions are welcome!

At the end of this foreword, I just would like to say thank you to all who contributed to this IEA-OES 2024 Annual Report but a special thanks to Ana Brito e Melo who is heading our secretariat, and taking care for all our reports and communications!

EXECUTIVE SUMMARY

Ana Brito e Melo, IEA-OES Executive Secretary

TidalKite at the testsite near Ameland. © SeaCurrent

Introduction

IEA-OES is a **Technology Collaboration Programme (TCP) on Ocean Energy Systems** within a framework created by the International Energy Agency (IEA).

The TCP mechanism is a flexible and effective means created by the IEA to research breakthrough technologies, to fill existing research gaps, to carry out deployment or demonstration programmes – in short to encourage technology-related activities in line with the IEA shared goals of energy security, environmental protection and economic growth, as well as engagement worldwide. Today, about 40 TCPs are working in the areas of:

- Cross-Cutting Activities (information exchange, modelling, technology transfer)
- End-Use (buildings, electricity, industry, transport)
- Fossil Fuels (greenhouse-gas mitigation, supply, transformation)
- Fusion Power (international experiments)
- Renewable Energies and Hydrogen (technologies and deployment)

Each of these areas are overseen by specialised Working Parties that report to the Committee on Energy Research and Technology (CERT), the main IEA body promoting the development, demonstration and deployment of technologies to meet challenges in the energy sector. The IEA-OES report to the Renewable Energy Working Party (REWP).

Work is funded by participants, and there is a close cooperation with the IEA-secretariat in Paris, which also provides a legal framework. The IEA offers clear rules for engagement and equitable sharing of rights and obligations, but also flexibility to adjust to evolving needs and interests of the Participants in TCPs.

The work of the IEA-OES covers all forms of energy generation in which sea water forms the motive power through its physical and chemical properties, i.e. wave, tidal range, tidal and ocean currents, ocean thermal energy conversion and salinity gradients. IEA-OES connects organisations and individuals working in the ocean energy sector to accelerate the viability, uptake and acceptance of ocean energy systems in an environmentally acceptable manner.

As of December 2024, the IEA-OES has 20 active Member Countries along with the European Commission establishing a robust international network. This diverse membership includes governmental bodies, utilities, universities, research organizations, energy agencies, and industry associations providing a rich diversity of perspectives and interests. One key advantage of joining the OES is the opportunity for participants to gain an international perspective on ocean energy opportunities and challenges currently shaping the ocean energy sector. This collaborative environment fosters a global approach to advancing ocean energy technologies and solutions.

The active members are: Australia, Belgium, Canada, China, Denmark, European Commission, France, Germany, Japan, Korea, India, Ireland, Italy, Monaco, New Zealand, Netherlands, Portugal, Singapore, Spain, Sweden, United Kingdom, and United States of America.

Small Island Developing States (SIDS) DOCK, representing 32 small islands and low-lying developing states across the globe, participates as an Observer.

This Annual Report showcases the collaborative work of IEA-OES, emphasizing key achievements and recent global developments. It also offers insights into ocean energy policies, research advancements, and deployment progress across member countries, highlighting the collective impact and progress of this international cooperation.

Key Achievements in 2024

New publications released

MARCH

Ocean Thermal Energy Conversion (OTEC) Economics: Updates and Strategies

APRIL

Workshop on Tidal Current Extractable Energy: Modelling, Verification and Validation

OCTOBER

Self-Sustained Desalination Technologies Powered by Ocean Energy

NOVEMBER

OES TASK 10 - Numerical Modelling WEC Report

DECEMBER

OES-Environmental State of Science Report

Dissemination of the International Vision for Ocean Energy: A Key Focus in 2024

Throughout 2024, the International Vision for Ocean Energy was widely promoted as part of a concerted effort to raise global awareness and drive action toward achieving the ambitious goals outlined in the roadmap "*Ocean Energy and Net Zero: An International Roadmap to Develop 300GW of Ocean Energy by 2050*," published in November 2023. This roadmap lays out a comprehensive vision and implementation strategy for the tidal stream and wave energy sectors, addressing key challenges and opportunities. It forecasts a global installed capacity of 300 GW by 2050, capable of generating 680,000 jobs, contributing $340 billion in GVA, and preventing over 500 million tonnes of carbon emissions.

In 2024, IEA-OES actively promoted its vision at several events, emphasizing the roadmap's key messages. The document shows the need for coordinated leadership in key areas such as market pull and technology push support mechanisms, infrastructure development, and regulatory and legislative frameworks. Throughout the year, targeted outreach efforts aimed to encourage the countries developing their ocean energy strategies to adopt this roadmap.

Integration of Social Acceptability into the Stage-Gate Metrics International Framework for Ocean Energy

In 2024, IEA-OES continued to promote the adoption of the *Stage-Gate Metrics International Framework for Ocean Energy*, which led to discussion on the integration of social acceptability as a relevant component. Since its inception in 2017, the framework has offered a robust approach for technical review and evaluation in the ocean energy sector, ensuring thorough due diligence in technology development.

With the discussion on the inclusion of social acceptability in the framework, the IEA-OES acknowledges that the success of ocean energy projects depends not only on technical and environmental considerations but also on fostering public trust and support. This effort aligns with industry feedback and reflects emerging priorities, demonstrating the framework's adaptability and relevance.

Since 2021, notable achievements include the publication of four reports, one of which was developed in collaboration with the International Electrotechnical Commission (IEC). The ongoing development and refinement of the framework continue to enhance its effectiveness as a key tool for guiding the evaluation of ocean energy technology. It has also been adopted by funding agencies to structure their calls for proposals.

Integration of Ocean Energy with Desalination Processes

In 2024, the IEA-OES concluded and published its comprehensive report on the integration of ocean energy with desalination processes, addressing the global challenge of freshwater scarcity. This study highlights the potential of ocean energy on the desalination process by offering sustainable, low-carbon solutions to meet increasing water demands, particularly in remote regions. It focus on the technical and economic synergies between ocean energy and desalination and details challenges, and opportunities for ocean energy integration.

Previous work on exploring alternative markets for ocean energy, included a study on ocean energy to power offshore aquaculture, and ocean energy for electricity production in islands and remote locations.

Ongoing outreach and engagement under the OES-Environmental Task

In 2024, the OES-Environmental (OES-E) Task, led by the U.S. Department of Energy (DOE) and implemented by Pacific Northwest National Laboratory, made significant progress in advancing knowledge on the environmental effects of marine renewable energy. A key milestone was the publication of the 2024 State of the Science Report. The Tethys knowledge management system continued to serve as a central repository for scientific literature, reports, and data on MRE's environmental impacts, supporting global information-sharing. Engagement with the ocean energy community remained strong through workshops, webinars, and conferences, ensuring continued collaboration among researchers, regulators, and developers.

OES-E's major accomplishments in 2024 also included advancing the risk retirement process, with guidance documents to support regulatory approvals and environmental assessments. Research efforts focused on scaling up ocean energy from single devices to arrays, assessing ecosystem-wide and cumulative effects, and evaluating environmental impacts in tropical and subtropical regions.

Economics of Ocean Thermal Energy Conversion (OTEC)

In 2024, the IEA-OES published its highly anticipated report on the Economics of Ocean Thermal Energy Conversion (OTEC), which can be considered a significant milestone in advancing the understanding and adoption of this technology. This comprehensive study addresses the critical economic challenges faced by the OTEC sector, providing information on the financial feasibility of full-scale OTEC plants.

Building on previous efforts, including the 2021 White Paper on OTEC, this report was the result of a collaborative effort by member countries—Japan, India, China, France, Singapore, and The Netherlands. The study focuses on evaluating cost data from pilot-scale demonstration plants and assessing the economic potential of OTEC, particularly in tropical regions with high thermal gradients.

Collaborative efforts on numerical modelling tasks on wave and tidal energy

Significant progress has been made in the OES task focused on the modeling, verification, and validation of ocean energy technologies, through international collaboration. Results of these efforts were showcased at the RENEW conference in October 2024, at Lisbon, where the OES Task 10 group also hosted a special session on the verification and validation of numerical models for wave energy converters. Additionally, a comprehensive OES report on numerical modeling was published mid-2024, detailing methodologies and including generic reference examples.

International Conference on Ocean Energy - ICOE 2024

The International Conference on Ocean Energy (ICOE) is a biennial event renowned for its focus on fostering innova-

tion, collaboration and dialogue within the ocean energy sector. ICOE 2024 was particularly notable, marking the conference's first venture into the Southern Hemisphere as it was hosted in Melbourne, Australia, from September 16-18. This year, the event was hosted by the Blue Economy CRC. The choice of Melbourne broadened the geographical reach of the conference and also enriched the event with local cultural heritage.

OES actively contributed to ICOE 2024 with a Poster Session Awards and an exhibition stand serving as a hub for engaging discussions and interactions. OES released a report "Key Takeaways from ICOE 2024" capturing the essence of the conference and offering a concise summary of key themes, such as technological innovation, policy development, and environmental impact.

Impactful collaborative initiatives highlighting OES's commitment to global cooperation

The IEA-OES is dedicated to fostering the growth and responsible exploitation of ocean energy, actively participating in initiatives that significantly contribute to the sector's advancement:

- **IEA Wind TCP:** Addressing shared challenges with offshore wind, IEA-OES collaborates on information exchange.
- **SIDS DOCK:** Partnering with SIDS DOCK, an UN-recognized organization, to connect small islands with global markets for climate-resilient energy solutions.
- **International WATERS Network:** Collaborating to establish a global database for marine energy test sites, reducing duplication and promoting shared resources.
- **INORE:** IEA-OES consistently supports young researchers through INORE, sponsoring activities like the European and North America Symposia.
- **IEC-TC 114:** Actively contributing to international standards for wave and tidal energy technologies through collaboration with IEC-TC 114.
- **Ocean Energy Europe (OEE):** Collaborating on data sharing to ensure a unified and clear message for the ocean energy sector.

Expanding Membership and Promoting Awareness

The IEA-OES remained dedicated to broadening its global membership base. The organization actively encourages the inclusion of new members worldwide and extends a warm invitation to key representatives from potential new member countries to participate as Observers in its Executive Committee meetings.

OES focuses on worldwide collaboration, leading effectively, sharing information, and connecting with people involved in ocean energy. The goal of IEA-OES is to increase its impact by spreading key messages and promoting the advantages of ocean energy. It acts as a central point for sharing information, raising awareness through discussions, webinars, and worldwide events. OES works closely with stakeholders and international groups to help ocean energy progress globally.

Country Highlights in 2024

Policy Landscape for Ocean Energy

The global ocean energy sector is undergoing substantial growth, driven by decades of dedicated innovation and development now beginning to reach important milestones and provide socio-economic benefits. These projects are contributing to creating high-value jobs, particularly in coastal communities, and supporting regional and national economic development. A recent report by Scottish Enterprise highlights the substantial economic potential of ocean energy; it projects that a commercial domestic tidal stream sector could contribute over £4.5 billion to the Scottish economy by 2050, while a similar wave energy sector could add another £4.2 billion. These figures show the transformative impact that sustained investment in ocean energy can have on economic landscapes.

The strategic plans of many countries aim to harness marine renewable energies to achieve carbon neutrality by 2050. While offshore wind power remains a cornerstone of these plans in many regions, there is also emerging support for the research and development of new marine renewable energy forms, potentially broadening the scope of technological advancements in the sector.

Tailored **market support schemes** and **research & innovation programmes** have been crucial in advancing ocean energy technologies. These programs help bridge the gap between prototype development and commercial viability by providing the necessary funding, expertise, and infrastructure. Notable is the European Commission targeted funding calls aiming to increase performance of ocean energy technologies with the focus on sustainability, operation and maintenance of ocean energy devices, improve knowledge and reduce LCOE. Similarly, the U.S. Department of Energy's Water Power Program has played a similar role in fostering innovation and supporting technology demonstration in the United States. Likewise, R&D funding initiatives in China have significantly contributed to the development of national capabilities and the deployment of ocean energy systems. In the UK, Wave Energy Scotland has been instrumental in advancing wave energy technologies through funding and supporting collaborative projects aimed at bringing innovative solutions to market readiness.

The industry faces several challenges that need comprehensive solutions: such as scaling up domestic supply chains that can handle the specific demands of ocean energy systems and reduce costs of production, installation, and maintenance of ocean energy systems. **Innovation in materials science, manufacturing processes, and operational logistics can drive down these costs.**

Several countries are developing legislative and regulatory frameworks to support the growth of ocean energy, driven by stakeholders who have expressed a strong desire for increased transparency and greater flexibility in regulatory decision-making. These frameworks are crucial not only for facilitating the growth of a sustainable ocean energy industry but also for encouraging innovation while minimizing administrative burdens for industry participants. At the same time, they uphold the highest standards for safety, security, and environmental protection.

Many countries with significant ocean energy potential still lack the necessary incentives or regulatory frameworks to fully leverage this resource. Despite broad support for renewable energy initiatives, specific funding and targeted initiatives for ocean energy remain limited in many regions, with most programmes encompassing all types of renewables rather than focusing on ocean energy.

The future of ocean energy depends on **coordinated policy frameworks**, clear government commitments, and ongoing innovation investment. With a strong project pipeline and continuous technological advancements, ocean energy has the potential to become an increasingly significant component of the global renewable energy mix. To fully realize this potential, it is essential to maintain momentum in innovation, secure ongoing investment, and enhance international cooperation to share knowledge and optimize technology deployment across different marine environments. Furthermore, engaging local communities in project developments will be key to ensuring sustainable and socially responsible expansion.

Table 1 highlights recent impactful initiatives in member countries that contribute to ocean energy development, while Table 2 summarises the range of national strategies and market mechanisms established in OES Member Countries.

TABLE 1. SELECTED EXAMPLES OF NATIONAL POLICIES RELEVANT FOR OCEAN ENERGY

Australia

Sustainable Ocean Plan

Outlining a collective vision for Australia's oceans up to 2040, focusing on sustainable economic growth. It was under development by the Australian Government, through the Department of Climate Change, Energy, the Environment, and Water (DCCEEW), and the draft was open for public consultation in 2024.

Belgium

Blue Accelerator project

Aims at providing a smooth development path for marine energy and maritime technology from early design stages to scaled models

Energy Transition Fund

Aims to encourage and support innovative projects in the field of energy.

Canada

Passage of Bill C-49

This bill amends existing offshore petroleum legislation to establish a comprehensive regulatory framework for jointly managing offshore renewable energy projects in the Nova Scotia and Newfoundland and Labrador Accord Areas.

Introduction of Fiscal Incentives

The 2024 federal budget introduced by the Government of Canada includes Clean Economy Investment Tax Credits aimed at encouraging investment in wave, tidal, and other clean electricity technologies.

Bill 471 – Advancing Nova Scotia Opportunities Act

This significant legislation, amended by the government of Nova Scotia, increases flexibility in the licensing process for tidal energy development within the province.

China

Energy Law

Enacted in November 2024, this law stands as the principal legislative framework within China's energy sector. It aims to facilitate the large-scale development and utilization of ocean energy, marking a significant step in the nation's energy strategy.

Roadmap for China's Green Transformation

Released in 2024 by the State Council of China, this document outlines strategic initiatives to cultivate new energy sources, including ocean energy. It emphasizes the adoption of appropriate measures to support the development of these emerging sectors.

Denmark

National Strategy for Wave Energy Development

Established in 2012, this strategy has consistently received support from the Energy Technology Development and Demonstration Program (EUDP) and Energinet DK.

Danish Wave Power Roadmap

Initiated in 2015, this roadmap was developed by the Partnership for Wave Power with backing from Energinet.dk and the Danish Energy Agency. It continues to drive wave energy initiatives in Denmark.

European Commission

"Delivering on the EU offshore renewable energy ambitions"

For ocean energy, the timeline has been adjusted, stating that achieving 100 MW of ocean energy capacity by 2027 is feasible, with the goal of reaching 1 GW by the end of the decade or early 2030s.

EU funding programmes

The Horizon Europe programme and the Innovation Fund launched new calls in 2024 for ocean energy.

New publication by the JRC on Ocean Energy in the European Union

This 2024 Status Report on Technology Development, Trends, Value Chains and Markets provides an evidence-based analysis feeding the policy making process and hence increasing the effectiveness of R&I policies for clean energy technologies.

France

National Sea and Coastal Strategy

This plan for 2024-2030 outlines strategic planning guidelines for maritime and coastal areas, highlighting marine renewable energies as key to achieving carbon neutrality by 2050 and supporting the research and development of new marine renewable energies, with a particular focus on marine tidal power.

Open-C Foundation Creation

A key initiative for management of various offshore test sites, enhancing France's capacity for ocean energy technology testing.

Ireland

Designated Maritime Area Plan (DMAP)

As part of the National Marine Planning Framework (NMPF), established to set out Ireland's future development for offshore renewable energies. The DMAPs will develop a multi-activity area plan which will promote the co-existence and co-location of offshore renewable activity with other marine usages and activities. In 2024, four sites for the future development of offshore windfarms off the south coast of Ireland were identified.

Offshore Renewable Energy Technology Roadmap

Maps the pathway to harnessing Ireland's ORE potential. It is an advisory report published by the Sustainable Energy Authority of Ireland (SEAI) in 2024 to inform strategic planning and policy development. Wave energy has been considered a technology that can have an impact.

India

Deep Ocean Mission programme

Funding small scale developmental projects related to marine energy.

Integrated Ocean Energy Atlas

Published in 2024 by the Indian National Centre for Ocean Information Services (INCOIS) under MoES showcases the vast potential of ocean energy resources in the Indian EEZ.

National Committee on Marine Energy Conversion Systems (ETD-54)

Created by the Bureau of Indian Standards (BIS) to formulate standards towards the development of ocean energy in India.

Italy

The FER 2 Decree: new incentive scheme for innovative RES plants

Incentives for innovative renewable source plants or plants with high generation costs having characteristics of innovation and reduced impact on the environment and the territory' (the so-called FER 2 Decree), which came into force on 13 August 2024.

Korea

2030 Ocean Energy Development Plan

Outlines a strategy for tidal and wave energy, progressing through four phases: (1) expanding R&D and establishing test sites, (2) constructing large-scale energy farms, (3) entering global markets and expanding domestic supply, and (4) developing a certification system and supportive policies. Updated to support the 2050 carbon negativity goal, this plan includes a detailed long-term roadmap.

Renewable Energy Portfolio Standard (RPS)

This policy mandates that power producers with a capacity of more than 500 MW generate a certain percentage of their electricity from renewable sources. This requirement is supported by a market-driven Renewable Energy Certificate (REC) system, where renewable energy producers earn certificates that utility companies buy to meet RPS quotas.

Monaco

National Green Fund

A fund dedicated to financing initiatives aimed at reducing greenhouse gas emissions, enhancing energy efficiency, and developing renewable energy sources.

Monaco Renewable Energies

The Government of Monaco and SMEG (Monegasque Electricity and Gas Company) have jointly established Monaco Renewable Energies (MER) to develop renewable energy production projects.

The Netherlands

DEI + ('Demonstrating Energy Innovation')

Government initiative to support demonstrating new technologies in real-world environments, thus facilitating the practical implementation and scaling of innovative solutions in the ocean energy sector.

New Zealand

Government-Encouraged Initiatives

Government-supported initiatives for offshore wind will impact ocean energy development significantly. Additionally, aquafarming in New Zealand is rapidly expanding, leading to a rising demand for energy and a growing interest in renewable energy sources.

Portugal

Offshore Renewable Energy Allocation Plan (PAER)

PAER identifies areas for the deployment of commercial renewable power plants.

Viana do Castelo Technological Free Zone (ZLT)

Launched by the government to enable the testing and experimentation of innovative technology-based technologies.

Singapore

Renewable Energy Integration Demonstrator - Singapore (REIDS)

Largest hybrid microgrid test and research platform in the tropics, dedicated to designing and testing solutions for sustainable and affordable energy access-for-all in Southeast Asia as well as the future of urban electricity distribution. REIDS is the largest hybrid microgrid test and research platform in the tropics.

Sweden

National Maritime Strategy

Ocean energy is a key component of Sweden's national maritime strategy. The government adopted three marine spatial plans for its territorial waters and Exclusive Economic Zone. These plans are essential for guiding governmental agency and municipal decisions about the optimal use of marine areas.

Spain

Roadmap for the Development of Offshore Wind and Marine Energies

Outlining Spain's objectives for the development of offshore wind and marine energies.

New legislative framework for offshore renewable energy

Introduces a competitive bidding process for offshore energy installations in designated High Potential Areas (ZAPER), as outlined in Spain's Maritime Spatial Planning (POEM) and provides a streamlined process for "innovative offshore renewable installations" including ocean energy projects.

UK

UK's flagship Contracts for Difference (CfD)

To date, contracts have been awarded for over 120 MW of tidal stream projects.

Wave Energy Scotland (WES) programme

Primarily funded by the Scottish Government, has consistently provided the Scottish wave energy sector with substantial support and guidance. This initiative has played a crucial role in advancing research, development, and deployment of wave energy technologies across Scotland.

Marine Energy Wales (MEW) 2024 State of the Sector Report

Highlights how Wales' marine renewable energy sector delivered an impressive £29.9 million to the Welsh economy during the 2023/24 financial year, bringing total cumulative spending and investment from the sector in Wales to roughly £292.9 million. Of this total, tidal stream has been by far the biggest contributor to date, injecting £116.1 million into the Welsh economy.

USA

"Oceans of Opportunity"

This new funding opportunity from the U.S. Department of Energy's Water Power Technologies Office (WPTO) will provide up to $112.5 million for wave energy development and testing over five years, representing the largest U.S. investment in wave energy to date.

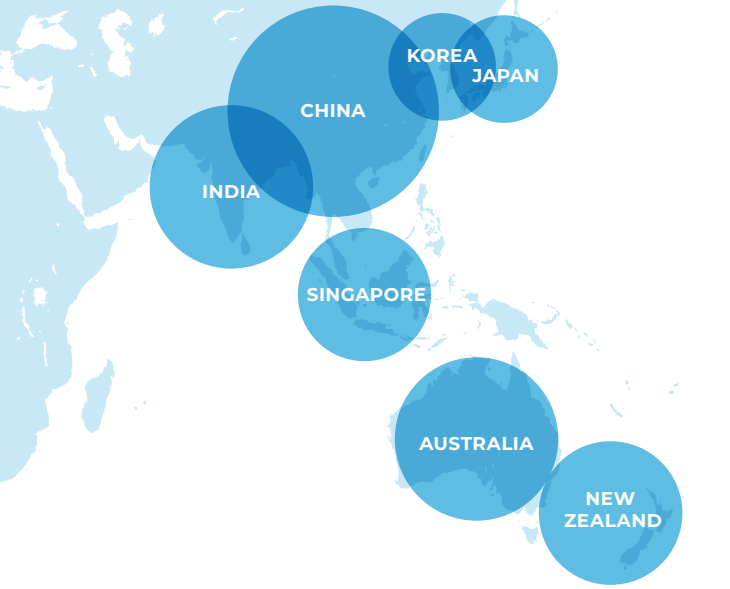
Clean Electricity Production and Investment Tax Credits

It provides incentives for companies to invest in clean energy technologies providing clarity and certainty for developers to undertake major investments.

TABLE 2. NATIONAL STRATEGIES FOR OCEAN ENERGY DEVELOPMENT AND MARKET MECHANISMS ESTABLISHED IN OES MEMBER COUNTRIES

	National strategy				Market incentives					
	Capacity targets	National Strategy	Technology Roadmap	Maritime Spatial Plan	Fee-in-Tariffs	Constracts for Difference	Green Certificates	Quota obligations	Auctions	Tax credit
Australia		●	●							
Belgium		●	●	●			●			
Canada	●	●	●	●	●				●	
China	●	●		●			●			
Denmark			●	●						
France	●			●	●				●	
India	●	●	●	●						
Ireland	●	●	●	●					●	
Italy	●	●		●	●					
Japan		●	●		●					
Korea	●	●	●					●		
Monaco				●	●					
Netherlands				●	●					●
New Zealand				●						
Portugal	●	●	●	●						
Singapore										
Spain	●	●	●	●					●	
Sweden		●		●			●			
UK	●	●	●	●		●				
USA		●	●	●						●

Progress in Demonstration Projects



Globally, ocean energy technologies are progressing from research and development to demonstration and pilot projects, with increasing focus on grid connection and commercial viability. Multiple wave and tidal energy devices are undergoing testing in real-sea conditions, demonstrating improved performance and survivability. Several projects are achieving significant milestones, including long-duration operation, increased energy production, and advancements in component design. Integration with other technologies, such as hydrogen production and desalination, is also being explored. While challenges remain in terms of cost reduction and scaling up to commercial levels, the sector is showing promising signs of growth, with increasing deployments and a growing pipeline of planned projects.

CHINA

- The **Wanshan Wave Energy Demonstration Project** continues to progress with its two 500 kW devices, "Zhoushan" and "Changshan," which have been operating continuously at sea.
- The **Penghu Wave Energy Deep-Water Aquaculture Platform** has maintained stable operation, successfully completing multi-species and multi-quarter aquaculture, and demonstrating excellent operational and economic results.
- The **LHD Zhoushan Tidal Current Power Station** has been in stable operation for over 7 years. The "Endeavour" turbine, China's first megawatt-level tidal current generator, was connected to the grid in March 2022 and has been operating continuously for over 30 months, generating more than 4.5 million kWh of grid-connected power by the end of 2024.
- The **Zhoushan Tidal Current Energy Demonstration Project**, carried out by the China Three Gorges Corporation, continues its technical transformations and installations in 2024, with grid-connected demonstration operations proceeding successfully.
- Led by Guangdong Grid Co. of the China Southern Power Grid (CSG), the "**Nankun**", China's first megawatt-class floating wave energy generation device, has advanced, with the device deployed for open sea tests.
- Several universities have successfully deployed wave and tidal energy pilot projects under real sea conditions. Additionally, the Guangzhou Institute of Energy Research of the Chinese Academy of Sciences has advanced its research on small wave energy power supply devices, developing a variety of small wave energy power supply buoys.

KOREA

- KRISO is leading a pioneering R&D project to produce green hydrogen using wave power at the **Yongsoo OWC** near Jeju Island, Korea. Major facilities for hydrogen production were installed at the Yongsoo OWC WEC by the end of 2024.
- A pilot plant of a **30 kW OWC wave energy converter** has been constructed at Mook-ri port on Chuja Island, led by KRISO. It is currently undergoing performance evaluation and technology verification.

- KRISO is also advancing a project to develop and deploy an OWC device integrated into newly constructed breakwaters. The project has selected Homigot Port in Pohang, on the East Sea, as the target site, with the consent process nearing completion.
- A 1 MW class horizontal axis tidal current energy converter has been developed and installed at the **Uldolmok tidal energy test site**.

INDIA

- The **National Institute of Ocean Technology (NIOT)** is progressing with setting up a 100 m^3/day capacity Ocean Thermal Energy Conversion (OTEC) powered desalination plant at Kavaratti Island in UT Lakshadweep.
- NIOT has also developed a customized IoT-enabled wave-powered fairway buoy, funded by Kamarajar Port Ltd. (KPL), designed for operation at KPL in Chennai. Andaman & Nicobar Administration, Chennai Port, and several other Indian ports, are considering the installation of these innovative buoys to enhance their operational capabilities.

SINGAPORE

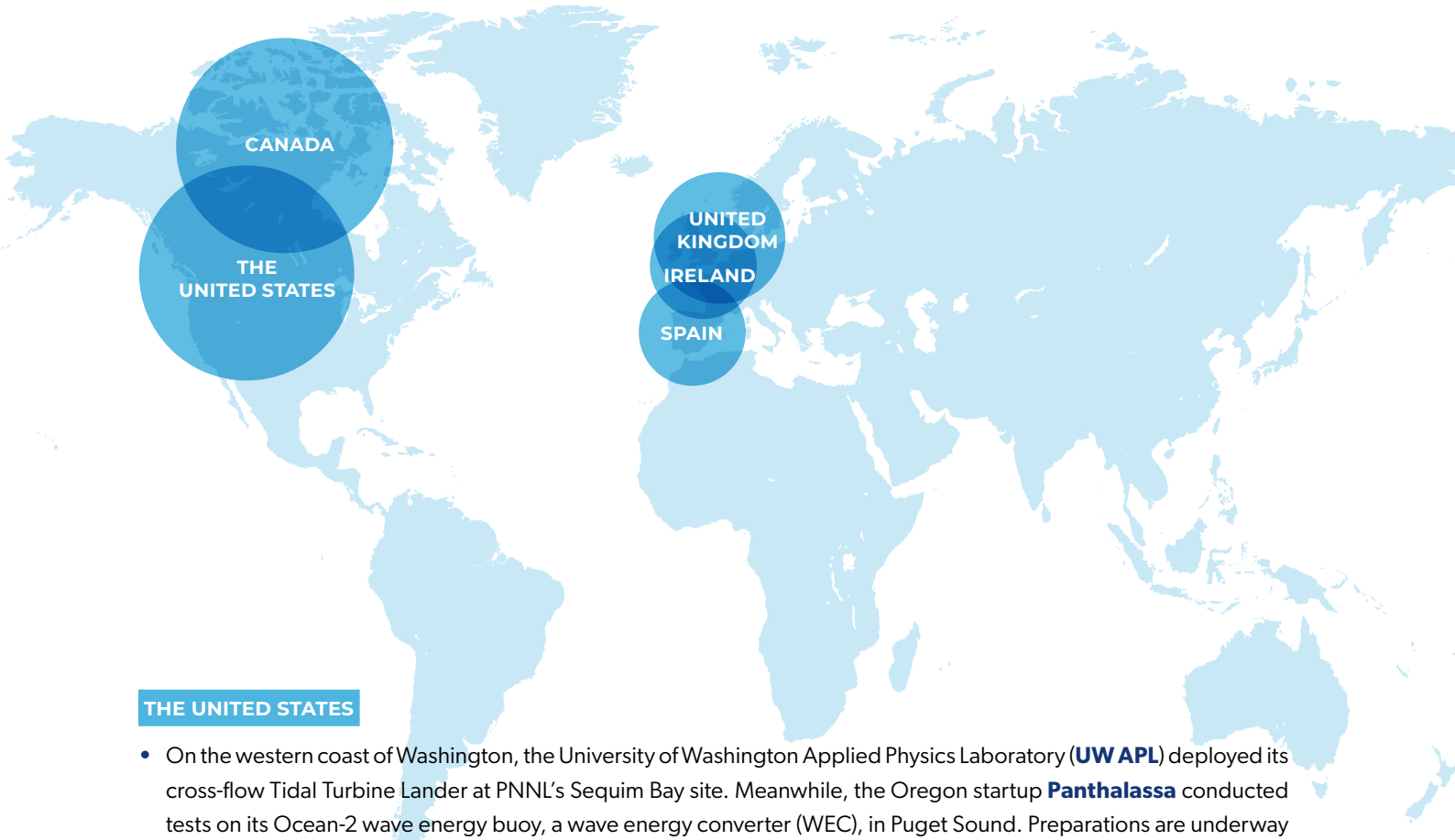
- The **Tanah Merah Ferry Terminal (TMFT)** located in Changi, features a floating pontoon integrating a pontoon-type Wave Energy Converter for demonstration of its fesibility.
- A feasibility study for developing a renewable energy farm in the waters surrounding **Raffles Lighthouse** is set to commence in Q4. Plans include installing solar panels on the water surface and tidal turbines below.
- **ERI@N**, supported by the Singapore Land Authority (SLA), has successfully implemented a renewable-powered water generation system on Kusu Island, with plans to expand to other islands like Pulau Hantu Besar.
- The construction of a **large-scale floating solar farm** is scheduled to start in 2025 at Kranji Reservoir, anticipated to be Singapore's largest, with operational status expected by 2027-2028.
- ERI@N has deployed an **offshore floating solar system** to meet the energy demands of aquaculture farms.
- REIDS Offshore, also known as **Tropical Marine Energy Centre (TMEC)** led by ERI@N and financially backed by ClassNK, is advancing offshore renewable energy integration, with a feasibility study conducted to assess ocean energy potential around Singapore's southern islands using resource mapping for suitable test sites.

AUSTRALIA

- The **MoorPower pilot** from Carnegie was successfully deployed at North Fremantle test site in Western Australia during 2024. Carnegie is advancing towards a commercial demonstration, planning to install commercial-scale MoorPower modules on an operational aquaculture feeding barge.
- Carnegie Clean Energy, through its subsidiaries **CETO Wave Energy Ireland** and **Carnegie Technologies Spain**, is set to deploy the first CETO wave energy converter unit in Europe at the BiMEP testing site in Bilbao, Spain in 2025.
- The **M4 wave energy project** led by The University of Western Australia, and developed by the University of Manchester and M4 Wave Power Ltd was deployed in November 2024 in Albany, 450 km south of Perth, Western Australia and is scheduled for decommissioning in early 2025 after about six months at sea, with additional deployments anticipated in 2025 and 2026 in collaboration with WaveX.
- WaveX has signed an MOU with the University of Western Australia (UWA), for the W5 project using WaveX D-Spar™ technology. The completion of preliminary structure and moorings design was achieved in 2024, underpinned by a recent collaboration agreement signed by Trident Energy (UK) and WaveX.

NEW ZEALAND

- Azura Wave Power has signed a Memoranda of Understanding for the deployment of wave energy converters in Australia and French Polynesia.
- The Waves and Dynamics Research Group at the University of Auckland has successfully deployed and tested two small-scale marine energy devices at aquafarms.
- The "Ruka Marine Turbine" project by Mana Wairua Energy has been accepted into the Callaghan Innovations Arohia Seed Fund program. A demonstrator model has been completed. A non-disclosure agreement has been signed with a delegation from Raiatea Island, French Polynesia.



THE UNITED STATES

- On the western coast of Washington, the University of Washington Applied Physics Laboratory (**UW APL**) deployed its cross-flow Tidal Turbine Lander at PNNL's Sequim Bay site. Meanwhile, the Oregon startup **Panthalassa** conducted tests on its Ocean-2 wave energy buoy, a wave energy converter (WEC), in Puget Sound. Preparations are underway by **Ocean Motion Technologies** to launch an updated wave-powered data buoy and autonomous underwater vehicle charging station in 2025.
- Further south, at PacWave South off the coast of Oregon, **C-Power** and **CalWave** will begin testing their devices in 2026.
- In Hawaii, **C-Power** has already deployed a commercial-scale SeaRAY autonomous offshore power system (AOPS) following a successful first-phase demonstration in 2023, along with subsequent system upgrades. Additionally, **Oscilla**'s 100 kW Triton-C WEC is moored at the Wave Energy Test Site (WETS) in preparation for its deployment.
- On the California coast, developer **Oneka** has completed a 30-day test of its IceCube wave-powered desalination device in collaboration with the Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC).
- In terms of riverine current technologies, **ORPC**'s Modular RivGen devices continue testing in Maine's Millinocket Stream, with additional units stationed in the Kvichak River at the Village of Igiugig in Alaska for ongoing evaluation.
- Additional projects include the **National Renewable Energy Laboratory (NREL)** conducting open water tests of its hydraulic and electric reverse osmosis (HERO) wave energy converter in North Carolina, and the **University of New Hampshire** planning to deploy its tidal energy testing platform on the Piscataqua River in 2025. Other active developers like **Littoral Power Systems**, **PacMar Technologies**, and **BladeRunner Energy** are planning for system deployments in 2025.

CANADA

- **Ocean Renewable Power Company (ORPC)** Canada completed a two-year demonstration of its RivGen device at the Canadian Hydrokinetic Turbine Test Centre (CHTTC) in Manitoba.
- **Yourbrook Energy Systems** is nearing completion of Phase 1 of a FEED study to support its Kamdis Tidal Power Demonstration Project in British Columbia.
- The University of Victoria's Pacific Regional Institute for Marine Energy Discovery **(PRIMED)** continues to support the development and uptake of wave and tidal energy in British Columbia's remote communities.
- On the east coast, **Eauclaire Tidal**, in partnership with Orbital Marine Power, is advancing toward deployment at the Fundy Ocean Research Centre (FORCE), with permitting activities for three devices currently underway.
- **Nova Innovation** and **New Energy Corporation** are making significant progress on projects aimed for deployment in the Bay of Fundy.

EUROPE

UNITED KINGDOM

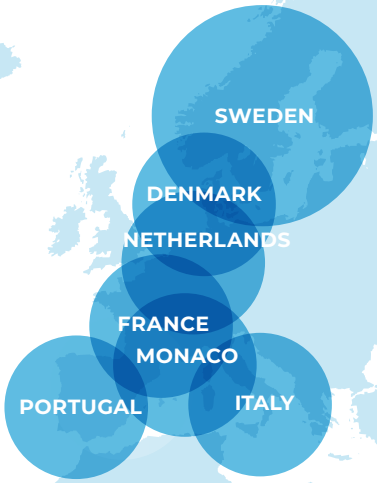
- **Magallanes Renovables** continued to enhance their ATIR turbine at the European Marine Energy Centre (EMEC). They are progressing with the design of the next-generation ATIR 2.0 device, for deployment at Morlais in 2027. In 2024, Magallanes won a 3 MW extension to their existing 1.5 MW capacity at EMEC under the CfD AR6, along with an additional 3 MW at Morlais from AR5.
- Throughout 2024, **Mocean Energy** expanded internationally with its Blue Star and Blue Horizon technologies. The year also marked the successful 13-month operational phase of their Blue X prototype connected to a subsea micro-grid off Orkney's east coast. Following inspection after retrieval in spring 2024, Blue X is being prepared for re-deployment in 2025.
- **MeyGen's** first phase, operational since 2018 and located in the Pentland Firth, returned all four 1.5 MW turbines to full operation. This phase has now delivered over 70 GWh of electricity, with 10 GWh generated in 2024 alone. Plans are underway to expand the capacity with an additional 59 MW using 3 MW turbines by the next phase. Phase 1 incorporated two different turbine technologies, **Proteus Marine Renewables** AR1500 and **Andritz Hydro Hammerfest** AH1000 MK1
- **Nova Innovation** has maintained the operation of the Shetland Tidal Array, accumulating over 80,000 hours of turbine operation. In 2024, Nova secured 6 MW of CfD for deploying turbines at the EMEC Fall of Warness site.
- **Orbital**'s O2 tidal turbine continues its long-term testing at EMEC, setting a new generation record in 2024. Orbital is also progressing with environmental surveys and consenting work for the Westray Tidal Array, aiming for final consent application in the upcoming year.
- **AWS Ocean Energy**'s Waveswing wave energy converter demonstrated its viability through successful at-sea testing of a 16 kW prototype at EMEC's Scapa Flow site.
- **HydroWing** is preparing to deploy a 20 MW tidal array at Morlais in Wales. After securing 20 MW of capacity under the CfD scheme for a 2027/28 commissioning, a demonstration project is planned for 2025.
- **QED Naval** made substantial progress in 2024, focusing on front-end engineering and design work for the next-generation Subhub-ID and enhancing their Tocardo T3 turbine. Their commercial efforts are gearing towards a financial investment decision for the first phase of a 30 MW project at Morlais, with operational experience from their Subhub technology at Strangford.
- **OceanEnergy** has committed to demonstrating its 1 MW OE35 floating wave energy converter at EMEC's Billia Croo site, with a two-year testing period expected to start in 2025/26.

IRELAND

- The **Saoirse project**, a pioneering 5 MW wave energy development, is progressing towards its planned deployment in 2029 off the coast of County Clare, Ireland. Utilizing CorPower technology, the project's advancement is contingent on securing necessary approvals and a grid connection. Simply Blue Energy and ESB Wind Development have formed a joint venture to develop this innovative wave farm.

SPAIN

- **Mutriku Wave Power Plant** continued to function as both a test site and an operational power plant, producing 210 MWh in 2024. Infrastructure improvements have been underway to accommodate the air turbines developed under the TurboWave commercial procurement initiative launched in late 2022.
- The Danish company **Wavepiston** installed its first full-scale energy collector at the PLOCAN test site in the Canary Islands, using wave movement to generate pressurized water for energy or desalination.
- Two prototypes, **CETO** by CARNEGIE and **MARMOKA** by IDOM, are scheduled for installation at BiMEP in summer 2025, marking significant progress in the EuropeWave project.



SWEDEN

- The utility-scale tidal energy project from **Minesto**, Dragon 12, rated at 1.2 MW, was commissioned and delivered its first electricity to the Faroe Islands' national grid. Minesto is now preparing for a 10 MW utility-scale kite array in the Faroe Islands.
- **CorPower's** C4 wave energy converter was installed in Aguçadoura, Portugal, in August 2023. After testing and operational maintenance verification, the first retrieval and tow-back were completed. Re-deployment is planned for early 2025.
- After enduring a year of testing under conditions including ice formation and storms, **NoviOcean** is developing a 1 MW full-scale pilot targeted for deployment in 2026. The location is yet to be determined.
- The first large-scale offshore pilot project of **OE Systems** is scheduled for installation and testing in early 2025 off Lysekil, Sweden, with all necessary regulatory approvals already secured.
- **Ocean Harvesting Technologies** and **Waves4Power** have done various R&D advancements throughout the year.

DENMARK

- **Wavepiston** is conducting full-scale tests at the PLOCAN site in Gran Canaria, focusing on desalination and power production. Additional development is underway in Martinique and Barbados.
- **Exowave**, is developing phase 1 of its 250 MW wave power initiative which involves demonstrating a 40 kW prototype in 14 m water depth at the North Sea test site near the Port of Hanstholm.
- **CrestWing** is seeking permission to re-launch the Tordenskjold plant prototype in the Kattegat for further testing to confirm its operational efficacy and performance.
- Nine startups are actively developing wave energy converters under the **Danish Partnership for Wave Energy**, facilitated by the Energy Cluster Denmark. These include Wave Dragon, Wavepiston, WaveStar, ExoWave, Floating Power Plant, Weptos, CrestWing, OceanSwellEnergy, and KNswing, with academic support from the Technical University of Denmark (DTU) and Aalborg University (AAU).

NETHERLANDS

- **Seaqurrent** successfully conducted offshore tests of their TidalKite 2.0 at a grid-connected site near Ameland, with further testing planned for the following year.

- **Wave Energy Collective (Weco)** successfully performed a series of tests on the Kaizen WEC in the Deltares wave flume and offshore at Scheveningen, with further testing planned to validate a fully functional system.
- **REDstack** continues to produce Blue Energy through salinity gradient power at the Afsluitdijk since 2014, with a new automated manufacturing line expected to be operational by the end of 2025.
- **Water2Energy** reinstalled its vertical axis turbine for new tests featuring newly patented pitch control technology.
- **Symphony Wave Power** completed assembly of a prototype and its dry testing facility, preparing for sea trials with a 40 kW prototype point absorber.
- Other Planned deployments by Dutch companies such as **Slow Mill Sustainable Power, Dutch Wave Power, Equinox**, and **AE WaveHexaPod** are set to advance the marine energy sector with innovative technology applications in the coming months.

PORTUGAL

- **CorPower Ocean** completed the initial testing and operational maintenance verification of its C4 wave energy converter in Aguçadoura, Portugal, with plans for re-deployment and further assessments in early 2025.

FRANCE

- **Seaturns** successfully tested a ¼ scale wave energy device at the IFREMER site for one year until September 2024, with a second testing phase underway. Plans for a 200 kW full-scale demonstrator at the SEMREV site highlight a strategic scale-up in technology.
- **Inyanga Marine Energy Group** acquired the D10 tidal turbine from SABELLA and secured operational authorization until 2028. The D10 has been operational in the Fromveur Passage since early 2022.
- **The FLOWATT Project**, led by Qair, Hydroquest, and CMN, aims to install a 17.5 MW tidal farm using six 2.8 MW vertical axis turbines. It is scheduled for deployment in 2028 in the Alderney Race.
- **Normandie Hydroliennes** was awarded the Innovation Fund for the NH1 project and plans to deploy a 12 MW pilot tidal farm with four AR3000 horizontal axis turbines by 2028 in the Alderney Race.
- **Legendre** is developing a 360-kW DIKWE wave energy converter for ports and breakwaters, with an installation planned in the north of France.

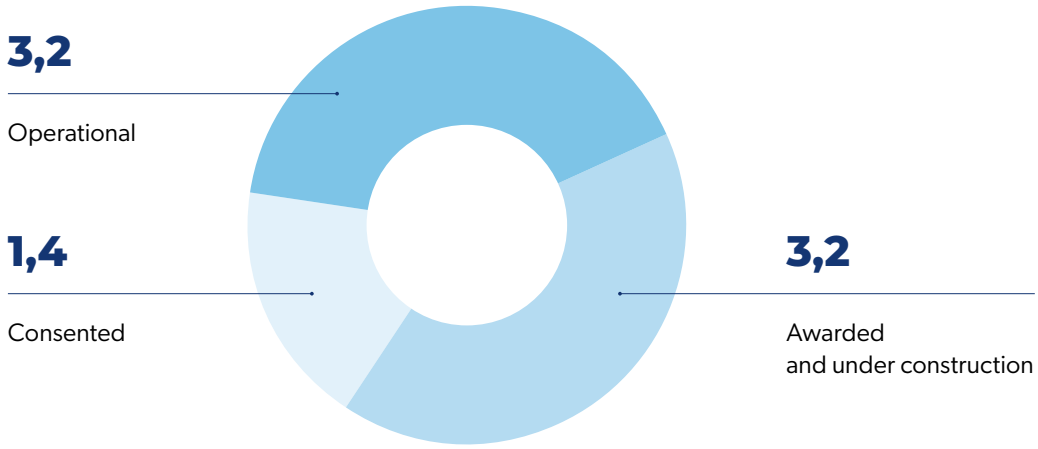
MONACO

- 80 seawater heat pumps produce 17% of the Principality's energy consumption (about 191 GWh/year) through the use of the sea as a renewable energy source for a heat pump system. Two new heating and cooling networks connected to seawater heat pumps has been put into service. They should supply 3500 homes and eliminate 6ktCO2eq of GHG emissions (approx. 8% of the total emissions of Monaco). These networks will produce around 26 000 MWh of completely decarbonized energy.

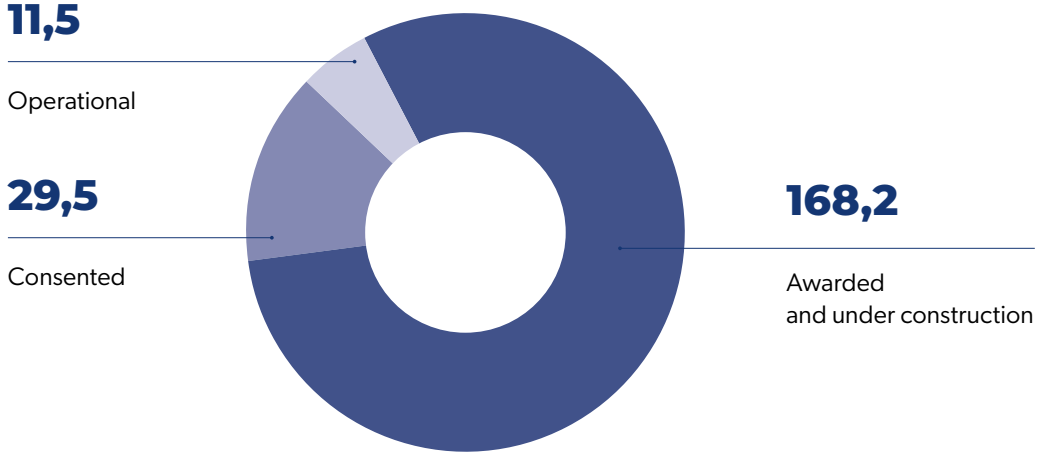
ITALY

- The Mediterranean University of Reggio Calabria has been advancing the **REWEC3** wave energy converter, an Oscillating Water Column (OWC) integrated into a vertical breakwater. The first full-scale installation occurred at the Civitavecchia port. Following this, the Port Authority of Civitavecchia committed to upgrading its infrastructure, adopting REWEC3 technology for the construction of 17 new caisson breakwaters, each 33.94 meters long, totaling 578 meters. A 20 kW Wells turbine has already been installed, with the potential for the entire system to reach a capacity of 2.5 MW.
- The Overtopping Breakwater for Energy Conversion (**OBREC**) is progressing with the development of a new PTO system for this innovative project.
- The Polytechnic of Turin has been developing and testing the **ISWEC** (Inertial Sea Wave Energy Converter), a wave energy converter using gyroscopic technology for energy generation. The 250 kW unit has been operational since 2023 off Pantelleria.
- **Gemstar Tidal Kite** by SeaPower s.c.r.l. continues being developed since 2005, targeting significant energy production in the Strait of Messina. Plans are underway to install the next full-scale 300 kW prototype in the Strait.

Summary of Installed Capacity in the OES Member Countries



WAVE ENERGY
Installed Capacity (MW)



TIDAL STREAM ENERGY
Installed Capacity (MW)

TIDAL RANGE

Country	Name of Project	Technology Developer	Installed Capacity
China	Jiangxia Tidal Power Plant	China Long Yuan Power Group Corp. Ltd	4.1 MW
France	La Rance Barrage	EDF	240 MW
Korea	Sihwa Lake Tidal Power Station	K-Water	254 MW

OTEC

Country	Name of Project	Technology Developer	Installed Capacity
Korea	OTEC Pilot Plant at Goseong	KRISO	20 kW
India	OTEC powered desalination plant at Kavaratti *(under construction)*	NIOT	65 kW
Japan	Okinawa OTEC plant	Xenesys	100 kW

SALINITY GRADIENT

Country	Name of Project	Technology Developer	Installed Capacity
Netherlands	REDstack at Afsluitdijk	REDstack	4-50 kW
FRANCE	SARBACANNE, Port-Saint-Louis-du-Rhône *(under construction)*	Sweetch Energy	-

Open Sea Test Sites

Open sea testing facilities play very important role in accelerating ocean energy technologies worldwide, supporting devices at various Technology Readiness Levels (TRLs) and under different environmental conditions. Pioneered by institutions like the European Marine Energy Centre (EMEC) in the UK, these facilities are renowned for fostering innovation by offering comprehensive support throughout the development stages of ocean energy projects. They provide a full spectrum of services, from prototype testing in real sea conditions to the refinement of operational strategies and performance evaluation. Moreover, these sites often host expert teams skilled in navigating regulatory frameworks and technical challenges, further easing the path from concept to commercialization for emerging technologies.

The IEA-OES has joined forces with the International WATERS network to create a central online database. This resource thoroughly compiles details about the infrastructures at various open sea test centers. The goal of this database is to enhance collaboration, foster knowledge sharing, and support joint problem-solving efforts across the ocean energy sector: https://www.internationalwaters.info/

UNITED KINGDOM

TEST SITE NAME	LOCATION
European Marine Energy Centre (EMEC)	Orkney, Scotland
FaBTest	Falmouth Bay in Cornwall
Marine Energy Test Area (META)	Milford Haven Waterway in Pembrokeshire
Morlais Tidal Demonstration Zone	West Anglesey
Perpetuus Tidal Energy Centre (PTEC)	South Coast of the Isle of Wight

CANADA

TEST SITE NAME	LOCATION
Fundy Ocean Research Centre for Energy (FORCE)	Minas Passage, Bay of Fundy, Nova Scotia
Canadian Hydrokinetic Turbine Test Centre (CHTTC)	Winnipeg River, Manitoba

IRELAND

TEST SITE NAME	LOCATION
Galway Bay Marine and Renewable Energy Test Site	Galway Bay
AMETS	Belmullet, Co. Mayo

USA

TEST SITE NAME	LOCATION
U.S. Navy Wave Energy Test Site	Kanohe Bay, Hawaii
Pacific Marine Energy Center PacWave North Site	Newport, Oregon
Pacific Marine Energy Center PacWave South Site	Newport, Oregon
Pacific Marine Energy Center Lake Washington	Seattle, Washington
Pacific Marine Energy Center Tanana River Hydrokinetic Test Site	Nenana, Alaska
Jennette's Pier Wave Energy Test Facility	Jennette's Pier, North Carolina
U.S. Army Corps of Engineers (USACE) Field Research Facility (FRF)	Duck, North Carolina
Center for Ocean Renewable Energy	Durham, New Hampshire
UMaine Offshore Intermediate Scale Test Site	Castine, Maine
UMaine Deepwater Offshore Renewable Energy Test Site	Monhegan Island, Maine
OTEC Test Site	Keahole Point, HI
Marine Renewable Energy Collaborative (MRECo) Bourne Tidal Test Site (BTTS)	Bourne, Massachusetts
Southeast National Renewable Energy Center - Ocean Current Test Facility	Boca Raton, Florida

PORTUGAL

TEST SITE NAME	LOCATION
Viana do Castelo test site	Viana do Castelo
Aguçadora test site	Aguçadora

SPAIN

TEST SITE NAME	LOCATION
BiMEP	Basque Country
Mutriku Wave Power Plant	Basque Country
Oceanic Platform of the Canary Islands (PLOCAN)	Canary Islands
Punta Langosteira Test Site	Galician coast

MEXICO

TEST SITE NAME	LOCATION
Port El Sauzal	Ensenada, Baja California
Station Puerto Morelos	Puerto Morelos, Quintana Roo

NETHERLANDS

TEST SITE NAME	LOCATION
REDstack	Afsluitdijk
Tidal test site Ameland	Ameland
Wave test site Texel	Texel

SWEDEN

TEST SITE NAME	LOCATION
The Lysekil wave energy research test site	Lysekil

DENMARK

TEST SITE NAME	LOCATION
DanWEC	Hanstholm
DanWEC NB	Nissum Bredning

BELGIUM

TEST SITE NAME	LOCATION
Blue Accelerator	Port of Ostend

JAPAN

TEST SITE NAME	LOCATION
NAGASAKI-AMEC (Kabashima) floating wind Site	Goto, Nagasaki
NAGASAKI-AMEC (Naru) Tidal Site	Goto, Nagasaki
NAGASAKI-AMEC (Enoshima •Hirashima) Tidal Site	Saikai, Nagasaki

CHINA

TEST SITE NAME	LOCATION
National Marine Test Site (Wehai)	Weihai, Shandong Province
National Marine Test Site (Zhoushan)	Zhoushan, Zhejiang Province
National Marine Test Site (Zhuhai)	Zhuhai, Guangdong Province

REPUBLIC OF KOREA

TEST SITE NAME	LOCATION
KRISO-WETS (KRISO-Wave Energy Test Site)	Jeju
Korea Tidal Current Energy Centre (KTEC)	Jindo (under development)

SINGAPORE

TEST SITE NAME	LOCATION
Sentosa Tidal Test Site	Sentosa island

FRANCE

TEST SITE NAME	LOCATION
SEM-REV, wave and floating offshore wind test-site	Le Croisic
SEENEOH estuarine and ¼ scale tidal site	Bordeaux
Paimpol-Brehat, tidal site	Bréhat
Sainte-Anne du Portzic, scaled wave and floating wind test-site	Brest

01 OVERVIEW OF OES

The International Energy Agency's (IEA) Ocean Energy Systems (OES) Technology Collaboration Programme is an intergovernmental collaboration between countries, to advance research, development and demonstration of technologies to harness energy from all forms of ocean renewable resources for electricity generation, as well as for other uses, such as desalination, through international co-operation and information exchange.

LHD Zhoushan tidal current power station © LHD

IEA-OES embraces the full range of ocean energy technologies:

- **Waves**, created by the action of wind passing over the surface of the ocean;
- **Tidal Range** (tidal rise and fall), derived from the gravitational forces of the Earth-Moon-Sun system;
- **Tidal Currents**, water flow resulting from the filling and emptying of coastal regions as a result of the tidal rise and fall;
- **Ocean Currents**, derived from wind-driven and thermohaline ocean circulation;
- **Ocean Thermal Energy Conversion (OTEC)**, derived from temperature differences between solar energy stored as heat in upper ocean layers and colder seawater, generally below 1000 m;
- **Salinity Gradients**, derived from salinity differences between fresh and ocean water at river mouths.

Offshore wind, marine biomass or submarine geothermal, which occupy sea space but do not directly utilize the properties of seawater, are not included in the IEA-OES remit.

Most ocean energy technologies are being developed to produce electricity, although some of them are being developed to deliver other or multiple products, derived from the physical and chemical properties of seawater (e.g. fresh water and sea water air conditioning).

Vision

"As the **authoritative international voice on ocean energy**, we collaborate internationally to accelerate the viability, uptake and acceptance of ocean energy systems in an environmentally sustainable manner".

Mission

The OES mission is to support a framework of activities that:

Stimulate research, development and deployment of Ocean Energy Systems in a manner that is beneficial for the environment and provides an economic return for those involved.
Support governments, agencies, corporations and individuals in the development and deployment of Ocean Energy Systems.
Educate people globally on the nature of Ocean Energy Systems, the current status on development and deployment, and the beneficial impacts of such systems, improve skills and enhance research.
Connect with organisations and individuals working in the ocean energy sector for knowledge exchange to accelerate development and enhance economic and environmental outcomes.

Objectives

1. **Stimulate** research, development and deployment
2. **Support** governments, agencies, corporations and individuals
3. **Educate** people globally on the nature of Ocean Energy Systems
4. **Connect** with organisations and individuals and exchange information

Stimulate research, development and deployment

Objective 1 — Stimulate collaborative work between OES country members to address challenges faced by the ocean energy sector avoiding duplication

- Foster and secure a strong commitment from all member countries and stimulate the participation of new countries in the OES to strengthen international collaboration and enhance OES's outreach worldwide.
- Continue to support and set up OES working groups on specific topics (wave and tidal modelling and OTEC development) with increased input from stakeholders (industry, government and research).
- Continue to work on developing strategic tasks such as LCOE, environmental issues, jobs creation and market opportunities.

Support governments, agencies, corporations and individuals in the development and deployment of Ocean Energy Systems

Objective 2 — Enhance the impact of OES's work and remain the primary source worldwide of high-quality information

- Develop shared key messages (e.g. via position papers and policy briefs), incorporating outcomes of technology improvements and environmental integration.
- Stimulate policymakers regarding the social, environmental and economic benefits of ocean energy, and stress that government policies remain crucial to attract investment.
- Collect and share recent research, market, policy and technological updates, in ocean energy developments in OES Member countries.
- Provide valuable inputs to the REWP and the IEA network; contribute to relevant IEA publications, events and other initiatives.

Educate people globally on the nature of Ocean Energy Systems

Objective 3 — Provide a platform for information exchange and discussion to increase awareness and understanding of the potential and benefits of ocean energy

- Collect and analyse information from country members on projects (WebGis Database), policies, consenting processes, capacity outlook, etc.
- Discuss and analyze good practices to achieve successful and cost-effective wide-scale deployment of ocean energy technologies, for utility-scale as well as niche markets, on a multi-country approach.
- Shaping the international discussion and continuing the series of public webinars/workshops and presence in international events; stimulate the participation of delegates in national events to spread OES activities worldwide.
- Highlight to stakeholders important developments, accomplishments in the ocean energy sector; provide relevant information and advice on ocean energy technologies and policies, from R&D to market deployment.

Connect with organisations and individuals and exchange information

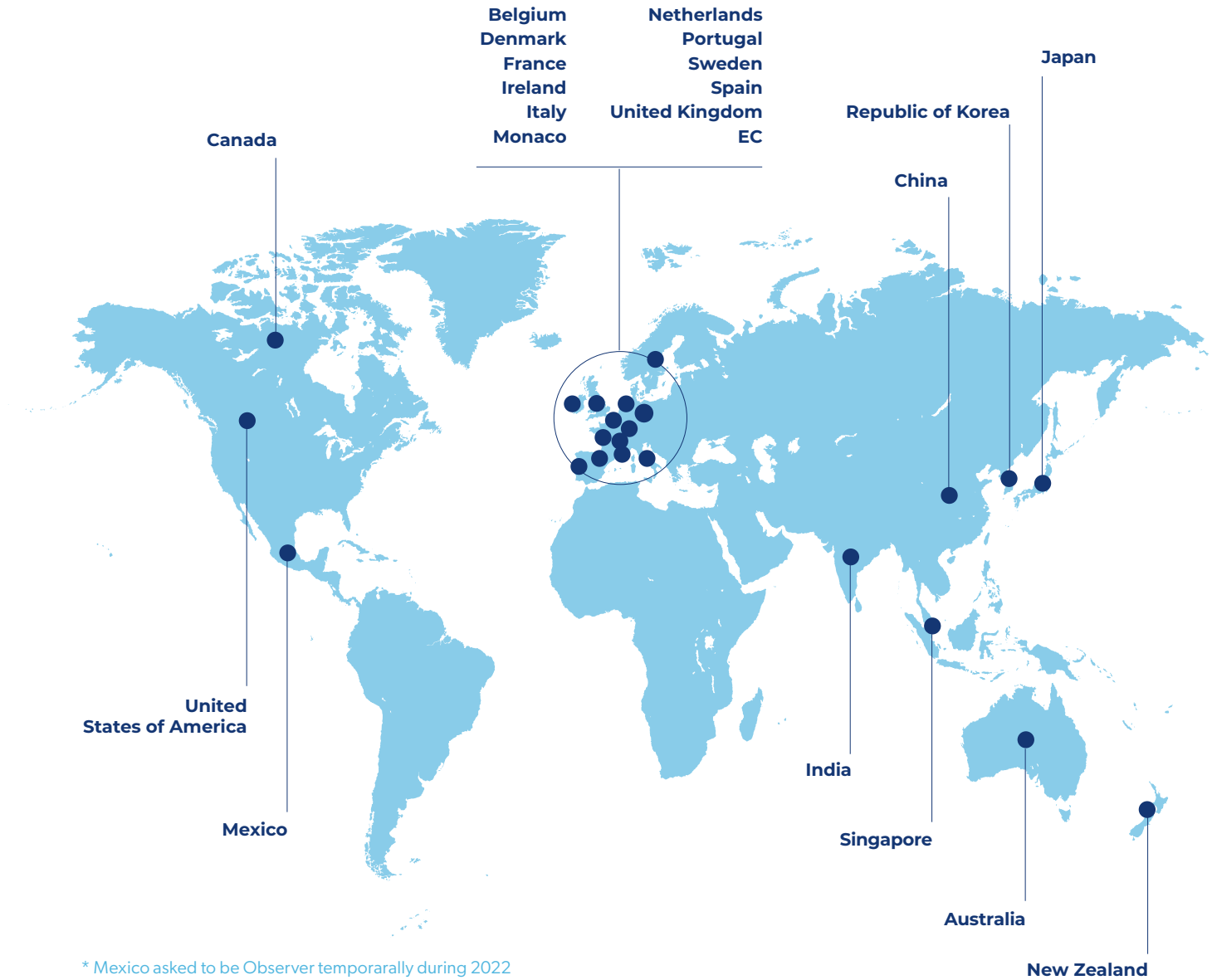
Objective 4 — Enhance cooperation with stakeholders and international organizations to share expertise and pool resources

- Expand interaction with research and industry in specific OES tasks.
- Increase cooperation with other TCPs to identify opportunities for knowledge transfer and joint tasks: address synergies, gaps and cross-cutting issues.
- Collaborate with international organizations, in particular, the International Renewable Energy Agency (IRENA), the World Ocean Council (WOC), the International Standards on Ocean Energy (IEC TC114), and support other multilateral initiatives engaged with ocean energy technologies such as International Network of Ocean Renewable Energy (INORE) a network of young researchers whose main focus is on offshore renewables.
- Continue to lead and host the International Conference for Ocean Energy (ICOE) series.

Membership

The International Energy Agency (IEA) Technology Collaboration Programme on Ocean Energy Systems (OES) was initiated by three countries in 2001 and has been growing steadily. As of December 2024, 22 Member Countries and the European Commission are members of the OES.

National governments appoint a Contracting Party to represent the country in the Executive Committee (ExCo). The Contracting Party can be a government ministry or agency, a research institute or university, an industry association or even a private company. Governments also nominate alternates, who may represent the government at ExCo meetings, if the nominated representative is unavailable. Consequently, there is a diversified representation of interests in the ExCo, which is seen as a key strength of the organization.



* Mexico asked to be Observer temporarally during 2022

CONTRACTING PARTIES

Year of signature	Country	Contracting Party
2001	Portugal	Instituto Superior Técnico (IST)
	Denmark	Ministry of Transport and Energy, Danish Energy Authority
	United Kingdom	Department of Energy and Climate Change (DECC)
2002	Japan	Saga University
	Ireland	Sustainable Energy Authority of Ireland (SEAI)
2003	Canada	Natural Resources Canada
2005	United States of America	United States Department of Energy (DOE)
2006	Belgium	Federal Public Service Economy
2007	Germany	The Government of the Federal Republic of Germany (non-active)
	Mexico	The Government of Mexico (non-active)
2008	Spain	BiMEP
	Italy	Gestore dei Servizi Energetici (GSE)
	New Zealand	Aotearoa Wave and Tidal Energy Association (AWATEA)
	Sweden	Swedish Energy Agency
2010	Republic of Korea	Ministry of Oceans and Fisheries
2011	China	National Ocean Technology Centre (NOTC)
2013	Monaco	Government of the Principality of Monaco
2014	Singapore	Nanyang Technological University
	The Netherlands	Netherlands Enterprise Agency
2016	India	National Ocean Technology Institute (NIOT)
	France	IFREMER
	European Commission	European Commission
2018	Australia	Commonwealth Scientific and Industrial Research Organisation (CSIRO)

50th ExCo Meeting, 17 October 2024, Melbourne, Australia

Executive Committee

The IEA-OES work programme is managed by an Executive Committee (ExCo), which is responsible for overseeing ongoing projects and identifying new strategic areas for collaborative research. The ExCo comprises representatives from each participating country or organization, with a list of members provided in Appendix 1. The committee meets biannually to make decisions on management and discuss implementation aspects of the work programme.

To support general administrative and communication matters, all Contracting Parties contribute annually to the OES Common Fund. This fund may also be used to facilitate coordination of ongoing R&D projects, launch new initiatives, organize workshops on prioritized topics, and commission studies or reports. However, it does not cover the costs of direct R&D activities; research should be funded by participants involved in a specific task. The annual membership fee is €7000.

The day-to-day decision-making to implement the annual Work Programme is managed by the Cabinet formed by:

- Chair: Matthijs Soede, European Commission
- Vice-Chair: Purnima Jalihal, India
- Vice-Chair: Christophe Gaudin, Australia
- Vice-Chair: Tim Ramsey, USA
- Secretary: Ana Brito Melo, Portugal

The ExCo Secretariat, managed by WavEC Offshore Renewables, is located in Lisbon, Portugal.

In 2024, the following ExCo meetings occurred:

- The 49th ExCo meeting was held virtually in two separate sessions on March 20-21, 2024, with 19 participants.
- The 50th ExCo meeting was held in Melbourne, Australia, on October 15-16, attended by 20 participants, and was followed by the ICOE 2024.
- Additionally, an extraordinary virtual meeting on June 18 with 18 attendees was held to approve the transfer of the Common Fund from WavEC to NREL, making NREL the new account holder while WavEC continued to manage the secretariat and communications.

Work Programme

The collaborative research work carried out by the OES is organized into specific projects using two distinct approaches:

- **Large Projects:** These are conducted by a group of countries interested in a particular topic, with only participants in the project contributing. When three or more contracting parties support a proposal and sufficient funding is raised, a new research project can be initiated. One of the proposing parties typically becomes the Operating Agent, responsible for managing the project and its budget. Participation by ExCo members is voluntary, and is typically based on cost-sharing, task-sharing, or both—this is the "Bottom-Up" approach.
- **Small Projects:** These projects are of interest to all members and are usually funded by the Common Fund, ensuring equal contribution from all members. Typically, an interested volunteer member prepares the Terms of Reference for any proposed task. Delegates are then invited to bid for participation, and applications are evaluated by a sub-committee of 3-4 voluntary ExCo members. The work is carried out by a group of members through cost- and task-sharing, and may also include external experts - this represents the "Top-Down" approach.

At present, the following projects have been initiated by the IEA-OES Executive Committee:

WORK PROGRAMME

Task No.	Title	Lead by	Status
1	Review, Exchange and Dissemination of Information on Ocean Energy Systems	Portugal	Active
2	Development of Recommended Practices for Testing and Evaluating Ocean Energy Systems	Denmark	Completed
3	Integration of Ocean Energy Plants into Distribution and Transmission Electrical Grids	Canada	Completed
4	Assessment of Environmental Effects and Monitoring Efforts for Ocean Wave, Tidal and Current Energy Systems	United States	Active
5	The Exchange and Assessment of Ocean Energy Device Project Information and Experience	United States	Completed
6	Worldwide Web GIS Database for Ocean Energy	United States	Active
7	Cost of Energy Assessment for Wave, Tidal, and OTEC at an International Level	UK	Completed
8	Consenting Processes for Ocean Energy on Member Countries	The Cabinet	Active
9	International Ocean Energy Technology Roadmap	UK	Active

10	Wave Energy Converters Modelling Verification and Validation	Denmark	Active
11	OTEC Development	India	Active
12	Stage Gate Metrics International Framework for Ocean Energy	European Commission	Active
13	Tidal Energy Converters Modelling Verification and Validation	Singapore	Active
14	Ocean Energy Jobs Creation: Methodological Study and First Global Assessment	France	Completed
15	Alternative Markets on Ocean Energy	The Cabinet	Active

OES has an internal prioritisation process for the selection of activities, which includes the analysis of the following points: how it fits with the OES Strategic Plan, the impact in Member Countries, the impact of the work and the relevance of the work being done by the OES. In many cases, before initiating a new project, the OES supports the organisation of workshops on a specific topic as a way to discuss the role that OES can play, as well as the format of the collaborative work.

The following tasks have been discussed by the delegates and it was suggested to be explored for global efforts:

- Co-location of ocean energy technologies
- Digitalization
- Storage and Microgrids
- Carbon Dioxide Removal
- Dispatchability of Ocean Energy
- Green Hydrogen and Tidal Current Energy

Participation in IEA Meetings

The **IEA Governing Board** holds the governance of the International Energy Agency (IEA). It is supported by several Standing Committees that are made up of member country government officials.

The **Committee on Energy Research and Technology (CERT)** coordinates and promotes the development, demonstration and deployment of technologies to meet challenges within the energy sector. The CERT has established four working parties:

- the Working Party on Fossil Energy;
- the Working Party on Renewable Energy Technologies;
- the Working Party on Energy End-Use Technologies;
- the Fusion Power Co-ordinating Committee.

The IEA-OES is part of the Working Party on Renewable Energy Technologies (REWP). In 2024, IEA-OES participated in two IEA REWP meetings:

- 85th REWP meeting, hybrid meeting format, 11-12 April, 2024
- 86th REWP meeting, hybrid meeting format, 9-10 October, 2024

02 COMMUNICATION AND DISSEMINATION

IEA-OES has an ongoing task dedicated to collate, review and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of ocean energy systems. This task focus on the development of quality information products and effective communication mechanisms in support of the OES strategy. It further aims to provide adequate and accurate information to policy makers and other stakeholders.

Wavepiston at the Plataforma Oceánica de Canarias (PLOCAN) test site @ Wavepiston

Overview in 2024

January

February

Report
Annual Report 2023

March

Report
Ocean Thermal Energy Conversion (OTEC) Economics: Updates and Strategies

Meeting
49 OES ExCo

April

Meeting
IEA REWP85

May

Video
"International Roadmap for Ocean Energy"

Webinar
Ocean Energy Outlook: Sweden, The Netherlands and Italy

June

Brochure
Spotlight on Ocean Energy Projects

July

Event participation
OECD Initiative on Global Value Chains, Production Transformation and Development

August

September

Reports
Self-Sustained Desalination Technologies Powered by Ocean Energy

OES-Environmental State of Science

International Conference
ICOE 2024

Meeting
50 ExCo

October

Report
OES TASK 10 - Numerical Modelling WEC

Webinar
IEA-OES Evaluation and Guidance Framework

Meeting
IEA REWP86

November

Event participation
International Waters Workshop

December

Report
ICOE 2024 Key Takeaways

IEA-OES has an ongoing task dedicated to collate, review and facilitate the exchange and dissemination of information on the technical, economic, environmental and social aspects of ocean energy systems. This task focus on the development of quality information products and effective communication mechanisms in support of the OES strategy. It further aims to provide adequate and accurate information to policy makers and other stakeholders. In this respect, the following main communication channels are used throughout the year:

- **Website** www.ocean-energy-systems.org: Serves as the primary source of communicating the activities of OES, publications and outputs of each task. It includes a restricted area for the ExCo delegates with pre-meeting materials and a repository of meeting presentations.
- **Social media:** To enhance visibility, OES actively shares updates through LinkedIn and Twitter.
- **Video:** Overview of the International Roadmap for Ocean Energy.
- **Annual Report:** This flagship document of IEA-OES marks industry developments and details national activities from member countries.
- **Project Spotlights:** Showcases a wide array of ocean energy projects and key policy initiatives.
- **Stakeholder Interviews:** The 2024 focus was on "Key Takeaways from ICOE 2024".
- **Technical Publications:** Releases several publications annually, highlighting the outcomes of various tasks and promoting ocean energy activities.
- **Webinars:** Several webinars were organized within the scope of the Tasks.
- **Participation in Events:** the delegates usually collaborate with international events promoting OES.

OES Webinar

MAY 23, 2024

Webinar on Ocean Energy Outlook: Sweden, The Netherlands and Italy

Moderated by:

Matthijs Soede, Senior Policy Officer at European Commission & Chairman of IEA-OES

Speakers:

Marit Stromberg, OES Delegate to Sweden, Swedish Energy Agency

Sjoerd Dijk, OES Delegate to The Netherlands, Netherlands Enterprise Agency

Luca Benedetti, OES Delegate to Italy, Gestore dei Servizi Energetici

Links to the presentation slides from these webinars can be found on the IEA-OES website page:
https://www.ocean-energy-systems.org/news-events/webinars/

Participation in Events

19 SEPTEMBER 2024, UNCC, BANGKOK

Regional Dialogue on Ocean-Based Climate Action

This event was organized by the Economic and Social Commission for Asia and the Pacific (ESCAP) and co-hosted by the Governments of Indonesia, Fiji, the Maldives, under the framework of a joint contri-

bution to the United Nations Decade of Ocean Science for Sustainable Development. OES participated online and gave a presentation of the International Vision for Ocean Energy by 2050.

3-4 JULY 2024, TERCEIRA ISLAND, AZORES

OECD Initiative on Global Value Chains, Production Transformation and Development

The Initiative is a global platform for policy dialogue and knowledge-sharing between countries from Africa, Asia, Europe and the Americas. It aims at improving evidence and at identifying policy guidelines to support production transformation and sustainable and inclusive participation to local, regional and global markets. OES was invited to attend the 22nd Plenary Meeting Session of the Organisation for Economic Cooperation and Development (OECD) to present the ocean energy technology development status.

Spotligth on 20 Projects

Selection of 20 representative projects exemplifying the diverse range of ocean energy resources and innovative advancements driving the growth of this promising sector, as well as 10 key policy initiatives to illustrate the commitment of governments worldwide.

International Conference on Ocean Energy ICOE 2024

The International Conference on Ocean Energy (ICOE) holds a prominent position as the flagship event of the IEA-OES.

IEA-OES maintains a close and integral relationship with ICOE since its inception in 2006. ICOE conferences, occurring biennially, center on the industrial development of ocean energy. The International Steering Committee of ICOE includes the Chairman of the OES and several Delegates. OES provides the historical archive of previous conferences. In 2024, this conference was held in Melbourne, Australia from September 17-19 and was sponsored by IEA-OES.

A notable aspect of the collaboration with ICOE is the IEA-OES's responsibility for the selection of the host country. This responsibility reflects a commitment to the success of ICOE.


ICOE
INTERNATIONAL CONFERENCE ON OCEAN ENERGY
MELBOURNE 2024
THE WORLD'S OCEAN LEADING ENERGY EVENT IS COMING DOWN UNDER
17th – 19th September, 2024
Melbourne, Australia
2024 INTERNATIONAL CONFERENCE ON OCEAN ENERGY
BROUGHT TO YOU BY
BLUE ECONOMY
COOPERATIVE RESEARCH CENTRE
Australian Government
Department of Industry, Science, Energy and Resources
AusIndustry
Cooperative Research Centres Program


MELBOURNE 2024


#ICOE2024


ENERGY

Key Takeaways ICOE 2024

OES released a report "Key Takeaways from ICOE 2024" offering a concise summary of key themes, such as technological innovation, policy development, and environmental impact. The report includes perspectives from attendees of ICOE 2024, providing unique perspectives, adding depth to the report. Notable highlights in the report include the release of the OES-Environmental 2024 State of the Science Report and a celebration of the IEA-OES Poster Award winners, with significant research contributions to the field.

Collaboration with International Initiatives

OES promotes international collaboration fostering and enhancing the development and sustainable use of ocean energy, with a number of organisations. **The following collaborative initiatives in 2024 are highlighted:**

The **IEA Wind TCP** is a technology collaboration program within the International Energy Agency, facilitating the exchange of information and research activities to propel the deployment of wind energy. Recognizing parallels between the challenges encountered in ocean energy adoption and those faced by offshore wind, such as cost competitiveness, grid integration, establishing a dedicated supply chain, and navigating hostile marine environments, OES is actively working towards collaboration with the Wind TCP. This collaborative effort is set to persist in 2025.

SIDS DOCK is a United Nations (UN)-recognised international organisation established in 2015, addressing climate change, resilience, and energy security in small islands. SIDS DOCK represents 32 small islands and low-lying developing states across the globe. It is so named because it is designed as a "DOCKing station," to connect the energy sector in SIDS with the global markets for finance and sustainable energy technologies. SIDS Dock is Observer of the OES.

INORE is a network of young researchers in renewable energy with a primary focus on offshore renewables. It was established by early-stage researchers for those engaged in various aspects related to offshore wind, wave, tidal, and other offshore energies. INORE facilitates collaboration and knowledge sharing among researchers worldwide.

OES consistently supports INORE activities annually, particularly those proposed by INORE involving the organization of seminars. This ongoing collaboration highlights OES's dedication to fostering the initiatives of young researchers in ocean energy. In 2024, OES sponsored the European and North America Symposia organized by INORE.

International Waters Workhop, FORCE, Canada, November 2024

The **International WATERS (Wave and Tidal Energy Research Sites) Network** was set up in 2013 by the European Marine Energy Centre (EMEC) and provides a forum for open sea tests in the marine energy space to discuss common challenges, explore collaboration opportunities and reduce duplication of efforts and resources.

In 2024, the Fundy Ocean Research Centre for Energy (FORCE), in collaboration with EMEC, hosted a workshop focused on consenting and regulatory issues, bringing the network together to discuss challenges, gaps, and opportunities in this critical area. The OES participated in this workshop and is seeking to support this network, recognizing the importance of streamlined regulatory frameworks and enhanced collaboration to facilitate the growth and deployment of ocean energy technologies.

IEA-OES has a formal liaison with the **International Electrotechnical Commission (IEC) Technical Committee (TC) 114, Marine Energy – Wave and Tidal Energy Converters**. IEC-TC 114 aims to develop international standards for wave and tidal energy technologies. Dr Purnima Jalihal, Delegate from India, has been nominated as the expert to coordinate, in particular, the collaboration with the working group "PT 62600-20 - General guidance for design and analysis of an Ocean Thermal Energy Conversion (OTEC) plant", on behalf of the OES. Further, a number of ExCo members serve as project leaders or participants in some of the TC114 working groups, providing technical information for future standards.

The European funded project, **SEETIP Ocean**, supports the activities of both the European Technology & Innovation Platform for ocean energy (ETIP Ocean) and the Secretariat to the SET Plan Ocean Energy Implementation Working Group (OceanSET). The project brings individuals and organisations together to exchange knowledge, create new knowledge and build more and deeper connections on the oceean energy sector. It aims to enhance cooperation and collaboration amongst stakeholders both inside and outside of the European ocean energy sector. OES collaborates with these initiatives on information and data sharing.

03 KEY TASK ACHIEVEMENTS

Deployment of the Sub-Hub tidal platform from Southampton to Langstone Harbour © QEDnaval

OES-ENVIRONMENTAL

COORDINATOR

Samantha Eaves, US Department of Energy (DOE)/Allegheny Science & Technology

PARTNERS

Bureau of Ocean Energy Management (US)
National Oceanic and Atmospheric Administration (US)

TECHNICAL CONSULTANTS

Andrea Copping and Lysel Garavelli,
Pacific Northwest National Laboratory

PROJECT DURATION

Phase I: 2010 - 2013
Phase II: 2013 - 2016
Phase III: 2016 - 2020
Phase IV: 2021 - 2024
Phase V: 2025 - 2028

Introduction

Phase 4 of OES-Environmental concluded in September 2024. Phase 5 of OES-Environmental was authorized in September 2024 by the Ocean Energy Systems (OES) Executive Committee, officially started in October 2024, and will continue through 2028.

The major accomplishments of OES-Environmental during 2024 included:

- Publishing the *2024 State of the Science* Report on environmental effects of marine renewable energy (MRE), holding a webinar to discuss the release, and planning a robust outreach plan for the contents of the document.
- Expanding the knowledge base on the environmental effects of MRE for MRE community through ongoing information collection and curation of the scientific literature that is stored and made accessible through Tethys.
- Using Tethys as the platform to collect, curate, and disseminate data and information collected on marine energy developments and research projects including the OES-Environmental "metadata forms".
- Continued work on the risk retirement process that included preparation and dissemination of countries' guidance documents.
- Active dissemination of information on risk retirement and associated processes for regulators and developers to assist with consenting, including addressing the need for baseline data collection and post-installation monitoring, with a particular emphasis on collision risk for tidal turbines.
- Examination of questions surrounding system-wide effects of MRE such as effects of scaling up from single devices to arrays, cumulative effects of MRE, ecosystem effects of MRE, and displacement of marine animals.
- Assessing the information available on the environmental effects of MRE in tropical and subtropical ecosystems, as represented by the OES nations.
- Continuing outreach and engagement to the MRE community through workshops, webinars, conferences, and online materials with particular emphasis on researchers, regulators, advisors, and MRE device developers.

Sixteen nations participated in Phase 4 of OES-Environmental: Australia, Canada, China, Denmark, France, India, Ireland, Japan, Mexico, Monaco, Portugal, Singapore, Spain, Sweden, the United Kingdom, and the United States (US). The US continues to lead the initiative, with Pacific Northwest National Laboratory (PNNL), one of the Department of Energy's national laboratories, serving as the Operating Agent and implementing the project. Sixteen nations are currently participating in Phase 5 activities: Australia, Canada, China, Denmark, France, India, Ireland, Japan, Mexico, Portugal, Singapore, Spain, South Korea, Sweden, the United Kingdom, and the United States.

2024 State of the Science Report

Throughout 2024, researching, writing, and publishing the *2024 State of the Science* Report has been the major focus of OES-Environmental. The "*2024 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World*" was released in September 2024 at the International Conference of Ocean Energy (ICOE) 2024 in Melbourne, Australia, during a keynote and two presentations. The report is over 300 pages long and includes 11 chapters written by 38 authors and contributors. Over 1000 comments from the public and 55 international scientists and engineers from 12 countries were incorporated into the final document before publication. The report, the executive summary, each individual chapter, and the supplementary material are all available on Tethys. The executive summary is available in eight languages: Chinese, English, French, Japanese, Portuguese, Norwegian, Spanish, and Swedish. Short science summaries for some of the *2024 State of the Science* Report chapters and sections were also prepared during 2024 and are also available for download on Tethys. The publication of the *2024 State of the Science* Report was announced to the MRE community through direct emails and in several Tethys Blasts (Tethys biweekly newsletter), newsletters from other organizations, and postings on Tethys social media. A webinar focusing on the release of the *2024 State of the Science* Report was held on 2 October 2024, bringing together 151 people online to hear the key findings from the report. Over 400 people registered for the webinar. The webinar is archived on Tethys and the recording has been viewed over 200 times since the event.

In 2024, an outreach plan was developed to share the findings of the *2024 State of the Science* Report to increase the visibility and reach of the report to existing and broader audiences The outreach campaign will be implemented in 2025 and will be accomplished by communicating findings and information on environmental effects of MRE from the report, developing associated products and materials, and conducting targeted outreach to various audiences. Key audience groups that will be targeted include existing audiences (MRE regulators, advisors, developers, researchers), STEM (Science, Technology, Engineering, and Mathematics) students (kindergarten through graduate school) and teachers, and the general public.

Working with OES-Environmental Analysts

During 2024, PNNL continued to organize and lead meetings with the OES-Environmental country analysts to coordinate cooperative work, approximately every 3 months. These meetings aim to discuss current OES-Environmental activities, receive input and feedback from OES-Environmental country analysts on these activities, and provide an opportunity to learn about current MRE development in each country. Each country analyst is asked to present updates on MRE development and environmental research in her/his respective countries and regions once every two years.

As part of their work with OES-Environmental, each nation's analyst continually shares information within their country, including introducing Tethys, gathering content for Tethys, and providing contacts with organizations in their country to identify relevant monitoring, data collection, research funding, and implementation activities. These activities set each analyst up as the ambassador for OES-Environmental within her/his country. The OES-Environmental analysts continue to engage their nation's regulators through a one-time survey to determine regulator understanding, information needs, and challenges, and to present the risk retirement and data transferability processes. The analysts also reach out to colleagues in their respective fields to initiate investigations into key areas of environmental effects that will assist the MRE industry.

During 2024, the country analysts were also heavily involved in the development and review of the *2024 State of the Science Report*, and several analysts served as chapter authors, contributors, and peer reviewers. Following the publication of the report, the country analysts provided translations of the executive summary into the language of their nation (other than English).

Risk Retirement

During 2024, OES-Environmental continued to update country-specific guidance documents on Tethys. These documents are intended to support regulators and advisors in their decision making during the permitting process and by consultants and developers as they prepare applications for permits and licenses. Country-specific guidance documents were completed and published on Tethys in 2024 for Ireland, Australia, Portugal, Mexico, Canada, and Denmark.

Metadata on MRE Projects and Research Studies

During 2024, OES-Environmental, with support from Aquatera Limited and help from country analysts, continued to collect and update information on new wave, tidal, and other MRE technology projects, as well as ongoing research studies, stored as metadata forms on Tethys. Existing metadata forms are updated annually by working with the country analysts, developers, and researchers. As of December 16, 2024, there are 208 metadata forms – 147 project sites and 61 research studies on Tethys. Of the 208 forms, 135 no longer require updates – 82 project sites and 52 research studies (projects were completed, never deployed, no longer in the water, or canceled; research studies were completed). In 2024, 45 forms were updated. The metadata forms continue to feed the Monitoring Datasets Discoverability Matrix, an interactive tool that classifies monitoring datasets from already permitted/consented projects, analogous industries, and research studies, for six key environmental stressors. The forms are highlighted in the Management Measures Tool, OES-Environmental's online tool to find management or mitigation measures used in past or current MRE projects.

Dissemination of Information on Environmental Effects

Ongoing work to collect, curate, and make accessible existing information on MRE environmental effects for Tethys continues to expand the platform and reach ever-growing audiences. Tethys supports OES-Environmental outreach, engagement, and dissemination by hosting materials on the public OES-Environmental page, hosting various tools and educational resources for users, and sharing announcements in the Tethys Blast. There are currently 4,373 documents that address environmental effects of MRE available on Tethys and the Tethys Blast is sent to the broad MRE community of more than 3,000 individuals.

Outreach and Engagement

OES-Environmental coordinated various opportunities to engage with students. In February 2024 an online Marine Energy Career Panel was hosted consisting of three panelists from PNNL, three panelists from National Renewable Energy Laboratory, and one panelist from Sandia National Laboratories. Panelists discussed their background, education, career path, and current work. There were 65 participants in attendance.

An in-person career panel was held at the Pan-American Marine Energy Conference (PAMEC) in February 2024 in Barranquilla, Colombia, with panelists consisting of national laboratory staff, MRE developers, test center staff, and researchers. Panelists discussed their background, education, career path, and current work. There were about 40 participants in attendance.

Workshops

OES-Environmental hosted, co-hosted, or supported four workshops during 2024 bringing together experts to further understand key interactions and to work towards consensus on how research and monitoring information can inform consenting processes, and accelerate deployments for the MRE industry:

- An in-person and online workshop brought together over 30 people at PAMEC in Barranquilla, Colombia, in January 2024 to discuss monitoring interactions between marine animals and MRE devices, environmental monitoring technologies and approaches, and how monitoring can be a part of MRE sector growth.
- An in-person workshop with 25 people at the 2024 Environmental Interactions of Marine Renewables (EIMR) Conference focused on modeling fish interactions with tidal turbines and included breakout groups to discuss model suitability, data collection knowledge gaps, and methods for informing future models.
- An in-person workshop with 22 people at ICOE 2024 on the environmental effects of permitting MRE off-grid applications with breakout groups discussing MRE off-grid use cases.
- An in-person workshop with 34 people at the 2024 Ocean Energy Europe Conference on the environmental effects of MRE, with a special focus on collision risk and underwater noise.

Conferences and Papers

During 2024, the OES-Environmental team presented their research through presentations, posters, and workshops at six conferences. The conferences and each contribution from the team are detailed in Table 1.

TABLE 1. CONFERENCES IN WHICH OES-ENVIRONMENTAL PRESENTED DURING 2024

Conference	Date and Location	Contributions
Pan-American Marine Energy Conference (PAMEC)	22-24 January 2024 Barranquilla, Colombia	**Presentations:** • Environmental effects of marine renewable energy in tropical and subtropical ecosystems • Assessing social and economic effects of marine energy: Tools and recommendations • From science to consenting: Environmental effects of marine renewable energy **Posters:** • From science to consenting: Applying environmental effects information to support regulatory decision-making • Investigating displacement of marine animals as a potential effect of marine renewable energy development • Update on Ocean Energy Systems-Environmental • Tethys: Knowledge hub on the environmental effects of wind and marine renewable energy **Workshop:** Marine energy career panel
Environmental Interactions of Marine Renewables (EIMR) Conference	15-19 April 2024 Orkney, Scotland	**Presentations:** • Collision risk of animals with marine renewable energy devices • Animal displacement from marine energy development: mechanisms and consequences • Recent advances in assessing environmental effects of marine renewable energy around the world • Tethys: An international knowledge hub on the environmental effects of marine renewables **Workshop:** Modeling fish interactions with tidal turbines
Offshore Renewable Energy Conference (OREC)	20-23 May 2024 Portland, Oregon, US	**Invited keynote presentation:** The role of environmental effects research in moving the industry forward

Marine Energy Technology Symposium + University Marine Energy Research Community (METS/UMERC)	7-9 August 2024 Duluth, Minnesota, US	**Posters:** • Status of environmental monitoring at marine energy projects around the world • Tethys: Knowledge hub on the environmental effects of marine energy • Update on Ocean Energy Systems-Environmental
International Conference on Ocean Energy (ICOE)	17-19 September 2024 Melbourne, Australia	**Invited Keynote:** Moving forward with marine renewable energy: but what about the environment? **Presentations:** • Social and economic effects of marine renewable energy • Successes and lessons learned from environmental monitoring at marine renewable energy sites around the world **Poster:** Tethys & OES-Environmental: Improving understanding of ocean energy's environmental effects **Workshop:** Environmental effects of permitting for marine renewable energy off-grid applications
Ocean Energy Europe (OEE) Conference	5-6 November 2024 Orkney, Scotland	**Workshop:** Environmental effects of marine renewable energy – collision risk and underwater noise

In addition, the OES-Environmental team published two journal articles in 2024:

- Hemery et al. (2024): "Animal displacement from marine energy development: Mechanisms and consequences" establishes a definition of displacement of marine animals in the MRE context and was published in Science of the Total Environment.
- Copping et al. (2024): "Recent advances in assessing environmental effects of marine renewable energy around the world" describes the findings from a metadata review of renewable energy projects around the world and was published in the Marine Technology Society Journal.

PERFORMANCE METRICS INTERNATIONAL FRAMEWORK FOR OCEAN ENERGY

TEAM

Led by the European Commission and delivered by Wave Energy Scotland (WES)

Introduction

A more rigorous technical review approach for the ocean energy sector has been recognised to be important at this stage, making use of improved evaluation methods and metrics that are currently applied in due diligence review and evaluation of ocean energy technologies. Considering the experience and lessons learned for more than two decades of ocean energy technology and market development, detailed monitoring of progress and success should have the following characteristics:

- Need to differentiate among the various needs of the development stages from R&D, Prototype, Demonstration, to Pre-Commercial and Industrial Roll-out;
- Need to define specific criteria to each development stage;
- A connection must be made between the performance criteria and the availability of certain types of support in the form of public and private funding;
- The process should use continued feasibility checks on the OE technology potential with an increasing focus on LCOE as the technology matures.

After an initial period of focusing on the technological feasibility where the only metric used was the successful technology evolution to higher TRL levels, economics and other social acceptance criteria have been identified to be considered at an early development stage for ocean energy technology.

Objectives

Task 12 - Stage Gate Metrics International Framework for Ocean Energy was initiated in 2017, as part of an ongoing collaboration to gain international consensus on a Technology Evaluation Framework to be used in ocean energy technology development programmes to objectively measure key, targeted areas and facilitate decision-making.

The main objectives to initiate this Task were:

- Build international consensus on ocean energy technology evaluation;
- Guide appropriate and robust activities throughout the technology development process;
- Share knowledge and promote collaboration;
- Support decision making associated with technology evaluation and funding allocation.

Consensus on technology evaluation and technology development activities will bring significant benefits for various stakeholders in the ocean energy sectors:

- Clarity in the expectations from different stakeholders during each stage of development, bringing clearer communication;
- Consistency in the use of terminology, and the process to evaluate technology, ensuring a level playing field;
- Stakeholders working together to build confidence and transparency in the sector;
- Efficient decision-making processes promoting direction of funding to the technologies with highest chances of commercial success;
- Technology development process consistent across the world, leading to more international collaboration more globally transferrable technology.

The group expected to be instrumental in driving wider uptake of the Framework is the public funders, whose application of the recommendations in public funding schemes would automatically drive uptake by applicant

technology developers. However, to ensure this alignment between funders and developers, and to achieve a seamless transfer of technology developers from public funding schemes to compliance with standards, certification and the expectations of private investors, engagement with all users will be required.

Therefore, the ExCo approved in 2021 the continuation of this Task, proposing the following objectives:

- To bring this framework to a stronger foundation of user acceptance, primarily with public funders and subsequently other users, achieving sufficient consensus and international adoption to warrant further developments;
- To identify, prioritise and deliver further developments and more detailed integration with other sector guidance;
- To develop the concept of a 'Technology Passport' - An internationally common development process and data package to facilitate simplified transfer of developers and technologies between national funding schemes and subsequently to private investors.

Achievements

The objectives of the Task were successfully achieved in 2024. Throughout the year, engaging discussions, webinars, and collaborative efforts contributed to the dissemination and refinement of the framework. The following reports have contributed in enhancing the understanding and application of performance metrics across the ocean energy sector. Additionally, concerted efforts were made to promote the framework, increasing its adoption and impact within the global ocean energy community.

WAVE ENERGY CONVERTERS MODELLING

COORDINATOR

Dr. Kim Nielsen, Development v Kim Nielsen, Denmark

PARTICIPATING COUNTRIES

Canada, China, Denmark, France, Ireland, Republic of Korea, The Netherlands, Belgium, Portugal, Spain, Sweden, UK, and the USA

Objective

The numerical modelling task on Wave Energy Converters (OES Task 10) was initiated in 2016 by experts from 13 countries with the objective to improve confidence in the prediction of power production from Wave Energy Converters using numerical tools.

The project focuses on numerical modelling of wave energy converters, to verify and validate the design and power production calculations, with the following long-term goals:

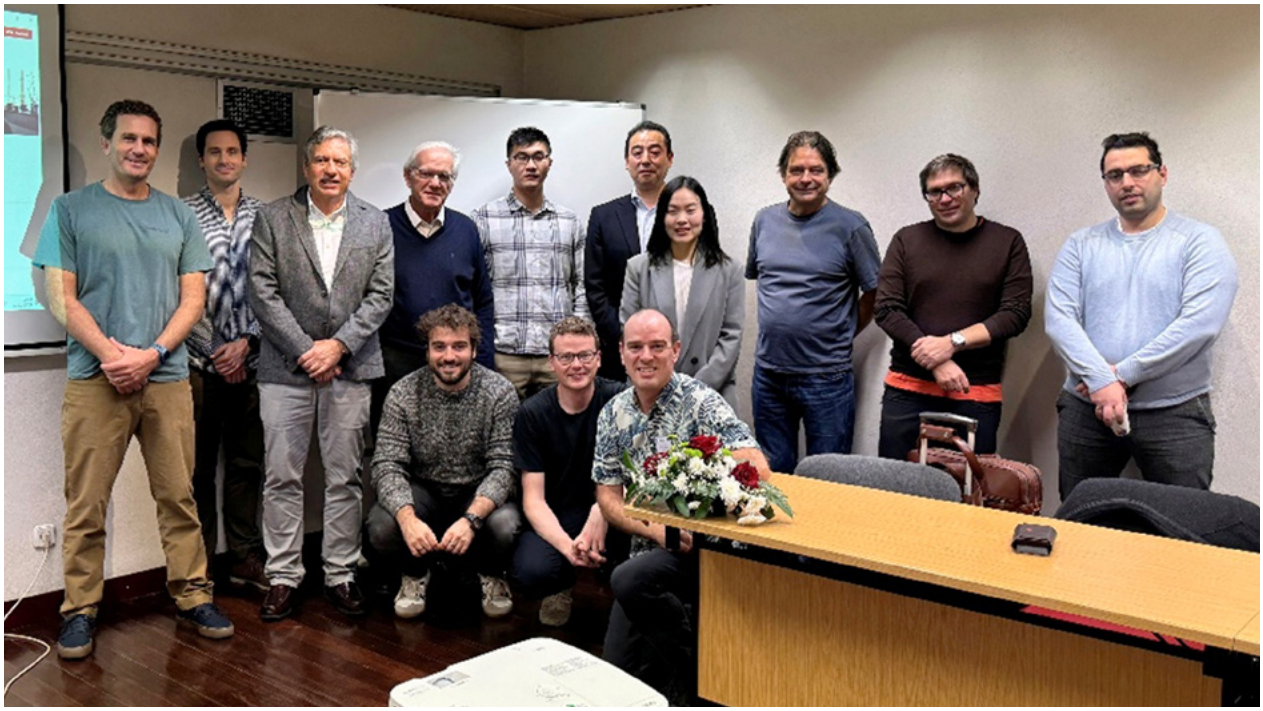
- To establish confidence in the use of numerical models.
- To identify uncertainties related to simulation methodologies.
- To establish well-validated standards for evaluating wave energy converters concepts.

Achievements in 2024

During 2024, the Danish partners made progress with support from the EUDP, coordinated by Aalborg University (Morten Kramer). The TEAMER program in the USA supported specific high-fidelity modeling (SPH and CFD) carried out by NREL and Sandia. Modeling continues to focus on two tracks: the "OWC case" and the "Sphere case," attracting participants with different interests and numerical tools.

Mid-2024, a high-quality OES report on numerical modeling of WECs was published, describing the efforts and methodology undertaken in the project and including some generic reference examples.

The OES Task 10 group was given a special session at the RENEW conference in October 2024 on the verification and validation of numerical models for WECs, where four papers were presented. Following the con-



OES Task 10 meeting in Lisbon, Portugal, November 2024

ference, a half-day face-to-face meeting was arranged to discuss the road ahead based on the experience gained.

The TEAMER funding for NREL and Sandia to perform specific CFD calculations using OpenFOAM and Dual SPHysics contributing to the sphere case simulations under OES Task 10 was completed in October 2024. The TEAMER project was coordinated in collaboration with the OES Task 10 partners interested in CFD simulations and results were presented at the RENEW conference 2024.

OWC case study: In 2024, the numerical simulation of the DTU OWC small-scale model test continued. This test case, prepared in 2021, featured a single OWC chamber placed on the sidewall of a 0.6-meter-wide wave flume. Progress has been made on the numerical simulation of these challenging valve cases, and results have been compiled in a paper submitted to the Journal of Ocean Engineering and Marine Energy.

Sphere case study: Running in parallel, the development of test cases using a sphere to validate hydrodynamic loads related to radiation, diffraction, and waves generated in the basin has continued with an experimental setup at Aalborg University. To measure the radiated wave loads on the sphere, the AAU team developed a new setup with the sphere attached to an actuator to measure the radiation forces while oscillating in still water. The plan is to further develop the sphere case with validation test cases including responses in waves with different PTO settings.

Future Plans

Following the face-to-face meeting in Lisbon, a questionnaire has been circulated to the 100 active members on the OES Task 10 mailing list. This includes an option to add a third track, "Floating WEC," as a new test case resembling a generic floating WEC with a simplified mooring system. Feedback will be analyzed, and it is planned that future OES Task 10 webinars will be announced with specific topics and possibly invited speakers presenting new research.

Acknowledgement

The project was initially supported by Bob Thresher from NREL, and currently, Thanh Toan Tran is the point of support. Special thanks also to Morten Kramer and Jacob Andersen from Aalborg University, and Harry Bingham from DTU for their leadership in presenting the results in recent and upcoming journal papers. Thanks to the EUDP for their continued support of the Danish team, and to TEAMER for their support of the project. We also extend our gratitude to all who have attended and contributed their time and effort.

TIDAL ENERGY MODELLING VERIFICATION AND VALIDATION

COORDINATOR

Dr. Narasimalu Srikanth, Energy Research Institute @ NTU, Singapore

PARTICIPATING COUNTRIES

Australia, China, France, Germany, Indonesia, India, Ireland, Republic of Korea, Malaysia, Philippines, Sweden, UK and USA

Objective

The numerical modelling task on Tidal Energy was initiated in 2018 by experts with the objective to improve confidence in the prediction of power production from tidal energy using numerical tools.

The project focuses on numerical modelling of tidal energy, to develop a standard methodology for modelling in harnessing tidal energy, with the following long-term goals:

- Survey numerical modelling approach used in tidal-current based energy projects
- Verification and validation of modelling tools & methodology against specific case studies

Introduction

The extraction of tidal energy for electricity generation is gaining interest due to the large portion of Earth covered by water. Identifying suitable sites and estimating achievable energy are crucial for evaluating tidal power resources. Coastal regions with features like bays and estuaries, which create tidal current variations, are ideal for harnessing tidal energy due to their high current velocities. Models are being developed to identify such sites based on flow velocities and power density. The accuracy of these models depends on the quality of input data and the hydrodynamic phenomena they simulate, with some using 3D simulations and others using 2D depth-averaged simulations. These models help pinpoint potential sites, which can later be verified with field data.

The International Tidal Energy Working Group, part of the Ocean Energy Systems (OES) initiative by the International Energy Agency, aims to establish a standardized approach for modelling tidal energy resources. This would boost confidence among stakeholders by providing reliable data on available tidal resources. The group brings together international research teams to share methodologies and results from resource studies. The main goal is to develop a simulation guideline report on tidal energy modelling, featuring case studies, comparisons of different modelling strategies, and validation against experimental data. The re-

port will also address assumptions in models, such as seabed friction effects.

This project's main goal is to develop a standardized methodology for modelling tidal energy by studying various factors that impact tidal modelling at ocean sites, as well as the assumptions behind simulations. An international team of tidal energy researchers formed a working group to collaborate on accurately modelling tidal energy resources and establishing guidelines for reporting them.

Achievements

The Energy Research Institute @ NTU (ERI@N) in Singapore organizes and hosts teleconferenced workshops on a biannual basis. These workshops bring together experts and teams from international tidal energy research groups. Notable attendees include Dr. Jérôme Thiebot and his team from the University of Caen, France; Dr. Sam Fredrickson and his team from the University of Gothenburg, Sweden; Dr. Matt Lewis and his team from Bangor University, UK; Prof. Roger Falconer and his team from Cardiff University, UK; and many others from institutions across countries including Australia, China, India, New Zealand, Germany, Indonesia, the Philippines, South Korea, and Singapore.

Based on the discussion on the workshops, the topics that are investigated are as follows:

- Wind - Wave generation: Dominant wave types in terms of wave period/frequency and amplitude. Classification and effects of damping parameters
- Wave-current interaction and wave breaking to address the following:
  - Resultant water surface elevation
  - Resultant direction of current
  - Basis for coupling between current and waves
  - Influence on tidal energy
- Modelling of the seabed and coastline depicting the quality of the sand in terms of its constituents for addressing the friction/drag force generated over the water flow.
- Effects of salinity and temperature in resultant tidal velocity and direction both qualitatively and quantitatively.
- Coupling of ocean model with CFD models for turbine site match making
- Better methods of validating the ocean models.
- Available open source ADCP and Tide gauges data for validation of tidal models.
- Hydrodynamic impacts of tidal current generation.
- Coupled 3d tide wave ocean models to parameterize realistic conditions to inform device scale studies.
- Parametrization of tidal turbines in the ocean model.
- Estimation of firm power and highest yield of tidal turbines as part of deterministic tidal resource prediction.
- Inclusion of technoeconomic aspects and environmental effects.
- Effects of power extraction on water level, current speed and residual current.

Some of the key findings in the workshop discussions are as follows:

- Narrow channels in temperate waters showed large flow perturbations with flow changes differing between ebbing and flooding tides. During ebbing tide, the changes are limited in amplitude and remain localised within the channel. During flooding tide, the changes are more significant, especially in the vicinity of of the sites where the water passing through the site is flushed into a large and shallow basin. It can also be seen that flow perturbation can be significantly reduced using a lower density of turbines, that extracting tidal energy at one site slightly reduces the resource of the other, and that the deployment of two turbines has a negligible effect on ambient current speeds.
- Vibrational tidal exchange flow between two seas with unequal density shows that a thicker interfacial layer is formed in line with the new boundary conditions and the layer velocities and densities change more smoothly. This situation is an indication that the mixing dynamics and momentum transfer between the layers. It was also observed that upper layer flow appears to be more dynamic than that in the lower layer.

As a further work, the international working group will be working on a new case study. The International members will be asked to include the various additional parameters such as wind wave generation (as mentioned earlier) in the new case study and will be asked to simulate based on their chosen codes and with their modelling expertise for numerical comparison study. Further technical report and joint journal publications in Top tier journals will be planned.

OCEAN THERMAL ENERGY CONVERSION (OTEC)

COORDINATOR
Dr. Purnima Jalihal, NIOT, India

PARTICIPATING COUNTRIES
China, India, Japan, Korea, France and USA

Introduction

Within the Ocean Energy Systems (OES), a specialized task group dedicated to Ocean Thermal Energy Conversion (OTEC) has been formed to spearhead the dissemination and demonstration of OTEC technologies. This group is actively addressing the technological and commercial barriers that currently impede OTEC's advancement, with the goal of sharing critical information with all relevant stakeholders.

The group's efforts are conducted by two sub-groups: the first, led by China, is tasked with assessing the global potential of OTEC, while the second, led by Korea, focuses on outlining the present status and future directions of OTEC projects.

Achievements

An important achievement of this group has been the compilation of a state-of-the-art report that provides a comprehensive overview of OTEC activities and projects around the globe.

This document lays the groundwork for developing an extensive work program dedicated to this task. Following this, the 2021 publication of a **White Paper on OTEC** introduced a series of recommendations aimed at encouraging the uptake of OTEC technology.

Subsequent efforts led to the approval of a new task in 2022, concentrating on the Economics of OTEC. This initiative was born out of the recognition of a significant lack of reliable cost data, leading the Executive Committee (ExCo) to endorse a strategy for gathering data from various demonstration plants worldwide to better assess the economic viability of OTEC systems. This research was carried out over the course of 2023.

Vega Consulting and Xenesys were selected to undertake this significant task, working in collaboration to connect with the global OTEC community. Their objective has been to assess the current state of expertise within the field of OTEC. The culmination of their efforts, a comprehensive final report, was published in 2024, providing valuable insights into the economic aspects of OTEC implementation.

ALTERNATIVE MARKETS FOR OCEAN ENERGY

Background

Exploring alternative markets for ocean energy has been a key focus of our task, as evidenced by previous studies on ocean energy applications in islands, and aquaculture. In 2024, we expanded this exploration to include the desalination sector. The study conducted this year, "Ocean Energy and Desalination," marks a significant achievement. It evaluates how integrating ocean energy with desalination processes can enhance sustainability and efficiency, offering promising opportunities for both water scarcity solutions and renewable energy expansion.

Objectives

The main aim of the study on ocean energy and desalination was to provide an understanding of the potential of using ocean energy to power the desalination process. This involves developing a detailed comprehension of the ideal locations for deploying hybrid systems that combine ocean energy with desalination technology. To achieve this, the task required an exhaustive examination of existing literature, research publications, industry requirements, and relevant findings from experimental and demonstration projects.

The overall scope of this activity involved:

- Evaluate the synergy between desalination technologies and ocean energy sources, considering factors such as electricity conversion. Explore various desalination processes (e.g., membrane, thermal) and technologies (Reverse Osmosis, Electro-Dialysis, Low Temperature Flash) to determine their suitability. The assessment will guide the selection of a location-specific combination of desalination technique and ocean energy sources, considering climatic, geographical, and logistical factors.
- Document the current status and power requirements of desalination plants and ocean energy sources. Include ongoing research in IEA-OES regions, highlighting the socioeconomic impact and technological challenges associated with implementing these projects.

Achievements

In 2024, a significant achievement of this task was the publication of the report titled "**Self-Sustained Desalination Technologies Powered by Ocean Energy**". This report discusses innovative desalination methods that harness power directly from ocean energy sources.

It serves as a complement to earlier studies including "*Ocean Energy in Remote Locations*" and "Ocean Energy and Aquaculture", further enriching our exploration of alternative markets for ocean energy. Together, these reports advance the promotion of sustainable and innovative applications, illustrating the broad potential of ocean energy beyond traditional power generation.

INTERNATIONAL VISION FOR OCEAN ENERGY

TEAM
University of Edinburgh - Policy and Innovation Group
US Department of Energy – Water Power Technologies Office
Nanyang Technological University

Background

Tidal stream and wave energy sector have the potential to become a significant part of the international low-carbon energy mix, driven by advancements in research, development, and innovation.

Recognizing the sector's capacity for substantial growth, there is a compelling need for synchronized research efforts, strategic leadership, and a definitive action plan to harness this potential. While previous ambitions envisioned the development of 300 GW of tidal stream and wave energy by 2050, promising substantial employment opportunities and notable reductions in CO2 emissions, these projections now require updates. Recent progress in technological research, supply chain development, and the escalating global demand for a diverse energy portfolio underscore the urgency of revisiting and revitalizing these goals to ensure the sector's impact is maximized and effectively commercialized worldwide.

Objective

The aim of this task was to produce a renewed **"Vision and International implementation strategy for the development and deployment of Ocean Energy"**. This strategy aims to reflect the latest advancements and shifts in the global energy landscape, setting a forward-looking framework that will guide the sector towards achieving its updated potential and contributing significantly to the international energy mix.

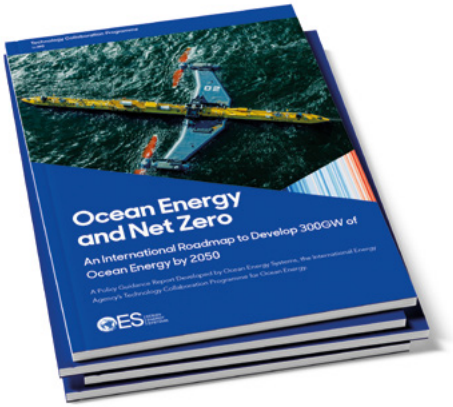
Despite the clear socio-economic benefits and Net Zero potential on offer, wave and tidal stream technologies face a number of challenges in their bid to reach commercial deployment. The high-level analysis, key results and policy recommendations contained within this IEA-OES Roadmap present a clear pathway by which these potential benefits can be realised and these challenges overcome. Harnessing the desire and momentum for a global Net Zero energy system and transforming it into proactive, visible and coordinated policy support mechanisms is the first step on this journey. It is time for the leading nations in the ocean energy sector to ensure that innovation and collaboration places the sector at the heart of the global drive for Net Zero.

Achievements

In alignment with the COP28 gathering, the IEA-OES launched its visionary publication, "Ocean Energy and Net Zero: An International Roadmap to Develop 300 GW of Ocean Energy by 2050," shortly before the conference in November 2023. This roadmap presents a detailed strategy aimed at accelerating the worldwide advancement of ocean energy, showcasing IEA-OES's commitment to shaping a sustainable and promising future for ocean energy as the international community convenes for COP28.

The year 2024 was dedicated to actively promoting the International Vision for Ocean Energy. This initiative, driven by the collaborative efforts of the University of Edinburgh - Policy and Innovation Group, the US Department of Energy's Water Power Technologies Office, and Nanyang Technological University, focused on broadening the understanding and support for ocean energy's role in the global low-carbon energy mix. The efforts aimed to align and invigorate research, development, and strategic leadership towards updating our goals and reinforcing the commitment to harnessing ocean energy's full potential.

However, achieving these ambitious forecasted benefits will not be possible without the implementation of a comprehensive and targeted policy support programme. The IEA-OES Ocean Energy and Net Zero policy guidance



By 2050, the ocean energy sector forecasts a global total installed capacity of 300 GW. This ambitious target is expected to generate 680,000 jobs, contribute $340 billion in gross value added (GVA), and prevent over 500 million tonnes of carbon emissions, underlining the sector's potential to drive socio-economic growth and combat climate change.

report has identified four key challenge areas, the overcoming of which are vital to the continued commercialisation of the ocean energy sector. While this policy guidance report was able to provide high-level policy recommendations to address these challenges initially, the ExCo agreed that there is a need for more granular and evidence-led assessment, analysis and policy delivery on the following challenge areas:

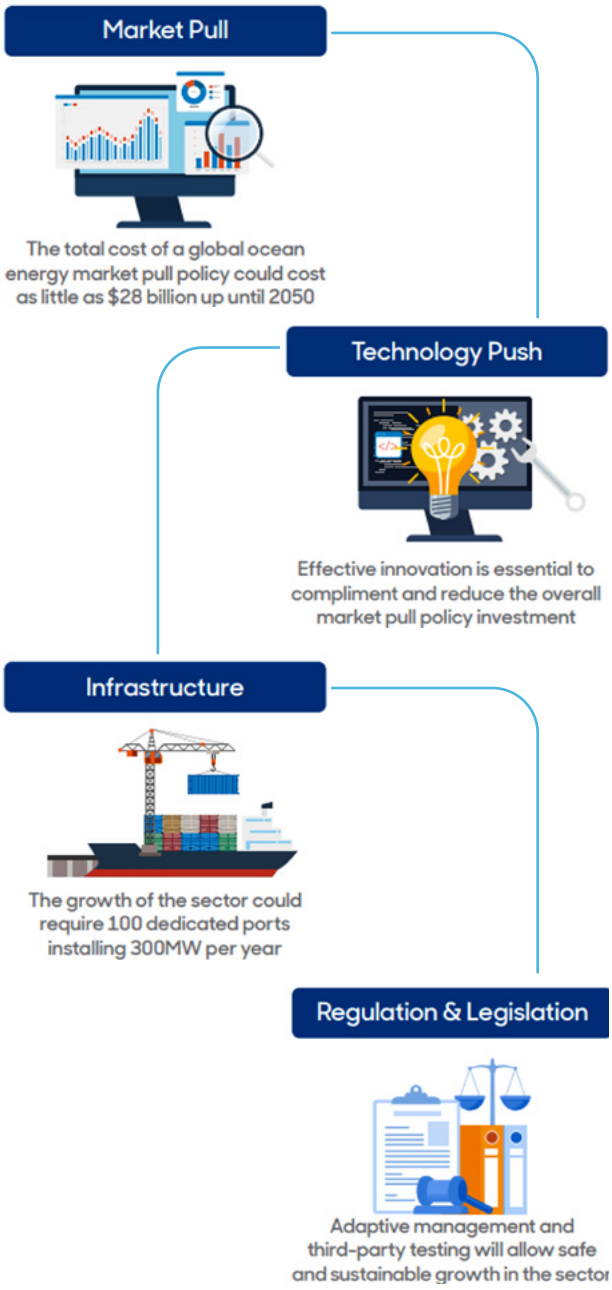
- Market pull policies,
- Technology push policies,
- Ocean energy infrastructure requirements, and
- Regulatory and legislative frameworks.

In late 2024, the following two studies were commissioned to the Policy and Innovation Group of the Edinburgh University:

- In-Depth Analysis and Policy Guidance Report for the Development of Market Pull Policy Support Mechanisms for the Ocean Energy Sector.
- In-Depth Analysis and Policy Guidance Report for the Development of Technology Push Policy Support Mechanisms for the Ocean Energy Sector

In 2024, the OES initiated the commissioning of the first two studies on market pull policies and technology push policies to the Policy Group at the University of Edinburgh.

The remaining studies on Infrastructure Requirements and Regulatory and Legislative Frameworks are scheduled for commissioning in 2025. These studies are essential for providing detailed, evidence-led assessments and analysis to address the key challenge areas identified in the International Vision report.



04 INTERNATIONAL ACTIVITIES ON OCEAN ENERGY

Dragon 4 in Vestmanna waters, Faroe Islands. @ Minesto

AUSTRALIA

REPORT PREPARED BY:
Irene Penesis, Blue Economy CRC
Christophe Gaudin, University of Western Australia
Philip Marsh, Blue Economy CRC

OVERVIEW

In 2024 significant progress was achieved in advancing ocean energy in Australia, with notable achievements particularly in wave energy. Two demonstration wave energy devices were successfully deployed in Australian waters: the MoorPower™ pilot off Fremantle, Western Australia, led by Carnegie Clean Energy, and the M4 wave energy project off Albany, Western Australia, led by The University of Western Australia – projects supported by the Blue Economy CRC. In addition to these ocean energy deployments, several companies advanced their research and design activities, including experimental testing at The University of Western Australia (UWA), Australian Maritime College, University of Tasmania (AMC) and The University of New South Wales facilities.

In 2024 key reports, webinars, and conferences also highlighted Australian-based advancements in ocean energy. Notably, the International Conference on Ocean Energy (ICOE2024) was hosted in Melbourne, Australia—the first time the event has been held in the Southern Hemisphere. During the conference, the Blue Economy CRC released the Ocean Wave in Australia report, emphasizing the complementary role of wave energy alongside solar and wind power. Further research initiatives led by the Blue Economy CRC, Marine Energy Research Australia (MERA), multiple universities, and other organizations have also significantly progressed ocean energy development and supported industry growth.

SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy – policy support

In 2024 there was a strong Commonwealth Government policy emphasis on net-zero and decarbonization activities, supported by policies, acts and plans including the: Net Zero Authority, Future Made in Australia, the Guarantee of Origin (GO) Scheme, the National Reconstruction Fund, the Hydrogen Headstart Program and Tax Incentive, and the Powering Australia Plan. Reviews and reports released included: the Sector Pathways Review, the Climate Change Authority Annual Progress Report 2024, and the annual Australian Energy Market Operator's (AEMO) Integrated System Plan (ISP). However, funding and focused initiatives specifically related to ocean energy remained limited to ARC-funded projects, the release of the draft Australian Sustainable Ocean Plan, and the ongoing offshore renewable energy area declarations supporting the previously declared Offshore Electricity Infrastructure Act 2021.

In addition to the Commonwealth Government's policy initiatives, Australia's state and territory governments have continued their support for renewable energy policies, primarily focusing on onshore renewable energy zone declarations and energy transformation plans. Specific support for ocean energy remains limited, with a notable exception being the Western Australia (WA)

Government, through the Department of Primary Industries and Regional Development (DPIRD) support of the activities of Marine Energy Research Australia (MERA). Additionally, the WA Government Department of Jobs Tourism Science and Innovation (JTSI) have supported WaveX for a second year with local funding for advanced control system integration into the D-Spar™ through MERA at the University of Western Australia (UWA) and partnered with Curtin University.

Market incentives

Renewable Energy Target scheme

The Renewable Energy Target (RET) scheme encourages renewable electricity generation by aiming to reduce greenhouse gas emissions from the electricity sector through the Large-scale Renewable Energy Target that sets out to deliver 33,000 GWh of extra renewable electricity each year and also the Small-Scale Renewable Energy Scheme for smaller scale systems.

Public funding programmes

Australia supports ocean energy development through various national and state funding programs. At the Commonwealth level, the Australian Renewable Energy Agency (ARENA) drives pre-commercial innovation, bolstered by $7.1 billion in funding announced in the 2024–25 Federal Budget. ARENA also supports the National Industrial Transformation Program that aims to reduce Scope 1 and Scope 2 emissions at` existing or planned industrial facilities in Australia. However, no current ARENA projects directly target ocean energy. The Cooperative Research Centre (CRC) program facilitates collaboration between industry and research sectors, which supports the Blue Economy CRC, as well as the CRC-P program which supports Australian industries ability to compete and produce in the short term, including funding for WaveX in partnership with University of Western Australia (UWA) and the Norwegian Geotechnical Institute (NGI). In 2024 the Australian Research Council (ARC) funded ocean energy projects across institutions such as UWA, Royal Melbourne Institute of Technology (RMIT), Swinburne University, University of Adelaide, and the University of New South Wales (UNSW). The Clean Energy Finance Corporation (CEFC) continues to promote private investment in large-scale commercial clean energy projects and provides concessional funding for interconnector projects. State governments also play a key role, with Western Australia actively supporting research and development through initiatives like the MERA offshore renewable energy innovation hub.

RESEARCH & DEVELOPMENT

Significant investment in ocean energy R&D projects occurred in 2024 through the following activities:

Australian Ocean Energy Group (AOEG)

In 2024, AOEG successfully completed the Ocean Energy Microgrid Project, termed "Project Aquagrid," which was funded by the Australian Fisheries Research and Development Corporation (FRDC). The project partners were AZURA Ocean Technology, Deloitte Climate & Sustainability, Emissions Solutions, Syncline Energy Pty Ltd, and aquaculture industry partner Ocean Road Abalone | Southern Ocean Mariculture. The project demonstrated the effectiveness of a customer-driven design approach in developing an ocean energy microgrid system tailored to the needs of Southern Ocean Mariculture, an abalone farm located in Victoria, Australia. Additionally, the FRDC featured an article in their December newsletter titled Ocean Energy Microgrids to Potentially Power the Future of Aquaculture, showcasing the potential of this technology to support sustainable aquaculture.

AZURA Ocean Technologies

Positive findings from the FRDC-funded 'AquaGrid' feasibility study have identified ocean energy microgrids as a viable option to power coastal aquaculture production and help decarbonise the sector. Based on these findings, Ocean Road Abalone | Southern Ocean Mariculture has entered into a Memorandum of Understanding with Azura as its technology supplier to implement the first scenario, with two 100 kW wave units, which could be scaled up at a later date.

Blue Economy Cooperative Research Centre

The Blue Economy CRC-Co Ltd, established in 2019 under the Australian Government's Cooperative Research Centre Program, is an independent not-for-profit advancing Australia's blue economy. Positioned near the world's largest seafood and energy markets, Australia has immense potential to grow sustainable marine industries. With over AU$300 million in funding, the CRC unites 43 partners from industry, research, and government across ten countries to tackle offshore food and energy

production challenges, driving innovation in aquaculture, offshore engineering, and renewable energy over a 10-year program. During 2024 the Blue Economy CRC continued to build on its impressive portfolio of projects that actively support and underpin the growth of ocean energy in Australia. Highlights of progress in 2024 funded by the Blue Economy CRC include:

- Ocean Wave Energy in Australia: which released a pivotal report at ICOE2024 outlining the ocean wave energy landscape in Australia, highlighting the exceptional characteristics of the Australian wave energy resource and demonstrating that there is particular value in terms of the dispatchability of wave energy. Funded by the Blue Economy CRC, this report was a collaborative effort led by UWA-MERA, and partners CSIRO, Griffith University, Australian Maritime College/University of Tasmania, Swinburne University of Technology, the University of Adelaide, BMT, Wave Swell Energy and Carnegie Clean Energy.
- Moorpower – Scaled Demonstrator: the pilot device off Fremantle, WA, led by Carnegie Clean Energy was redeployed for winter. This redeployment follows successful operating with over 2,000 hours of operations data gathers and analysed during 2023-2024.
- Mooring Tensioner for WECs – MoTWEC: led by Carnegie Clean Energy has completed its final testing cycles. The MoTWEC project tackles the cost and energy storage challenges of wave energy conversion through this novel Mooring Tensioner technology. The MoTWEC project has been incorporated on the 2024 deployment of the MoorPower device as part of the Scaled Demonstrator project and will also be deployed at a larger scale during the ACHIEVE Programme deployment of CETO at BiMEP in 2025.
- Seeding Marine Innovation in WA with a Wave Energy Deployment in Albany: funded by the Blue Economy CRC, WA Department of Primary Industries and Regional Development and UWA, a prototype version of the M4 (short for 'Moored MultiModal Multibody') Wave Energy Converter was deployed in King George Sound, Albany in 2024.
- Modelling and operation of a hydrogen microgrid with 700 kW electrolyser: Blue Economy CRC is constructing and commissioning the first DC hydrogen microgrid in Hobart, Tasmania in 2024-2025, producing hydrogen to power fuel-cell buses and support research into the provision of electricity and hydrogen to relevant industries, particularly aquaculture.
- Alternate energy solutions for aquaculture: Seafood Industry Australia (SIA) and the Blue Economy CRC have joined forces to deliver FRDC project 2023-080: Alternative energy solutions for aquaculture, which seeks to provide a wholistic decarbonisation decision platform as the aquaculture industry builds its climate resilience.
- System level modelling to improve the performance of Offshore Sustainable Power: which supports the development of the Blue Economy CRC's offshore hydrogen DC microgrid infrastructure, where advanced electrical and power system analysis and modelling tools are utilized to identify and achieve optimal performance scenarios.
- Marine Spatial Planning for a Blue Economy: project released a draft Guiding Principles for an Australia MSP Framework, that outlined the first steps in developing a unified whole of marine estate approach specifically for Australia. Also released were reports on the: Evaluation of potential for interaction and/or conflict among ocean users and the environment in offshore waters in Australia, identifying synergies and trade-offs between sectors in the Blue Economy Zone, and Initial perspectives from First Nations people in developing an Australian MSP Framework.
- Risk-based Procedures for Safe and Reliable ORES: that aims to develop a framework for risk assessment methods, decision-support tools and a set of procedures that will enhance the safety, value-adding and cost-effectiveness of ocean energy.
- Data Infrastructure Design for the Blue Economy: continued to build stakeholder engagement by bringing together digital experts, data scientists, engagement specialists, project partners, stakeholders and end-users through a series of workshops to design fit-for-purpose infrastructure to manage Blue Economy CRC knowledge and data.
- Analysing Graduate Attributes and Employability of BE CRC PHD students: continued to analyse and qualify the impact on graduate attributes that arise from the Blue Economy CRC research activities for educational and engagement programs at universities, researchers and practising engineers.
- Cultural licence to operate in the Blue Economy: released their final Cultural License to Operate report that presents a framework for industries to collaborate with First Nations, fostering trust and cultural legitimacy in Blue Economy operations.

- Ethics values and social licence research: released four reports on: Ethical Values and Principles, Tasmania Blue Economy: Salmon Aquaculture, Ethical Risks in the Offshore Blue economy, and Understand the Social License to Operate (SLO) that were designed to help industry and government strengthen ethical practices in Blue Economy operations.
- Modelling of scalable offshore seaweed mariculture platforms: which aims to enhance seaweed farming using Marine Permaculture (MP), a technique that utilises submersible platforms to access deepwater nutrients, ensuring seaweed growth despite warming temperatures.
- Developing Production Systems for Offshore Kelp Mariculture: progressed on the commissioning of a kelp trial research farm in Tasmania's Derwent River that will use a novel wave-powered pump developed by the Australian Maritime College (UTAS) to deliver nutrients to the facility. The hydrodynamic behaviour of the wave pump was tested in AMC's Towing Tank at a 1:21 scale as shown in Figure 1.

Carnegie Clean Energy

In 2024, Carnegie Clean Energy and its subsidiaries continued to advance the commercialisation of the CETO and MoorPower wave energy technologies. Achieving significant milestones through collaborative efforts, driving progress in both technology development and real-world deployment.

Through the ACHIEVE Programme, Carnegie has continued to advance towards the deployment of CETO at the Biscay Marine Energy Platform (BiMEP). The fully submerged, point absorber wave energy converter will represent the first grid connected CETO unit in Europe. With €7.05M ($11.66m AUD) support for the project acquired though the EuropeWave PCP Programme, the Basque Energy Agency; Ente Vasco de la Energia, and the Spanish Governments RenMarinas Demos Programme. The unit will be deployed for 2 years, providing both electricity and valuable data to the team as it continues the commercialisation pathway of the CETO technology. To date, activities for the ACHIEVE Programme have included the detailed design and procurement of critical components of the CETO Unit, as well as development of the Carnegie Technologies Spain team delivering the project.

Commonwealth Scientific and Industrial Research Organisation (CSIRO)

CSIRO, in partnership with the Australian Energy Market Operator (AEMO), industry and key stakeholders released their annual cost estimates for future new-build electricity generation in Australia, GenCost 2023-2024.

Hydrokite Project Development

Founded in January 2024, Hydrokite Project Development (Hydrokite) is an Australian company specialising in inno-

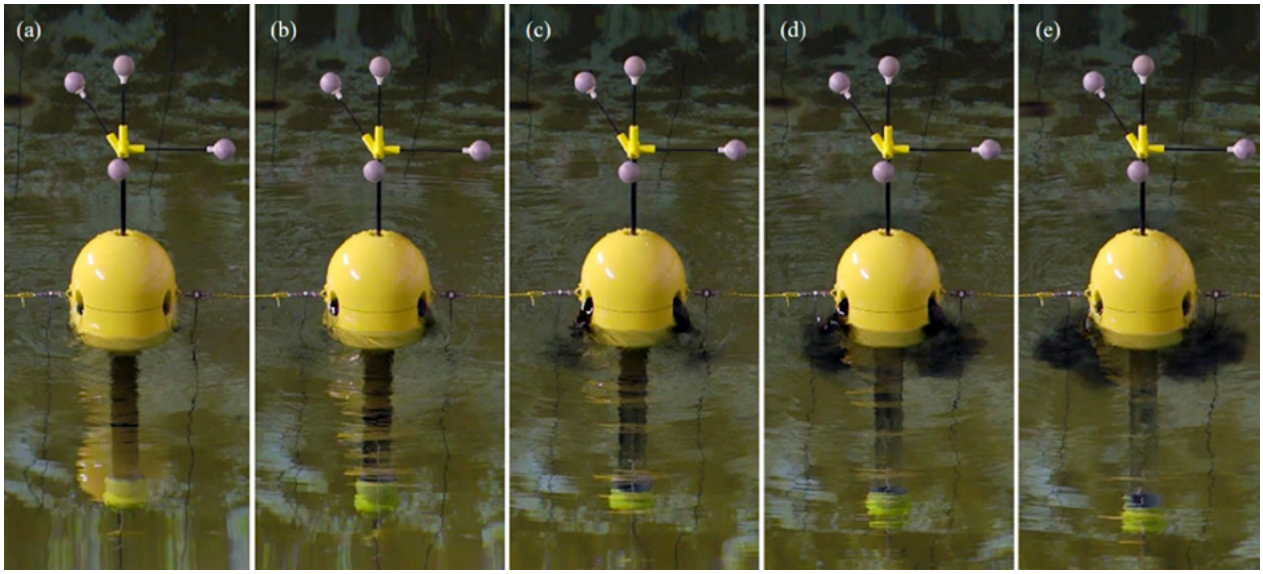


Figure 1: Dye tests showing the wave-driven seawater pump in action. Here, each image represents 5 consecutive oscillations.

Through pioneering research and strategic partnerships, Australian universities are driving the evolution of ocean energy technologies, paving the way for enhanced coastal protection, efficient energy generation, and significant advancements in pilot projects.

vative tidal and ocean current energy solutions. Partnering with Swedish tidal energy leader Minesto, Hydrokite is introducing advanced technologies, such as Minesto's unique tidal kite systems, to Australia and New Zealand. In its inaugural year, Hydrokite explored demonstration projects, leveraging insights from the ARENA-funded AUSTEn initiative that assessed Australia's tidal energy potential, conducted high-resolution mapping, and evaluated economic feasibility. Hydrokite's 2024 efforts focused on identifying optimal sites to showcase the efficiency and viability of Minesto's tidal kite technology. Based on these evaluations, two concepts have been selected for further feasibility studies in 2025. The first is an offshore site near Broome, and the second is in the Banks Strait, with potential to supply power to Flinders Island. In 2025, Hydrokite will also focus on securing resources to advance these projects, marking a critical step towards commercialising tidal energy in the region.

Royal Melbourne Institute of Technology (RMIT)

Supported by the ARC, RMIT University has made significant strides in wave energy research through two key projects. A completed ARC-funded Discovery Project developed a novel speed-amplified flux-switching electromagnetic wave energy harvester, leveraging ocean surface heave motion to convert kinetic energy into electricity. A prototype was successfully validated in 2022, leading to 15 Q1 journal publications, three Ph.D. and one master completion, with the project featured in over 120 stories and reported by 135 international media outlets, including prominent American and European channels, generating media coverage worth over $1.5 million and producing significant social impact. Building on this, a new ARC-funded Linkage Project (LP240100007) is underway that aims to develop a modular, speed-amplified linear generator for wave energy conversion, involving advanced hydrodynamic and magnetic simulations, prototype construction, and testing.

Swinburne University

Funded by the ARC Linkage Project LP180101109 "Controlling coastlines while generating power" aims to produce strategies for protecting coasts from damaging waves using farms of wave-energy machines, which also generate electricity. The project led by Swinburne University in partnership with the University of Adelade and University of New South Wales, and industry partner organisations Moyne Shire Council and Mid-West Ports Authority, has achieved several major milestones including numerical optimisation of wave farms for coastal protection, and experimental validation in several wave flumes. Experimental testing of optimised arrays of OWCs in UNSW Sydney's Water Research Laboratory 3D wave basin was completed in 2024, with preliminary results demonstrating a clear wave-energy reduction zone forming behind the array and influence on a mobile shoreline sediment tracer model. Array layouts are being optimised for two applications: mitigation of coastal erosion, and reduction of problematic waves in harbours.

University of Adelaide

Supported by the ARC and in partnership with Carnegie Clean Energy, the University of Adelaide (IE230100545) continues to work on the development of a deployment-ready robust controller for wave energy converters. This project aims to improve the economic viability of the CETO system that converts the power of ocean waves into electricity. It will develop control systems which will effectively predict, model and respond to wave activity, maximising energy production and resulting in an overall reduction in the cost of renewable energy.

University of Queensland (UQ)

Researchers at the University of Queensland's School of Civil Engineering are working on developments of oscillating wave surge converters (OWSCs) with adaptive geometries. The adaptive geometry enables effective control of the excitation load, flap rotation, Power Take-Off

(PTO) load, and foundation load, enhancing the OWSC's survivability in strong wave conditions and expanding its operational window. The geometry of the OWSC can also be adjusted to maximize power production under specific operational conditions. Supported by the ARC, UQ secured a 4-year Future Fellowship (FT230100109) focusing on Offshore Wind, Floating Solar systems and Offshore Aquaculture. The project aims to tackle key hydrodynamic challenges of offshore renewable energy and resources, through an integration of numerical modelling, physical testing and field measurement, in partnership with world-leading industry partners.

University of Western Australia

Alongside the significant activities at the UWA-MERA test site, UWA-MERA continues to successfully collaborate on research and development with a range of partners.

In 2024, a UWA-MERA collaboration with Perth-based wave energy developer WaveX achieved significant milestones in advancing its D-Spar wave-powered generator technology. The company was awarded AU$2.4 million federal grant through the Cooperative Research Centres Projects (CRC-P) to deploy a large-scale D-Spar prototype in Albany, Western Australia. This project is a collaboration with the University of Western Australia (UWA) and the Norwegian Geotechnical Institute (NGI) Perth, focusing on evaluating the performance of shared helical anchors for offshore renewable energy. In addition, WaveX received a AU$40,000 Innovation Booster Grant (IBG) from the Western Australian State Government to integrate advanced control systems into its D-Spar wave-powered generator. In October 2024, WaveX completed its second round of 1:100 physical model testing at UWA's Coastal and Offshore Research Laboratory.

Also in 2024, a UWA-MERA collaboration with CorPower Ocean and the Australian Ocean Energy Group (AOEG) have continued to work together during 2024 on the ARC Linkage Project "Efficiently unlocking full-scale WEC dynamics for industry cost reduction" (LP210100397). A unique set of experiments has been conducted at UWA which allows separation of different sources of hydrodynamic nonlinearity.

Wave Swell Energy

After a highly successful demonstration of the Wave Swell Energy (WSE) technology at King Island, Tasmania, in 2021 and 2022, which included the design, construction, transport, deployment, operation, and maintenance of its UniWave200 WEC, all components of that WEC have now been fully decommissioned, recycled, and/or repurposed. These latter achievements have enabled the satisfaction and official sign-off of the final component of the company's funding agreement with the Australian Renewable Energy Agency (ARENA), thereby establishing the technology's lifecycle as sustainable from 'cradle to grave'.

As reported in the previous annual OES Report, data from the project, and the analysis of the results, is the basis of a peer-reviewed journal paper, lead-authored by Pacific Northwest National Laboratory (PNNL), part of the US Department of Energy. This paper has now been published in Transactions on Sustainable Energy, a journal of the Institute of Electrical and Electronics Engineers (IEEE), the world's largest technical professional society. The UniWave200's total wave-to-grid conversion efficiency of close to 50% (or more) for waves of greater than 1 metre in height, places the technology among the top echelon of renewable energy technologies in terms of full-cycle energy conversion efficiency.

WSE has continued to make strong commercial progress during 2024, developing a pipeline of potential future projects, with particularly strong engagement in the US. The technology exhibits a high degree of versatility, with the ability to be deployed in multiple different platforms, including nearshore, offshore, coastal structures, offshore floating vessels, and more. The incorporation into coastal structures as a form of protection against erosion allows the WSE technology to double as a means of both mitigating against, and adapting to, the effects of climate change.

WaveX

WaveX is a private Western Australian company focussed on the commercialisation of its Wave Powered Generator (WPG) IP called the D-Spar™. Since then, and in close collaboration with UWA, WaveX' proprietary WPG's have accelerated up the TRL scale, with ABL-Group (OWC) issuing a Statement of Feasibility in June 2024. WaveX now have an EOI's from a major gas utility and global aquaculture supplier, after passing the next milestone of our patenting pathway. In close collaboration with UWA, WaveX completed its most robust tank testing to date with a grant from the Western Australian government – department of Jobs Tourism Science and Innovation (JTSI).

In 2025, WaveX plans to deploy a much larger prototype in an open water environment, and commenced its engagement with a broader cross section of industry in 2H

2024, winning the Subsea Engineering Australia award for Innovation, the Climate Technology Award at SXSW Sydney, and being a finalist in the WA Innovators of the Year event in October 2024. This followed a string of press in the Australian Financial Review, Renew Economy and the ABC via news and radio. WaveX was the recipient of funding through the WA innovation hub CERI (Centre for Entrepreneurial Research and Innovation www.ceri.org.au).

TECHNOLOGY DEMONSTRATION

Existing open sea test sites

Australia features test sites for wave energy devices, primarily focused on evaluating technologies at lower Technology Readiness Levels (TRLs). Additionally, regulatory pathways support both commercial and research and development deployments within declared areas designated through the Offshore Electricity Infrastructure Act (OEI) 2021 and associated Acts.

University of Western Australia – Marine Energy Research Australia (UWA-MERA)

The University of Western Australia (UWA) operates its offshore renewable energy innovation hub through Marine Energy Research Australia (MERA). Headquartered at the regional campus of UWA in Albany, MERA also has a node in Perth and members based on the UWA metropolitan campus and access to state-of-the-art UWA laboratory infrastructure. Since 2021, the research centre has been supported financially by the WA State Government through the Department of Primary Industries and Regional Development (DPIRD) and by the Blue Economy CRC for the execution of the Albany M4 wave energy project. MERA collaborates across academic, industry, and Government partnerships to promote knowledge sharing and to accelerate the uptake of offshore renewable energy technologies in Australia and internationally. MERA's Albany HQ is firmly networked into the regional ecosystem of local and State Government agencies and other key stakeholders with activities in costal and marine areas. Through the current M4 wave energy project, MERA is working to develop the Albany outer harbour, King George Sound, into a nursery test site for offshore renewable energy technology prototypes. MERA's expertise is acknowledged for strong region-based delivery of public and school STEM engagement programs.

Projects in the water

The Albany M4 project

UWA-MERA has deployed the M4 (for Moored Multi-Mode Multibody) wave energy demonstrator as shown in Figure 2 and Figure 3 on the 11th of November 2024 in Albany, 450 km south of Perth, Western Australia (WA). This deployment is the result of nearly four years of collaboration between UWA-MERA, the Blue Economy CRC and the Department of Primary Industries and Regional Development (DPIRD) of Western Australia. The M4 is a hinged attenuator line-absorber type WEC developed by Prof. Peter Stansby from the University of Manchester and M4 Wave Power Ltd. It has undergone extensive optimisation through modelling and tank testing, with published results demonstrating high energy capture and excellent survivability.

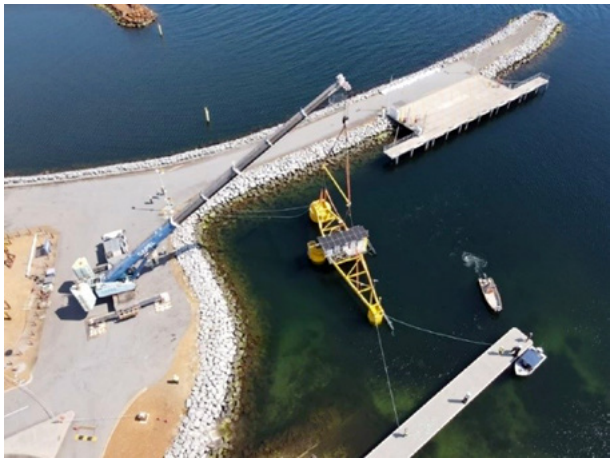


Figure 2: M4 being lifted into the Albany Marina (Oct. 2024)

Figure 3: M4 operating at sea (Nov. 2024).

Figure 4: Carnegie's MoorPower during redeployment at the offshore test site in North Fremantle WA (CCE, 2024).

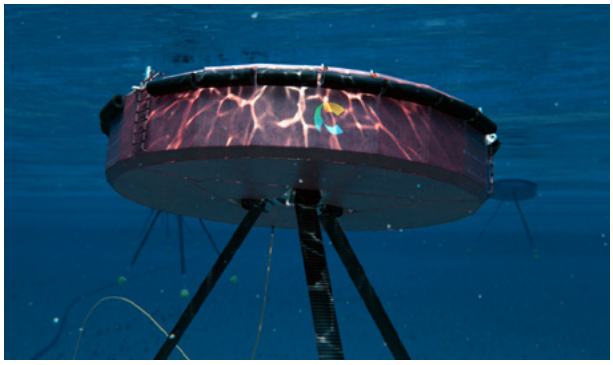


Figure 5: Conceptual image of Carnegie's CETO unit (CCE, 2024).

The M4 is 24 m long, weighs about 40 tones and has a rated capacity of 2 x 5.5 kW. The project, of a total budget of AUD 4.8 M, involves multiple partners, including the Australian Maritime College who undertook wave tank testing, the University of Queensland who undertook hydrodynamic optimisation, BMT who undertook the design of the mooring system and the M4 structure and the environmental impact assessment, the University of Manchester who designed the Power take-off (PTO), and RMIT University who assisted with PTO development. This is the first and only fully open-source deployment where all data and information associated with the project, including power generation, are made available in the public domain and from which all the lessons learnt will be published, aiming at uplifting the whole industry.

M4 will be decommissioned early 2025, after about 6 months of operation at sea. The project also aims at solidifying the potential of Albany as an ocean energy testing site for Australia and additional deployments are expected in 2025 and 2026, notably in collaboration with WaveX.

MoorPower™ Demonstrator

During 2024, Carnegie successfully deployed a scaled demonstrator of the MoorPower technology shown in Figure 4. Designed to address the growing need for clean and reliable power in offshore industries, MoorPower offers a sustainable alternative to traditional diesel generators for applications such as aquaculture and moored vessels. Leveraging Carnegie's existing CETO wave energy expertise, MoorPower is specifically engineered to meet the unique demands of offshore platforms. The successful validation of the MoorPower modules at Carnegie's North Fremantle test site in Western Australia represents a crucial step in the technology's development. Carnegie is now progressing towards a commercial demonstration of the MoorPower technology, with plans initiated to install commercial-scale MoorPower modules on an operational aquaculture feeding barge.

Projects planned for deployment

Carnegie Clean Energy

Carnegie Clean Energy, through its subsidiaries CETO Wave Energy Ireland and Carnegie Technologies Spain, is set to deploy the first CETO wave energy converter unit in Europe at the BiMEP testing site in Bilbao, Spain in 2025. This project is supported by a multi-faceted funding approach, with contributions from the EuropeWave PCP Programme, Spain's RENMARINAS DEMOS Program and the Basque Energy Agency's support.

WaveX

WaveX has signed an MOU with UWA for the W5 project using WaveX D-Spar™ technology. This project will leverage the lessons learned and knowledge gained by the deployment of the M4 device in King George Sound in Albany, and seek to demonstrate the full system at prototype scale. 2024 saw the completion of preliminary structure and moorings design for the project, by Naval Architects Alpha-One-Marine, and commencement of electrical system design by a global engineering design house in Perth. The project will be underpinned by a recent collaboration agreement signed by Trident Energy (UK) and WaveX to integrate Tridents Power Pod II with the WaveX D-Spar. The Power Pods will be housed in the D-Spar hull in a protected and atmospherically controlled climate that is easily accessible for maintenance and inspection during operations.

SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

National Marine Energy Standards Committee – EL066

The Marine Energy standard committee marked its fourth year of operations and continued work in standards development, with members collaborating with international expert committees on tidal resource assessment and characterizations and biofouling of marine energy devices. Activities included Australian representation at the International Electrotechnical Commission (IEC) TC 114: Plenary meetings in Jeju, South Korea, and in Edinburgh, Scotland.

WaveX

WaveX via its existing oil and gas industry contacts and membership of the Australia-Korea Business Council (AKBC), is seeking to work with the Korean Research Institute for Ships and Ocean (KRISO) at their test facility on Jeju Island, for a commercial-scale deployment of the WPG technology in 2026/2027. WaveX also remains in close contact with facilities and industry partnerships in the USA, Japan, Scotland and Norway for post-Albany deployments according to its development pathway using the OES Guidelines.

RELEVANT NATIONAL EVENTS

Relevant events in 2024

International Conference on Ocean Energy (ICOE2024)

The 10th International Conference on Ocean Energy (ICOE 2024) took place from 17–19 September 2024 in Melbourne, Australia, marking the first time this global event was held in the Southern Hemisphere. Hosted by the Blue Economy CRC and Chaired by Professor Irene Penesis, Research Director of the Blue Economy CRC and Professor Christophe Gaudin, Director of the UWA Oceans Institute. ICOE 2024 brought together experts to share milestones and explore the future of ocean energy. At this conference, attendees engaged with opportunities across Australia, Asia, New Zealand, and the Pacific Islands, a region increasingly recognized as a global hub for ocean energy with significant untapped potential. An image gallery from throughout the conference is available on the website.

International Towing Tank Conference (ITTC)

The 30th International Towing Tank Conference (ITTC2024) was held from 22–27 September 2024 in Hobart, Australia.

Blue Economy CRC Webinar Series

In 2024 the Blue Economy CRC webinar hosted nine webinars on ocean energy, offshore wind and blue economy developments and cultural licence topics.

Relevant events planned for 2025

Australia has officially bid to co-host COP31 in partnership with the Pacific.

BELGIUM

REPORT PREPARED BY:
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OVERVIEW

Ghent University has coordinated the European COST Action CA17105 "WECANet, an open pan-European Network for Marine Renewable Energy with a focus on wave energy" funded by the European COST Association which involves 31 countries. WECANet focused on scientific excellence and inclusiveness by fostering training, networking and collaboration in Europe for wave energy. The Coastal Engineering Research Group (CERG-UGent) is an international player in the field of Blue Energy with its pioneering research tools. CERG-UGent focuses on the research topics of wave and tidal energy, and offshore floating wind turbines and other floating structures, and is pioneer in investigating parks of energy devices.

Ghent University is strategic partner in the Infradev MARINERG-i project coordinated by the MaREI Centre at University College of Cork Ireland, which brings together all the European countries with significant testing capabilities in offshore renewable energy.

The Flemish Agency for Innovation and Entrepreneurship (VLAIO) is supporting since 2018 the 'Blue Cluster' which was set up aimed at large companies and SMEs active in the blue economy sector, including marine energy.

The West Flanders Development Agency responsible for the implementation of the social economic policy of the Province of West Flanders, is supporting developments in the blue energy field, promoting the development of ocean energy technology by the academic sector and private companies. The Fabriek voor de Toekomst Blue Energy of POM West Flanders was established by the province of West Flanders to give businesses in this industry every possibility to grow via innovation. Moreover, POM has introduced TUA West (Technical University Alliance West Flanders) with a focus on improving cooperation between the province's higher education establishments and making knowledge more readily available to the industry and especially the many SMEs in the region.

SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy

Belgium's renewable energy policy is aligned with the EU targets. Belgium's land-based and offshore wind energy developments are essential for both the Belgian and European targets for energy development from renewable sources. Belgium proposes an 18.3% share of energy from renewable sources in gross final consumption of energy in 2030 as contribution to the EU renewable energy target for 2030.

A green energy certificate market is implemented to support onshore renewable energy production with Tradable Green Certificates (TGC). For each renewable technology, a stakeholder analysis is put forward to determine the level of support. A generic business case is constructed with input of the developer, the technology supplier, investors, banks, etc. This exercise will determine the cost of the renewable electricity and the matching value of the TGC in €/MWh. The business case is frequently updated in order to align the new TGC support with the technology evolution.

To maximize Belgium's own renewable electricity production, the federal government decided to increase the capacity of offshore wind installations in the second offshore wind zone, the Princess Elisabeth Zone, to a range between 3,15 and 3,5 GW. Together with the existing offshore wind farms, the total offshore wind capacity in Belgium can as such increase to 5,8 GW by 2030, almost tripling the current offshore capacity. By 2030, around

25% of the Belgian electricity production can come from the Belgian North-Sea, saving in total 8,6 million tons of CO2 per year. A first phase of 0,7 GW is to be installed by 2028 and the remaining 2,1 GW is to be taken into service by the end of 2029.

Marine renewable energy is seen as a new emerging industry, highly relevant for Flanders. There are several initiatives promoting the development of the blue economy, including marine energies.

The Flemish Agency for Innovation and Entrepreneurship (VLAIO) has been supporting the '**Blue Cluster**' aimed at large companies & SMEs active in the blue economy sector, including marine energies. The Blue Cluster, a Flemish spearhead cluster focussed on the sustainable blue economy has, together with its members from industry and academic partners revised its offshore renewable energy R&D roadmap.

The **West Flanders Development Agency (POM West Flanders)**, is supporting developments in the blue energy field, promoting the development of ocean energy technology by the academic sector and private companies. The Fabriek voor de Toekomst Blue Energy of POM West Flanders was established by the province of West Flanders to give businesses in this industry every possibility to grow via innovation. Promotion, research, training and infrastructure. The partnerships aim to create an optimal breeding ground for a future-oriented economy. This is possible thanks to a close collaboration between education, science, industry and local government. One example is the periodic, structural meeting of the "core group" blue energy, organised by POM West Flanders, which brings together the main players in the blue energy field.

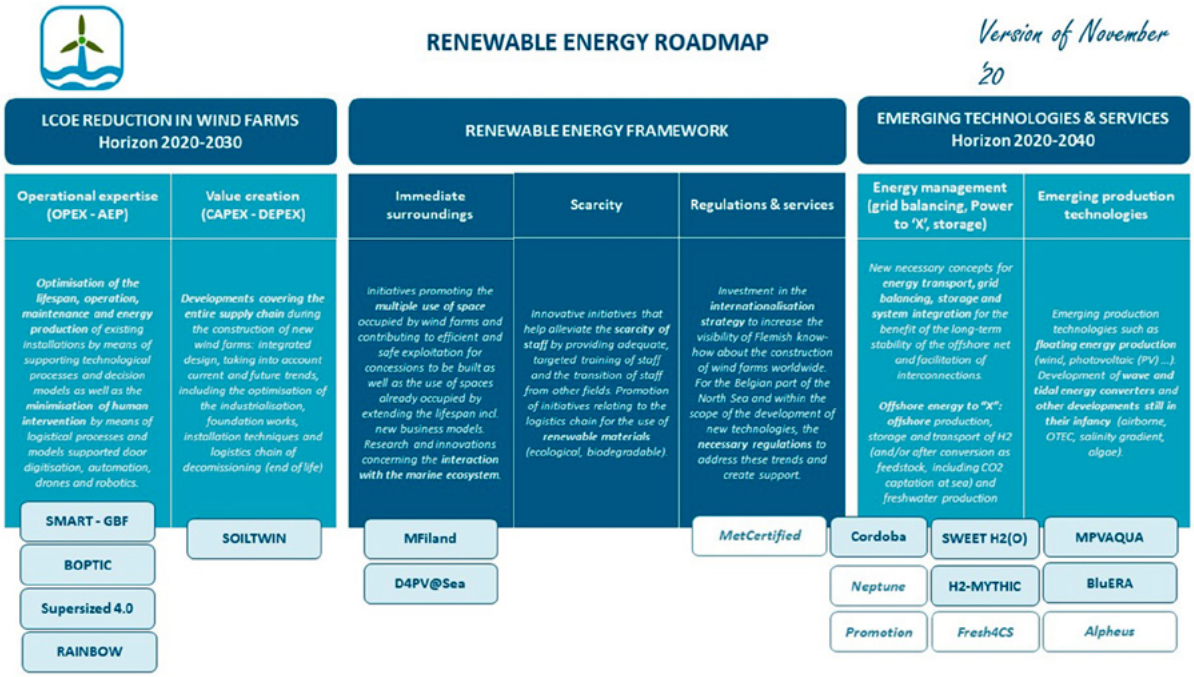
Market incentives

The first wind energy zone in the Belgian North Sea has been fully built within the set timeframe. The last two wind farms in this zone, Northwester II and SeaMade, were built and commissioned in spring and autumn 2020 respectively. With these two new wind farms, 8 wind farms are now operational in the Belgian North Sea, with a total installed capacity of 2,262 MW.

In 2020, Belgian offshore wind farms generated 6.7 TWh of electricity. This represents 8.4% of total electricity consumption in Belgium or the electricity consumption of around 1.9 million families. From 2021 onwards, the 8 wind farms together produce around 8 TWh of renewable energy annually. This corresponds to the electricity consumption of approximately 2.2 million families, which is almost half of Belgian households, or 10% of the total electricity demand in our country.

The Blue Cluster

The Blue Cluster is a not-for-profit cluster organization grouping over 200 private businesses and public part-



ners, dedicated to the blue economy. Their mission is to strengthen the competitiveness of the blue economy in Belgium. The Blue Cluster is recognized by the Flemish government as a spearhead cluster, and is a strategic partner of Flanders Investment and Trade.

The Blue Cluster is focused on innovation an internationalization trajectories to stimulate blue growth but acts also as a sector federation defending the stakes of a sustainable blue industry. The cluster is an important networking organization to bring together many companies that work (often partially) in a maritime context. By fully incorporating cutting-edge SME's in the cluster organization and the innovation projects, the Blue Cluster ensures that they can accelerate their growth.

Besides its role in innovation and international development, the cluster takes the lead in the development of a blue strategy for Flanders, and provides policy advice to the Flemish authorities to implement this strategy.

More information: https://www.blauwecluster.be/about

The Fabriek voor de Toekomst Blue Energy

In order to help businesses in West Flanders to grow regionally and internationally via innovation, the Province of West Flanders established cluster platforms in the framework of the Provincial Development Agency West-Flanders (POM) to proactively prepare its industries for the future. The Fabriek voor de Toekomst Blue Energy, focusing on wind, wave and tidal energy, is situated at the Belgian coast and in the Ostend area. Through a partnership between all relevant actors at the local, provincial and Flemish level, SMEs are supported in their future-oriented and sustainable development: from practical services to promotion, research, training and infrastructure: the cluster platforms aim to create an optimal breeding ground for a future-oriented economy.

More information:
http://www.fabriekenvoordetoekomst.be/fabriek-voor-de-toekomst-blue-energy

Public funding programmes

Every year, POM West Flanders launches a call for project called the "Quick Wins", in which a number of short-term innovation cooperation projects are funded (50%) with the ambition to finalise with a pilot installation, test setup or prototype.

The Federal **Energy Transition Fund** in Belgium aims to encourage and support research and development in the field of energy. As part of the Energy Transition Fund, the Directorate-General Energy organizes each year a call for proposals in accordance with article 3, §1, of the Royal Decree of 9 May 2017 laying down the conditions for use of the Energy Transition Fund.

The current call aims to support innovative and research projects within five energy sectors with that of renewable energy in the Belgian exclusive economic zone of the North Sea being one of them.

The budget of the Energy Transition Fund is awarded as a subsidy to projects that meet all relevant conditions and relate to research and development, investment in research infrastructure, innovation clusters or on innovation by SMEs.

The Blue Cluster has a dedicated budget from Flanders Innovation & Entrepreneurship to cofund industry driven R&D projects on the subject of offshore renewable energy. The projects have to involve at least 3 Flemish companies and have to respond to the roadmap mentioned above. The annual budget for co-funding R&D projects with support of the Blue Cluster is 8 million Euro.

RESEARCH & DEVELOPMENT

Fundamental research projects at the Coastal Engineering Research Group of Ghent University (UGent-CERG) dedicated to ocean energy research

The Coastal Engineering Research Group (UGent-CERG, http://awww.ugent.be) is led by Professor Peter Troch, and is situated within the department of Civil Engineering.

UGent-CERG has a large experience in the field of marine renewable energy and coastal and offshore engineering performing integrated research using physical and numerical modelling and field measurement campaigns. The main infrastructure and know-how include prototype field measurements, wave flumes/basin for physical scale modelling, and numerical tools. The specialized staff members of the research group are involved in national and international projects on coastal defence, ocean energy conversion and offshore structures. UGent-CERG has a strong pioneering role in Belgium in marine renewables and offshore moored floating structures. Moreover,

UGent-CERG is coordinating the new Coastal & Ocean Basin (COB), which has a focus on offshore renewable energy technologies and coastal and offshore structures.

The research within UGent-CERG focuses on wave-structure interaction, wave overtopping, offshore renewable energy, development of numerical models, experimental research in the laboratory and data analysis. UGent-CERG has supported a substantial number of fundamental research projects and PhD researchers on these topics, as these are core scientific topics for the group. The Research Foundation Flanders (FWO, https://www.fwo.be/) and the UGent Special Research Funds funded PhD research projects and three post-doctoral Fellowships, carried out at UGent-CERG. All of these research topics focus on the numerical and experimental modelling of offshore moored floating energy devices and structures, and Wave Energy Converter arrays/farms. Moreover, FWO (the Flemish Research Foundation) funded the development, construction and testing of WEC array scale models in the Coastal and Ocean Basin in Ostend. The WECfarm testing took place in 2023 and was carried out by researchers of UGent-CERG.

The experimental setup of the five-WEC array the Coastal and Ocean Basin Ostend: overview and detail.

(Photos from: *T. Vervaet, L. Cromheeke, N. Quartier, M. Streicher, V. Stratigaki, P. Troch, 2024. Physical modelling of a centralized controlled array of five WECfarm wave energy converters. 9th International Conference on Physical Modelling in Coastal Engineering (Coastlab24), Delft, Netherlands, May 13-16, 2024*).

At CERG there are currently three running PhD research topics dedicated to wave energy, supervised by Professor Peter Troch and Dr. Vicky Stratigaki:

- Numerical hydroelastic analysis of moored flexible offshore floating structures (PhD researcher: Rafail Ioannou);
- Integrated Smoothed Particle Hydrodynamics platform for modelling marine renewable energy technologies and moored floating structures validated using experimental modelling. (PhD researcher: Laurens Cromheeke);
- Time-domain wave propagation modelling for assessing the impact of WEC farms on the wave field and the local morphodynamics and sediment transport (PhD researcher: Paulino Meneses Gonzalez).

In 2024 the wave energy PhD research of Dr. Timothy Vervaet on experimental testing of wave farms has been successfully completed.

Coastal & Ocean Basin

The facility is targeting the fields of renewable energy and coastal and offshore engineering, and is co-funded by the Hercules foundation, VLAIO (Flanders Innovation & Entrepreneurship) and the Flemish Ministry of Mobility and Public Works. The exploitation will be managed by Ghent University, KU Leuven and Flanders Hydraulics Research. The basin will be equipped with a unique combination of a narrow paddle wave generator in L-shape and a bidirectional current system, to achieve high quality short-crested waves at almost any relative angle with the current.

The COB is 30.0m long by 30.0m wide and has a variable water depth up to 1.4m, allowing for test conditions from coastal to near offshore applications. A pit located in the middle of the basin allows experiments with mooring lines at a depth in excess of 4.0m. The facility is fully equipped with a state-of-the-art Qualisys motion tracking system.

Ghent University is very active in the Blue Energy - Blue Growth - Blue Economy sectors, with the Coastal Engineering Research Group led by professor Peter Troch being specialized in Marine Renewable Energy, Marine Technology, and Coastal & Offshore Engineering (www.ugent.be). Ghent University presented recently the new COB facility through a new video available here:

https://www.offshore-energy.biz/presenting-the-new-coastal-ocean-basin-in-ostend/.

The Coastal & Ocean Basin, together with the new towing tank, forms the Flanders Maritime Laboratory, located at Ostend Science Park (Ostend, Belgium).

MARINERG-i

The Coastal Engineering Research Group of Ghent University (UGent-CERG) is strategic partner in the H2020 MARINERG-i project coordinated by the MaREI Centre at University College of Cork Ireland, which brings together all the European countries with significant testing capabilities in offshore renewable energy. Ghent University is participating in MARINERG-i with marine energy technologies testing infrastructure which includes wave flumes and the new Coastal and Ocean Basin (www.cob.ugent.be).

The MARINERG-i - Offshore Renewable Energy Research Infrastructure, is setting out to become the leading internationally Distributed Research Infrastructure in the Offshore Renewable Energy (ORE) sector, with a network of test facilities spread across Europe. In June 2021 it was announced that MARINERG-i was from that moment onwards included in the ESFRI Roadmap as the new distributed infrastructure for dealing with Green Deal targets. ESFRI, the European Strategy Forum on Research Infrastructures, is a strategic instrument to develop the scientific integration of Europe and to strengthen its international outreach.

ESFRI has established a European Roadmap for Research Infrastructures (new and major upgrades, pan-European interest) for the next 10-20 years, stimulates the implementation of these facilities, and updates the roadmap as needed. The ESFRI Roadmap arguably contains the best European science facilities based on a thorough evaluation and selection procedure. It combines ESFRI Projects, which are new Research Infrastructures in progress towards implementation, and ESFRI Landmarks successfully implemented Research Infrastructures enabling excellent science.

The "Blue Accelerator" test platform

The Blue Accelerator project was initially introduced by the Flemish consortium of Ghent University (Coastal Engineering Research Group - UGent-CERG), the Public Provincial Economic Development Agency of West Flanders (POM West Vlaanderen), the Flanders Marine Institute (VLIZ), the Technical University Alliance for economic transformation in West Flanders (TUA West) and VITO NV. The Blue Accelerator project aims at providing a smooth development path for marine energy and maritime technology from early design stages to scaled models at the UGent wave flume and the Coastal & Ocean Basin (both managed by UGent-CERG), and to scaled prototype at the Blue Accelerator open sea test site. The Blue Accelerator is a maritime innovation and development platform and testing site for offshore blue economy research and industry projects. It is a versatile testing site, which allows to perform tests above, on, and underwater offering a broad range of services, e.g. marine sensors, fast and communications and transfer data system, energy supply in a secure and safe environment following the offshore industry standards and in-land storage space. POM West-Flanders holds a 15-year exploitation permit. The Blue Accelerator consortium is aiming at offering a grid connection by 2023 for offshore renewable energy projects.

The Blue Accelerator open sea test site at Ostend, Belgium.

The Blue Accelerator platform is located about 500 m off the port of Ostend. At this location, the average water depth is about 10 m and the tidal range 4 m. The testing zone is delimited by a circular area with a diameter of 440 m. The annual average significant wave height, Hs, and the energy period, Te, are 0.65 m and 4.9 s, respectively, with a wave power of 4.33 kW per metre of wave-front (wave energy resource assessment from historically recorded data at 51.247°N, 2.928°E). A long-term statistical study has predicted extreme values up to 8.5 m of wave height, when considering a return period of 100 years. Ocean currents between 0.15-0.9 m/s can be found at the Blue Accelerator testing site with values up to 1.87 m/s.

OWI-Lab

OWI-Lab (https://owi-lab.be/about-us) is the continuation of the R&D&I collaboration partnership between wind energy experts from Sirris, Vrije Universiteit Brussel and Ghent University within the IBN-Offshore Energy. The key pillars of the initiative are: (Test / Experiment) -Infrastructure, Expertise and the collaborative R&D&I Platform. Through technology expertise & infrastructure, innovation support services and international collaboration OWI-lab seeks to be a leading expertise centre that is supporting (international) innovation in the offshore energy sector. The R&D collaboration includes fundamental, applied and industry driven research & development and providing access to testing - and demonstration opportunities in real environments. OWI-lab provides access to unique and real-life test and demonstration infrastructure, operational insights and associated application knowledge to support R&D and innovation in our target group. This target group involves companies active in the onshore – and offshore wind energy business. The testing infrastructures and respective expertise services are also available to international partners.

OPIN

Sirris from Belgium is partner in OPIN (Ocean Power Innovation Network), an Interreg Northwest Europe project from the European Research and Development Fund (ERDF). OPIN is a cross-sectoral collaborative network that aims to accelerate the growth of the ocean energy sector and its supply chains across the partner regions of Belgium, Ireland, the UK, France, the Netherlands and Germany.

ITEG - Integrating Tidal Energy into the European Grid

A €11 million Interreg North-West Europe (NWE) project has been launched in Orkney to develop an all-in-one solution for the generation of clean predictable energy, grid management, and the production of hydrogen from excess capacity. Led by the European Marine Energy Centre (EMEC) in Orkney, Integrating Tidal Energy into the European Grid (ITEG) project brings together partners from across the UK, France, Belgium and the Netherlands to address energy-related carbon emissions in North-West Europe and tackle grid export limitations faced in remote areas such as Orkney. Funded by the Interreg NWE programme, part of the ERDF (European Regional Development Fund), the project will deliver an onshore energy management system at EMEC's Fall of Warness tidal test site, off the northern Orkney island of Eday. This will support the production of hydrogen using an AREVA H2Gen electrolyser, the first to be deployed in the UK, which will be powered by Scotrenewables' next generation 2 MW floating tidal energy converter, the SR2-2000. Power-Link from UGent had a role in communication and dissemination.

More information:
http://www.nweurope.eu/projects/project-search/iteg-integrating-tidal-energy-into-the-european-grid/

ELBEPlus project

ELBEPlus project Seven European clusters, including The Blue Cluster, join forces to shape a pan-European blue energy cluster with global ambitions. The focus is on wave energy, tidal energy and offshore wind energy, both fixed and floating. In addition, an analysis is carried out of the challenges for marine energy technologies, new value chains and opportunities for companies, also for companies that are not necessarily involved in this sector. This project is supported by the EU COSME programme.

More information:
https://www.blauwecluster.be/project/elbe-plus-european-leaders-blue-energy

Soiltwin

Today we see an industry-wide mismatch between design expectations and the as built dynamics related to monopile foundations. This mismatch results in a sub-optimal (fatigue) design and ultimately a higher cost for offshore energy. It is the general consensus of both academia and industry that this is due to errors in the interaction between the monopile and the surrounding soil. Current soil-structure interaction models are not "tuned" to correctly assess the soil stiffness at small displacements for short and large diameter piles, i.e. monopiles. This project, a collaboration between Ghent University (UGent-CERG) and the Vrije Universiteit Brussel, therefore aims to calibrate those models by updating them based on Finite element analysis and lab-experiments at the Coastal and Ocean Basin (COB) and on-site measurements.

More information at:
https://owi-lab.be/soiltwin

EnerGhentIC

EnerGhentIC is the interdisciplinary community of Ghent University researchers (38 professors, 210 FTE researchers, 5 faculties) working on the energy challenge. EnerGhentIC focusses on three main activities: (1) to stimulate research and valorisation in amongst other offshore wind, wave & tidal energy, (2) provide education and training for both professionals as well as master and PhD students and (3) to support and stimulate the energy transition. In this regard, EnerGhentIC engineered several strategic alliances, research collaborations and licensing deals with industrial partners for example IBN-Offshore Energy, Belgian Offshore Platform, OWI-LAB. Within specific projects, EnerGhentIC functions as liaison between industrial and academic partners and as valorization manager during and after the project.

BlueBridge

BlueBridge (former GreenBridge) is an incubator/innovation centre focused on blue growth located in West Flanders. Bluebridge is located in the high-tech knowledge hub Ostend Science Park (OSP) in the inner port of Ostend, covering marine and maritime topics. The R&D component is being represented at site through the expertise of Ghent University: the research groups StressChron and representatives of two consortia: Marine@UGent and EnerGhentIC. Their expertise encompasses stress physiology of fish, aquaculture, blue biotech, coastal defence and blue energy amongst many. A strong emphasis lies on industrial applications of the research and commercialization of fundamental research results.

More information at:
https://ostendsciencepark.be/bluebridge/bluebridge/

CANADA

REPORT PREPARED BY:
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OVERVIEW

The development of marine renewable energy continues to advance in Canada, supported by an evolving policy framework at both the federal and provincial levels. These policies are designed to foster the growth of offshore renewable energy technologies such as wind, wave, and tidal energy, while ensuring that project activities are conducted safely and responsibly.

In 2024, Canada took significant steps forward with the passage of Bill C-49, which amends existing offshore petroleum legislation to create a comprehensive regulatory framework for the joint management of offshore renewable energy projects in the Nova Scotia and Newfoundland and Labrador Accord Areas. This legislation is instrumental in guiding the development of offshore wind, tidal, and wave energy projects, ensuring that they are managed with the highest standards of safety, environmental protection, and sustainability.

The Government of Canada also launched new initiatives aimed at supporting the marine renewable energy sector through fiscal incentives. In the 2024 federal budget, Clean Economy Investment Tax Credits were introduced to help drive investment in wave, tidal, and other clean electricity technologies, reinforcing Canada's commitment to a clean and resilient energy future.

At the same time, the Government of Nova Scotia has introduced the *Advancing Nova Scotia Opportunities Act*, which enhances the flexibility of tidal energy development in the province. This legislation supports the province's ambition to integrate offshore renewable energy into its clean electricity and net-zero goals.

The Canadian sector continues to focus on realizing opportunities in marine renewable energy for remote and coastal communities that are reliant on diesel for electricity generation – a major market in Canada and also globally. Notably, Ocean Renewable Power Company (ORPC) Canada successfully completed its two-year demonstration of its RivGen device in Manitoba at the Canadian Hydrokinetic Turbine Test Centre (CHTTC). Yourbrook Energy Systems is moving closer to completing Phase 1 of a FEED study which will support its Kamdis Tidal Power Demonstration Project in British Columbia. The University of Victoria's Pacific Regional Institute for Marine Energy Discovery (PRIMED) also continues work to support wave and tidal energy development and uptake in British Columbia's remote communities. On the east coast, Eauclaire Tidal and Orbital Marine Power are working towards a deployment at the Fundy Ocean Research Centre, with permitting activities underway. Nova Innovation and New Energy Corporation continued to make progress on advancing projects targeted for deployment in the Bay of Fundy.

SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy

Government of Canada

Canada is proactively developing the legislative and regulatory framework to enable the development and growth of offshore renewable energy. In October 2024, Bill C-49, *An Act to amend the Canada-Nova Scotia Offshore Petroleum Resources Accord Implementation Act and the Canada-Newfoundland and Labrador Offshore Petroleum Resources Accord Implementation Act and to make consequential amendments to other Acts* reached Royal Assent, establishing the regulatory framework for joint management of offshore renewables. This legislation supports offshore renewable energy projects such as offshore wind,

wave, and tidal energy off the coasts of Nova Scotia and Newfoundland and Labrador. It also expands the mandate of the Offshore Petroleum Boards to the Offshore Energy Regulators, serving as the lifecycle regulators for offshore renewable energy projects in the Canada-Nova Scotia and Canada-Newfoundland and Labrador Offshore Accord Areas.

In 2024, the Government of Canada finalized and brought into force the federal *Canada Offshore Renewable Energy Regulations* (CORER), which establish comprehensive requirements related to safety, security, and environmental protection for the offshore renewable energy sector under the *Canadian Energy Regulator Act*. The CORER provide industry and other stakeholders with a clear understanding of the regulatory expectations and ensure project proponents adopt best practices and best available technologies throughout the lifecycle of offshore renewable energy projects, from site assessment through construction, operations, and finally, decommissioning and abandonment. These federal regulations do not apply to tidal energy projects in Canada's Bay of Fundy, as these tidal projects fall primarily under the jurisdiction of the provincial government of Nova Scotia.

Forthcoming regulations under the amended Accord Acts will provide similar regulatory certainty under the Canada-Nova Scotia and Canada-Newfoundland and Labrador joint management areas and ensure a coherent offshore renewable regulatory regime across Canada. Through these measures, Canada is establishing the legislative and regulatory regime to enable a competitive and sustainable offshore renewable energy industry while upholding the highest standards for safety, security, and environmental protection.

In June 2024, Fisheries and Oceans Canada released the Blue Economy Regulatory Roadmap. This roadmap outlines actions the Government of Canada will take to support innovation and economic growth in Canada's oceans. It focuses on five main areas, one of which is marine renewable energy and environmental protection. The roadmap advances four initiatives under the marine renewable energy and environmental protection theme, including the efforts outlined above to advance marine renewable energy legislation and regulations in the offshore. The remaining initiatives are focused on developing information products to clarify the project review process; exploring opportunities to improve review of clean growth projects; and supporting increased collaboration and coordination among federal departments in support and regulation of marine renewable energy projects. Updates on the progress of initiatives will be provided to partners and stakeholders as they are implemented.

Canada is proactively developing the legislative and regulatory framework to enable the development and growth of offshore renewable energy.

In fall 2024, the Impact Assessment Agency of Canada (IAAC) launched a discussion paper to receive input on a review of the *Physical Activities Regulations* which includes a threshold for tidal and offshore wind projects to undergo an impact assessment.

In late 2024, the Government of Canada released its final *Clean Electricity Regulations and Clean Electricity Strategy*, designed to help Canada achieve a net-zero electricity grid by 2035, in close collaboration with provinces, territories, Indigenous partners, industry, and others.

Tidal Energy Task Force

In February 2024, the Task Force on Sustainable Tidal Energy Development in the Bay of Fundy (the "Tidal Energy Taskforce"), an initiative established by the Government of Canada to address regulatory challenges faced by the tidal industry, published its final report. The purpose of the Task Force was to:

- build on work to date to clarify requirements for fish protection
- improve transparency and methodology of risk assessment and decision making on tidal turbine deployments

- reduce turnaround time for regulatory decisions for tidal energy projects in the Bay of Fundy

A key outcome of the Tidal Energy Task Force is the establishment of a "Revised" Staged Approach to authorizations under the federal Fisheries Act. This approach is intended to provide a fifteen-year conditional authorization for the staged deployment of small arrays of tidal devices with clear requirements for fish protection and monitoring. Although designed to address the conditions in Nova Scotia's Minas Passage, the revised staged approach could be adapted to tidal energy projects elsewhere in the Bay of Fundy.

Other key recommendations and actions from the Tidal Energy Task Force included:

- Establishing of a Risk and Monitoring Working Group ("Working Group") to support improved approaches and technologies for risk assessment and monitoring;
- Potentially enhancing the role of the Fundy Ocean Research Centre for Energy (FORCE) as a hub that integrates technical, environmental, and regulatory considerations while fostering innovation, practical applied science, and leadership;
- A commitment by Fisheries and Oceans Canada (DFO) to improve the understanding of risk assessment and monitoring by sharing information on its national approach to risk assessment, developing information materials on monitoring requirements for tidal energy proponents, and supporting the Working Group;
- Establishment of an oversight committee to track and monitor progress of its deliverables and to provide oversight and accountability to the Risk and Monitoring Working Group.

Nova Scotia

In September 2024, the Government of Nova Scotia introduced Bill 471 – *Advancing Nova Scotia Opportunities Act*, an important piece of legislation to help ensure offshore wind and tidal energy developments can contribute to achieving the province's clean electricity and net zero goals.

The Bill proposed amendments to the *Marine Renewable-energy Act* that create more flexibility for tidal energy development by creating the ability to split an existing license into two or more licenses. This ability provides greater alignment with other federal and provincial regulatory requirements and creates more options for industry to plan and deliver projects, while maintaining existing requirements for environmental protection. The Bill reached Royal Assent on September 20th.

Market incentives

Government of Canada

As opportunities and interest in Canada's marine renewable energy sector increase, the Government of Canada's 2024 Budget outlined measures that will help support and drive project development and growth in ocean energy sectors. These measures include the launch of the Clean Economy Investment Tax Credits through the finalization of legislative processes. These include a refundable 15% Clean Electricity Investment Tax Credit for eligible investments in wave, tidal, and other clean electricity technologies, a refundable 30% Clean Manufacturing Investment Tax Credit for new machinery and equipment used to manufacture or process key clean technologies, and extract, process, or recycle key critical minerals, including renewable energy equipment, and a refundable 30% Clean Technology Investment Tax Credit for investments in eligible property such as machinery and equipment used to manufacture or process clean technologies.

RESEARCH & DEVELOPMENT

Fundy Ocean Research Centre for Energy (FORCE)

In 2024, FORCE led and engaged in several R&D focused initiatives. These included:

Alignment of Acoustic Tagging Efforts

Several organizations are using acoustic telemetry to track movements of fish in the Bay of Fundy. Recently, DFO in partnership with the Ocean Tracking Network (OTN) at Dalhousie University, are planning to deploy an array of acoustic receivers to track movement of salmon. FORCE has been working to align individual research efforts by working with DFO, OTN, Confederacy of Mainland Mi'kmaq, and Acadia Tidal Energy Institute (ATEI) to help facilitate the collection of data on tagged fish across a broader area and improve efficiency.

Field Studies with Acadia Tidal Energy Institute (ATEI)

FORCE has been working with ATEI to improve monitoring capabilities by designing field studies for new and existing monitoring technologies, testing different sensor mounting configuration and exploring AI and machine learning.

Fish Synthesis Report

FORCE commissioned Dr. Graham Daborn (professor emeritus, Acadia) to build a synthesis of all fish studies of the Minas Passage to date which can serve to inform and strengthen monitoring programs and applications for Fisheries Act authorizations.

Adaptive Environmental Effects Monitoring Program (AEMP) Template

FORCE is helping developers ensure they use the most accurate and up-to-date scientific information as they apply for project authorization through DFO, using a standardized monitoring program template.

HydroAware Project

HydroAware is focused on expanding the use of artificial intelligence in fish tracking, in both acoustic telemetry technology and emerging tagless detection. FORCE is partnering with Innovasea, NB Power, Canada's Ocean Supercluster, and NS Power to enable energy generation while protecting critical fish populations.

A component of the project aims to use AI to make tracking technology perform better in the harsh, noisy, high-flow environments of Minas Passage, and provide exponentially more data than humans can produce manually counting fish on video for a few hours each week.

The objective is to bring Innovasea's technology to the tidal sector to dramatically reduce the cost, time and effort required for environmental monitoring and informing regulatory decisions – a potential game-changer for project timelines.

National Research Council (NRC)

National Research Council Canada's Ocean, Coastal and River Engineering Research Centre (NRC-OCRE) has completed research to characterize the hydrokinetic energy (HKE) resources of Canadian rivers and is conducting ongoing research to improve the performance of HKE turbines. Satellite imagery data and analytical methods were leveraged to estimate the HKE energy at river cross-sections across Canada in 100-meter spacing intervals. Most notably, through validation of the newly developed Canadian River Hydrokinetic Energy (CRHE) Database using field-measured data collected in Ontario, Quebec, and Nunavut and using Water Survey of Canada measurement data, confidence in using the CRHE Database estimates has been established. Communities and HKE developers will be able to explore the CRHE Database through an online mapping web application, increasing the accessibility and usefulness of the database, and the database will also be available for direct download.

NRC-OCRE is conducting an ongoing study to understand the conditions under which cavitation occurs due to HKE turbines, which will aid to bridge the gap between resource availability and the technical challenges of HKE resource extraction. This will be completed through both physical and numerical modelling. Ongoing research in 2025 will include the use of analytical methods to estimate river HKE resources globally using newly available datasets, ongoing publication of results from the development of the CRHE database, and ongoing data collection and analysis of HKE turbine cavitation. Additionally, the possibility of HKE resource extraction in the Canadian Arctic will be explored further with collaboration from local communities and local renewable resource developers.

Natural Resources Canada – CanmetENERGY-Ottawa

In the current year, CE-O has continued to focus on advancing projects for the new project cycle, including the development of marine technologies, enhancement of resource assessment tools, and support for the growth of marine renewable energy. In collaboration with CE-O, ORPC has carried out a site characterization project on the St. Maurice River to support the development of a demonstration project. River flow data were collected using an Acoustic Doppler Current Profiler (ADCP) and a Remotely Piloted Aircraft System (RPAS). This data will be used to validate numerical models, which will help identify optimal locations for hydrokinetic deployment in the river.

CE-O and Primed at the University of Victoria have jointly launched a project to improve tidal energy resource assessments in Quatsino Narrows by developing and validating a high-resolution hydrodynamic model. The project includes deploying an ADCP to measure tidal elevations and current velocities, conducting a drone survey to capture high-resolution video and surface current data, and using these measurements to calibrate the model. The collected data will be analyzed to generate reports on tidal currents, velocity distributions, and potential energy output, along with recommendations for site selection and development. The goal is to identify optimal locations for Tidal Energy Converters (TECs) and support sustainable tidal energy growth in British Columbia.

CE-O and Carleton University are also working to enhance the predictive accuracy of river flow and related parame-

ters through machine learning models, aiming to produce resource assessment maps for medium and large rivers in the Yukon and Northwest Territories.

CE-O, NRC, and Laval University are continuing our research on cavitation, its impacts, and potential preventive measures. An axial-flow hydrokinetic turbine model has been designed and will be manufactured and tested at NRC's St. John cavitation tunnel facility. In parallel, numerical models are being developed to accurately replicate the experimental conditions in the test facility.

University of Victoria (UVic)

The University of Victoria (UVic) continued to make progress leading several projects and initiative focused on wave energy and clean energy for remote community development working with local suppliers, industry, researchers, and Indigenous communities. UVic continues to lead this work through PRIMED, which is aimed at eliminating the uncertainty and risk for "first-of-a-kind" community based marine renewable energy projects. Key projects and activities over 2024 included:

Yuquot Wave Energy Project

The project team, led by the Mowachaht/Muchalaht First Nation, continues to advance detailed design, costing, and environmental assessment works for the Yuquot Wave Energy Project. The project is engaging with relevant federal and provincial regulators and will be submitting permit and license applications spring/summer 2025 in order to progress through regulatory requirements toward full project build out in 2028/2029. The project team held a regulatory workshop in February 2024 to reintroduce the Project in its current iteration to pertinent regulators. It provided the opportunity to solicit guidance on necessary works such as environmental studies and submission of designs needed to support permit and license applications in the Project design, development, and construction phases.

Figure 1: Hydrophone deployment at proposed WEC site

In July 2024, a hydrophone was deployed at the identified wave energy converter installation site in collaboration with Ocean Networks Canada. This was done in an effort to characterize the baseline soundscape and the presence of cetaceans in the area, with the target species of interests being Gray Whales. The hydrophone was recovered in November 2024 and the data is currently being analyzed that will inform baseline environmental assessment report, construction management plan, and operations management plan.

Haida Gwaii Marine Energy Planning

PRIMED has continued its research program in collaboration with the Council of the Haida Nation (CHN) looking to characterize marine renewable energy (wave, tidal, offshore wind) resources around Haida Gwaii. This program is comprised of resource characterization through field work/data collection and model development that will then support site identification research and energy integration modelling.

Previous works include the deployment of multiple acoustic doppler current profilers, deployment of a TRIAXYS wave buoy, and most recently the deployment of a Floating Light Detection and Ranging (FLiDAR) WindSentinel buoy unit to characterize the offshore wind and wave resource off the coast of Síigee G̲adsguusd McIntyre Bay in September 2024. This site was selected in consultation with the CHN Marine Planning Program and is strictly for research purposes – it is not a proposed site.

TECHNOLOGY DEMONSTRATION

Existing open sea test sites

FORCE

FORCE is Canada's lead centre for the demonstration of in-stream tidal energy technologies and continues to lead various research and initiatives to gather knowledge about tidal energy and support technology and project demonstration. In 20234, FORCE continued to support tidal energy projects at its site led by Eauclaire Tidal, Occurrent Power, and DP Energy (*see section 4 for more details*).

The Province of Nova Scotia and FORCE are in ongoing discussion around an upcoming berth tendering process to fill two vacant berths at FORCE: Berths B (cabled) and E (uncabled).

Blind Channel Test Centre

Following assessment and consultation with stakeholders on the results of the front-end engineering phase, the Blind Channel project team took selected designs forward through detailed engineering design in 2024. This also included procurement/contracting for build and installation of onshore and offshore components.

Installation of a 25-kW tidal energy converter on site is expected to occur spring 2025 and commissioning by summer 2025 followed by operation of the resident HPG turbine for at least 18 months. Works include the completion of the hybrid renewable energy system microgrid comprised of tidal, solar, diesel, and a turnkey battery energy storage system and microgrid controller solution developed by BMT Canada and PRIMED.

Pacific Regional Institute of Marine Energy Discovery (PRIMED) has also advanced regulatory and consultation aspects of the project with federal, provincial, and Indigenous governments. A baseline environmental assessment report has been completed along with the development of PRIMED's environmental monitoring program comprised of a suite of instruments including optical cameras, a hydrophone, an imaging sonar, and vessel-based surveys.

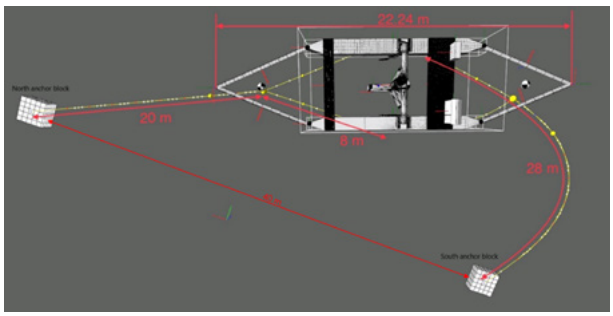

Figure 2: Blind Channel Tidal berth design

Projects in the water

Ocean Renewable Power Company (ORPC) Canada

In 2024, ORPC Canada successfully completed its two-year demonstration of the RivGen® Power System at the Canadian Hydrokinetic Turbine Test Centre in Manitoba. The company also conducted resource assessment and feasibility studies in partnership with remote and Indige-

Figure 3: RivGen® Power System at the Canadian Hydrokinetic Turbine Test Centre in Manitoba

nous communities in Yukon, Northwest Territories, British Columbia and Quebec, as well as industrial users on the St. Maurice River and St-Lawrence River (QC), assessing the potential for these free-flowing rivers to provide baseload energy in preparation for further deployments.

Projects planned for deployment

Eauclaire Tidal & Orbital Marine Power

In December 2023, Eauclaire Tidal announced it had partnered with Orbital Marine Power (Orbital) to deploy its technology at FORCE. Scottish-based Orbital already operates the world's most powerful tidal turbine, the 2 MW O2. The floating device is 74 meters in length, supporting two 1-MW turbines. Orbital's floating technology is designed to:

- Make installation and maintenance easier, lowering operational costs and risk.
- Capture energy from stronger currents near the surface, generating more electricity.

A majority of Orbital's project work is completed in controlled environments, i.e., shipyards and onshore factories, to minimize offshore construction work and lower manufacturing and installation costs.

Orbital is collaborating with FORCE and Acadia University in their application to Fisheries and Oceans Canada (DFO) for a Fisheries Act authorization to deploy three devices at FORCE.

New Energy Corporation

New Energy Corporation received support from the DFO for the installation of a 25 kW system in Grande Passage, Nova Scotia. This project, in collaboration with Sustainable Oceans Applied Research and the Canadian Hydrokinetic Turbine Test Center, is largely focused on optimizing the installation of a single system first, which will be fully equipped with a variety of environmental sensors and cameras to gain a thorough understanding of marine interaction with the turbine. Knowledge from the initial installation will be brought forward to other project sites in the region, including New Energy's 800 kW birth in Minas Passage.

Internationally, New Energy designed and delivered a state-of-the-art 5 kW floating hydrokinetic turbine prototype to a large US customer. The delivery of this system is as part of a demonstration and research and development program that is intended to increase the accessibility and ease of deployment for hydrokinetic technology in a variety of application types.

Nova Innovation

Nova Innovation continues to plan for the installation of its 1.5 MW tidal energy project in Petit Passage, Nova Scotia and is currently assessing the logistical, contracting, and scheduling options for deployment of the first of the Phase 1 turbines.

Yourbrook Energy Systems

Yourbrook Energy Systems signed an MOU with TII Yaada Energy, the energy company of the Haida Nation, to move forward in a partnership that will align with the existing plans to get Haida Gwaii off diesel.

With support from Natural Resources Canada (NRCan), Yourbrook is working towards completing Phase 1 of a FEED study in March 2025. Phase 2 will be completed in mid 2025 and construction of the Kamdis Tidal Power Demonstration Project has a projected start in September 2025.

RELEVANT NATIONAL EVENTS

Relevant events in 2024

Marine Renewables Canada 2024 Annual Conference
November 19-21, Halifax, Nova Scotia

Relevant events planned for 2025

Marine Renewables Canada 2025 Annual Conference
November 12-14 Halifax, Nova Scotia

CHINA

REPORT PREPARED BY:
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National Ocean Technology Center

OVERVIEW

In 2024, with the aim of achieving the goal of "carbon peak and carbon neutrality", China has implemented a series of plans and policies to promote green and low-carbon development, and supports the accelerated development of marine renewable energy such as ocean energy. China has continuously pushed for the large-scale utilization of ocean energy, carried out large-scale demonstration projects of tidal current and wave energy, supported the cultivation of new ocean energy technologies, continuously expanded the application scenarios of ocean energy, and expedited the development of ocean energy industrialization.

SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy

In November 2024, China promulgated and implemented the "Energy Law". The "Energy Law" serves as the fundamental and leading legislation in China's energy domain. It consists of nine chapters, namely general provisions, energy planning, energy development and utilization, energy market system, energy reserve and emergency response, energy scientific and technological innovation, supervision and management, as well as legal liability. It will come into effect on January 1, 2025. The "Energy Law" proposes to facilitate the large-scale development and utilization of ocean energy.

In August 2024, the State Council of China released the China's Energy Transition White Paper, which indicated that accelerating the development of energy transition, achieving sustainable energy utilization, continuously enhancing people's well-being, and providing an inexhaustible driving force for the world economy has become an international consensus. The white paper also pointed out that China has made positive advancements in the large-scale utilization of ocean energy.

In July 2024, the State Council of China issued the "Opinions on Accelerating the Comprehensive Green Transformation of Economic and Social Development", which set forth the key tasks for promoting green transformation and provided a development roadmap for China's green transformation. The Opinions proposed that, in light of the specific circumstances of different regions, appropriate measures should be adopted to develop new energy sources such as ocean energy.

In May 2024, The State Council of China issued the Action Plan on Energy Conservation and Carbon Reduction for 2024-2025. The Action Plan sets specific targets for China's energy conservation and carbon reduction by 2025. In terms of key tasks, the Action Plan proposes to promote the large-scale development and utilization of ocean energy.

Market incentives

In April 2024, with the objective of accelerating the demonstration application and promotion of green and low-carbon advanced technologies, NDRS released the List of Green and Low-Carbon Advanced Technology Demonstration Projects (the first batch). The megawatt-level wave energy key technology research and demonstration application projects were included in the first list of projects.

In March 2024, China's National Development and Reform Commission (NDRS), Ministry of Industry and Information Technology (MIIT), Ministry of Natural Resources (MNR), and other ministries jointly issued the "Green Low-carbon Transformation Industry Guidance Catalogue (2024 edition)". The "Catalog" is based on the "Green Industry Guidance Catalogue (2019 edition)" and has been revised in light of the new circumstances, new tasks, and new requirements of green development. The Catalogue proposes to support the development of green and low-carbon energy transformation industries such as the manufacturing of marine energy development and utilization equipment, and the construction and operation of marine energy utilization facilities.

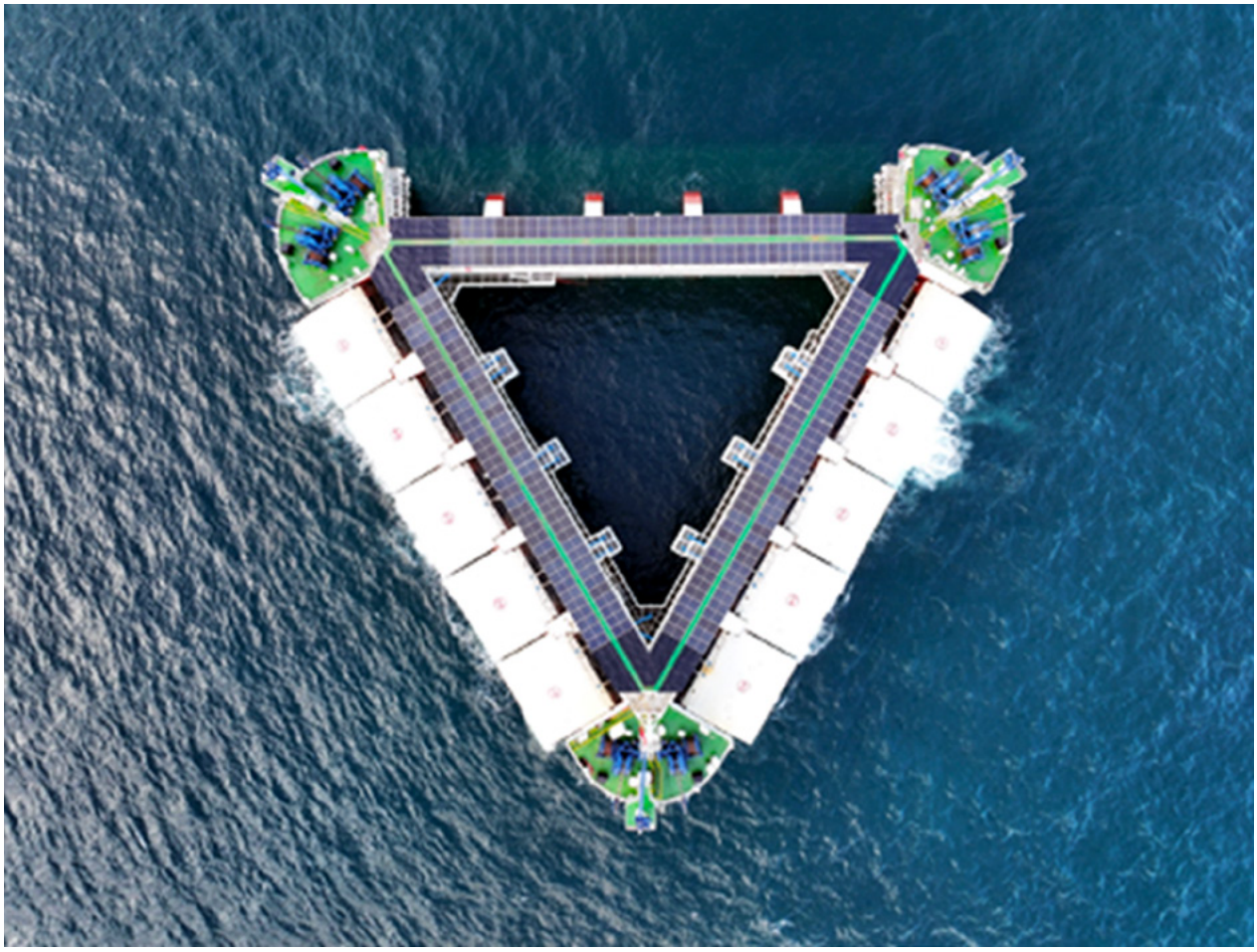
Public funding programmes

In 2024, in order to promote the innovation and development of renewable energy technology, the Ministry of Science and Technology (MOST) of China continues to support the research of ocean energy technologies.

RESEARCH & DEVELOPMENT

Wave energy

In 2024, Guangdong Grid Co. of China Southern Power Grid (CSG) led the joint development of China's first megawatt-class floating wave energy generation device, **"Nankun"**, and it has been deployed for open sea



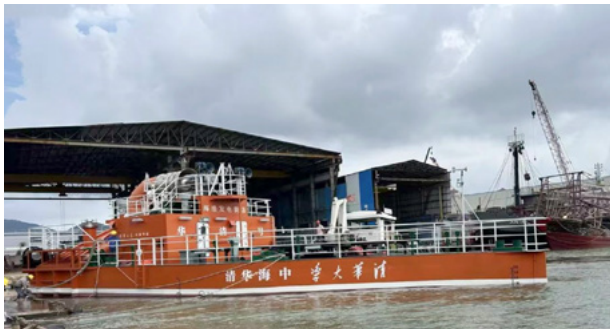
Nan Kun in sea trial operation

tests. “Nankun” has a triangular structure, which is highly resistant to typhoons and provides clean power supply for the island and other areas. During the sea trial, "NanKun" successfully endured the test of a strong typhoon, verifying its survivability and reliability in harsh sea conditions.

The research team of **Shandong University** persists in conducting research on wave energy utilization technology. Based on previous studies, the team initiated the development and sea trial work of the third-generation oscillating float wave energy power generation device. This device has been deployed in the sea area of Jiaoji Island, Shandong Province since 2023 and was recovered in October 2024, completing a total of 388 days of sea tests. During the sea trial, it has withstood several typhoons and still maintained normal operation. Compared with the first and second generation products, the third generation products have higher power generation efficiency, better working reliability, and lower manufacturing and maintenance costs.

In January 2024, on the basis of the first generation of 30 kW wave power generation prototype machine, the second generation 100 kW pneumatic wave power generation device developed by Tsinghua University research team **WaveLoong®** was successfully launched in Jiangmen City, Guangdong Province, and carried out sea test operation.

Shandong University wave energy device in sea trial



WaveLoong® OWC wave energy device

Guanhai I wave energy buoy in sea trial

The Guangzhou Institute of Energy Research of Chinese Academy of Sciences has carried out continuous research on small wave energy power supply devices, and successfully developed a variety of small wave energy power supply buoys. At present, Guangzhou Energy Institute is carrying out the development of 10 kW **"Guanhai I"** wave energy in-situ power supply observation buoy, and has carried out sea test operation.

The research team of **Jimei University** continues to carry out research on wave energy power generation technology, and has developed the "Jida" series wave energy power generation platform. At present, the team is carrying out the research and development work of the "Jida IV" 100 kW wave energy generation platform, and the "Chengyi I" 200 W small wave energy generation buoy for ocean observation instruments.

Tidal current energy

Focusing on the characteristics of low-velocity current energy resources, with an emphasis on low-velocity start-up, efficient energy transfer and electromechanical conversion technologies, the research team of **Zhejiang University** has carried out the development and real sea condition testing of a 4kW dual-impeller low-velocity tidal current energy turbine. Regarding the power supply for ocean observation instruments, the research team from Zhejiang University has developed a 100 W low-velocity tidal current power generation device and deployed it for open sea testing.

TECHNOLOGY DEMONSTRATION

Existing open sea test sites

In 2024, the Ministry of Natural Resources of China persisted in promoting the construction of the National Marine Comprehensive Test Site. In May and October, the unveiling ceremonies of the National Marine Comprehensive Test Ground (Zhoushan) and the National Marine Comprehensive Test Ground (Zhuhai) were respectively held in Zhoushan, Zhejiang and Zhuhai, Guangdong. At present, the Weihai, Zhoushan and Zhuhai sites have initially been equipped with the capacity to offer test services for tidal current energy turbines and wave energy devices.

Deployment of test equipment in Zhoushan test site

Projects in the water

Wanshan 1 MW (2×500 kW) Wave Energy Demonstration Project

In 2024, two 500-kilowatt wave energy generation devices, "Zhoushan" and "Changshan", continued their demonstration operation. By December 2024, the project had met the design requirements.

500 kW "Zhoushan" and 500 k "Changshan" wave energy platforms

Penghu Wave Energy Aquaculture platform

The Penghu wave energy deep-water aquaculture platform has maintained stable operation, successfully completed multi-species and multi-quarter aquaculture, and achieved excellent demonstration and economic results. As a successful case of the combination of marine energy and marine aquaculture for "green development", this platform has formed a series of products that can meet the needs of users in different sea areas.

Multi-type deepwater aquaculture platforms

LHD Zhoushan Tidal Current Power Station

The LHD Zhoushan tidal current power station has maintained stable operation, having been in operation for more than 7 years. In March 2022, the "Endeavour" turbine, China's first megawatt-level tidal current energy generator developed and built by the project, was successfully deployed and connected to the grid. As of the end of 2024, the generator has been in continuous operation for over 30 months, with a cumulative grid-connected power generation of over 4.5 million kWh.

LHD Zhoushan tidal current power station in operation

Zhoushan Tidal Current Energy Demonstration Project

In 2024, the China Three Gorges Corporation continued to carry out the technical transformation and installation of the tidal current energy turbines of the Zhoushan Tidal Current Energy Demonstration Project and conducted grid-connected demonstration operation. The demonstration project has three public test berths for tidal current energy and can provide offshore testing services for tidal current energy prototypes. It is the first tidal current energy demonstration project in China with public testing service capabilities. It stands as China's first tidal current energy demonstration project equipped with public testing service capabilities. By December 2024, the project had met the design requirements.

SG500A/B tidal current energy turbines

SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

On November 1, 2024, the 2024 APEC Economies' Marine Energy Integration and Development Seminar was held in Shenzhen, China. The seminar was themed on promoting the integrated development of marine energy among APEC economies, facilitating the sustainable development and utilization of marine energy in APEC economies, and fostering exchanges and cooperation in marine energy among APEC economies. It aimed to ex-

plore the multi-field integrated development of marine energy and related industries through interdisciplinary discussions and exchanges, build a platform for marine energy cooperation and exchanges among APEC economies, share innovative resources and development experiences, and support the sustainable development of the marine energy industry in APEC economies in the future. A total of 23 experts and scholars from China, South Korea, Japan, Malaysia, Indonesia, Papua New Guinea and other countries attended the meeting.

RELEVANT NATIONAL EVENTS

On October 31, 2024, the "2024 Marine Renewable Energy Industry Development Forum" was held at the Shenzhen Convention and Exhibition Center (Futian). This forum, with the theme of "Accelerating the Development of New Marine Productivity and Promoting the Large-scale Utilization of Marine Energy", was guided by the goal of practicing the concept of green development and building a new pattern of marine energy. It focused on the development trends of the marine renewable energy industry at home and abroad, and conducted exchanges and discussions on hot issues such as policy mechanism guidance, high-tech innovation, industrial application demonstration, public service platform construction, and international cooperation and exchange, providing a high-level cooperation platform for the marine energy industry. A total of more than 200 experts and scholars from enterprises, social organizations, universities and research institutions related to the marine renewable energy industry participated in this forum.

2024 Marine Renewable Energy Industry Development Forum

DENMARK

REPORT PREPARED BY:
Kim Nielsen, Development v Kim Nielsen

OVERVIEW

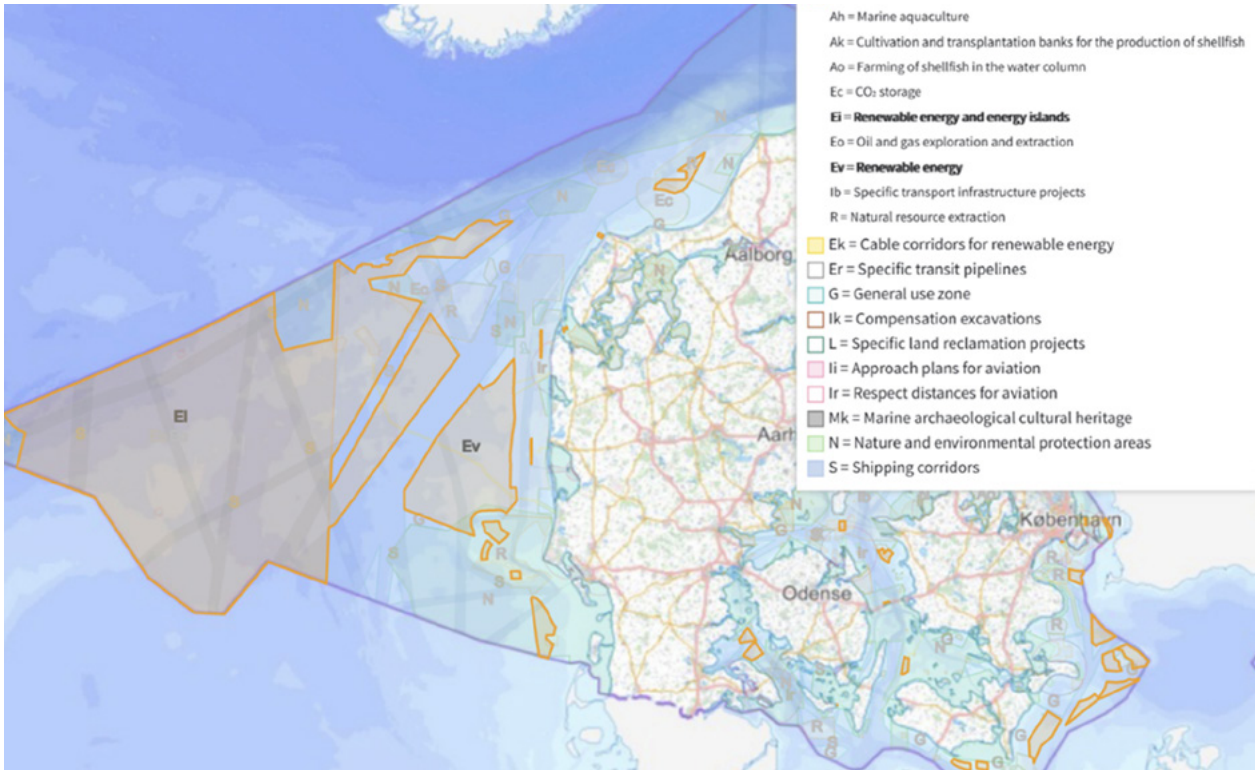
The Danish Partnership for Wave Energy is hosted by Energy Cluster Denmark and in 2024 the partnership included nine active startup companies working on development of the wave energy converters: Wave Dragon, Wavepiston, WaveStar, ExoWave, Floating Power Plant, Weptos, CrestWing, OceanSwellEnergy and KNswing with academic support from DTU and AAU.

To celebrate and promote wave energy, "Bølgeenergiens dag" (the Day of Wave Energy) was announced for the first time in 2024 hosted by its creator HORTEN, with the aim to attract investors and an interested audience. More than 65 delegates turned up to celebrate the Danish achievements in development of wave energy converters, since the initial involvement almost 50 years ago following the energy crisis in 1973. The Day of Wave Energy is expected to become a reoccurring annual event and in 2025 it will be held on the 27th of March.

SUPPORTING POLICIES FOR OCEAN ENERGY

Marine spatial planning policy

Denmark has created a plan for the use and share of the space at sea "the Havplan" and the test site DanWEC



The Danish "Havplan" indication of the spatial planning

for testing Wave Energy Converters is included in the Havplan. The Danish Energy Agency is responsible for the permitting of wave energy test installations at sea.

National ocean energy policy

Wave energy activities in Denmark continue to be driven by the 'Strategy for Wave Power' published in 2012 and by the 'Danish Wave Power Roadmap' from 2015 developed by the Partnership for Wave Power with support from Energinet.dk and the Danish Energy Agency. The Danish National Energy and Climate Plan (NECP) covers various dimensions, including the deployment of renewable energy sources, energy efficiency, and energy security – and it is expected that wave energy will be included when the technology reaches sufficient maturity in reliability and cost effectiveness.

Market incentives

There are at present no dedicated market incentives for wave energy in Denmark such as special feed in tariffs. The fundamental principles to make wave energy successful are the same that made Danish wind energy technology an international success:

- Financial incentives
- Guaranteed demand
- Long-term framework conditions

The Danish partnership proposes to combine project funding with revenue support e.g. feed in tariff from initial demonstration of the projects at official test sites.

Public funding programmes

The Energy Technology Development and Demonstration Programme EUDP is the main national funding programme under which ocean energy development can be supported in Denmark. Established in 2007, EUDP is a grant-based programme that supports pre-commercial projects in the development and demonstration of new energy technologies.

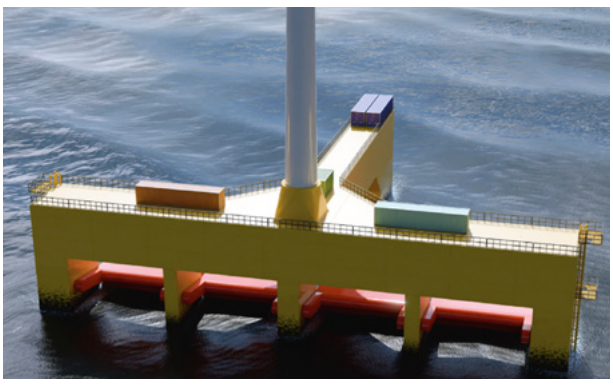
EUDP was established to ensure that innovative technology projects are carried out that support the achievement of energy policy objectives of security of supply, Danish independence from fossil fuels, global climate concerns, a cleaner environment, and cost-effectiveness. The typical EUDP project is industry-driven and has 3-5 participants (project leader and partners), a project duration of 3 - 4 years and receives funding of DKK 2 - 15 million with a EUDP funding share of 40 – 60 %. Since its creation, the EUDP has helped fund almost 600 projects and has a remarkable track record of advancing the technological maturity level (TRL) of the funded technologies from an average of 4 (technology validated in a lab) to an average of 7 (later stages of product development).

RESEARCH & DEVELOPMENT

Researchers from both Aalborg University (AAU) and the Technical University of Denmark (DTU) are collaborating with the wave energy developers on a range of research projects as mentioned below.

SHY project: Seawater HYdraulic PTO using dynamic passive controller for wave energy converters, is a €4m project led by Wavepiston with the industry and research partners DTU, Maynooth University, Marine Systems Modelling, Julia F. Chozas, Applied Renewable Research, PLOCAN, FibronPipe and Leser. The project is funded by the EU Horizon Europe programme.

The SEAWORTHY project (Sustainable dispatchable Energy enabled by wAve-Wind OffshoRe plaTforms with onboard HYdrogen) is a groundbreaking commercial-scale endeavor that integrates wind, wave, and hydrogen technologies to deliver clean, dispatchable offshore power. Supported by a €26 million grant from the European Commission's Innovation Fund, SEAWORTHY aims to demonstrate the commercial viability of this integrated approach. The project will deploy a platform featuring a 4.3 MW wind turbine, which has already been procured alongside a 0.8 MW wave energy converter, and a hydrogen system comprising a 1 MW electrolyzer, 48 MWh of energy storage, and a 1.2 MW fuel cell. This platform is set to be installed at the PLOCAN test site off the coast of Las Palmas, Gran Canaria, Spain, marking the world's first wind-wave-hydrogen unit.



Floating Power Plant

Ongoing projects funded by EUDP include:

The **HydroFlex** project, coordinated by FPP and involving Aalborg University (AAU) Build as partner, focuses on optimizing a combined system of floating wind energy and hydrogen storage, with the potential to integrate wave energy. Floating wind turbines enable the utilization of marine areas that are inaccessible to conventional, fixed-anchored turbines due to water depth, thereby tapping into previously untapped wind energy potential. The HydroFlex project aims to enhance this combined system, with plans to test and demonstrate the new design on a laboratory scale. The final full-scale demonstration is intended to take place within the framework of the SEAWORTHY project (mentioned above).

Weptos is working on the optimisation of the design combining model scale tests at AAU with detailed design.

OES Task 10 on Numerical modelling and Verification, with funding covering the Danish participation in the Task of the international collaboration on modelling Ocean Energy Converters under OES. It is led by AAU and include DTU, FPP and Development v Kim Nielsen.

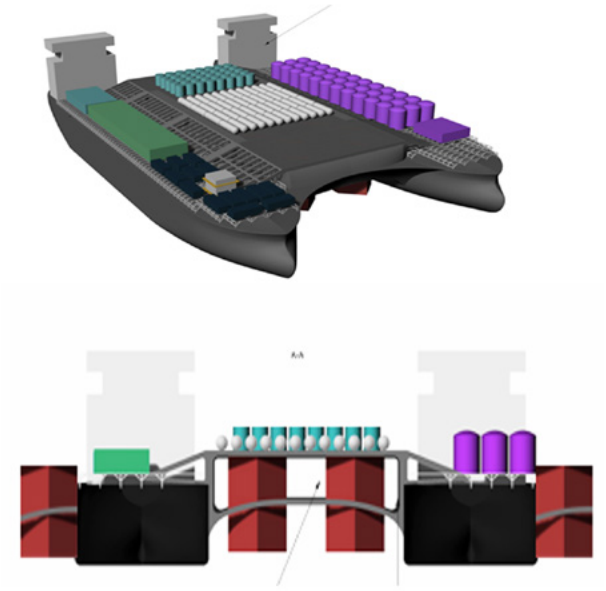
Demonstration of a market-mature, profitable, efficient and reliable wave energy plant, a project is led by CrestWing funded by EUDP to optimize their PTO (power take-off), where a test bench at Aalborg University in Esbjerg was developed.

COHSI-WEC project, led by Wavepiston and concerns the development and testing of a lighter, cheaper, and more robust version of its energy collector. DTU and AAU are partners in the project on accelerated testing, numerical modelling, and wave tank testing of their new flexible blades. Full-scale offshore testing of the novel concept is scheduled for completion at PLOCAN, Gran Canaria.

250 MW wave power in the Danish North Sea by 2030 (phase 1), in which Exowave is planning to be able to establish a 250 MW wave power plant together with an offshore wind farm before 2030 in Danish waters. The purpose of this phase is to develop and demonstrate a wave power plant with an associated water turbine generator that must be able supply approx. 100 kWp of electricity.

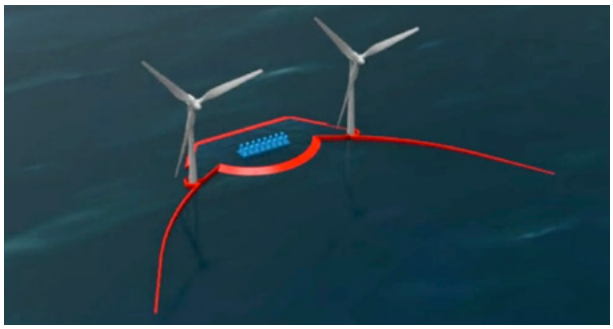
Other ongoing wave energy projects:

OceanSwellEnergy plan to convert used ships to harness wave energy. The idea is to use single hull vessels at suitable size/length with OWC's attached to the outside skin on both sides of the hull coupled to turbines for power conversion to electricity. In another larger scale combine two up to 350 m long ships together as a catamaran, integrate OWC chambers into or connected to the hull outside skin to absorb the energy from the waves and on the large deck and in-hull have ample room for hydrogen production, P2X plant, desalination equipment, data warehousing or accumulated energy storage. The unit(s) is intended for mooring as single line moorings at up to very large water depths with minimum footprint on seabed.



Ocean Swell Energy

Wave Dragon is focusing on the development of a 3 MW wave power project at Gran Canaria's PLOCAN. The plant consists of a 1.5 MW wave power converter equipped with two 750 kW wind turbines. In parallel, an 8 MW plant is also being developed again with 2 wind turbines integrated. This plant will be the first in a planned wind farm off Wales, which in the first phase is expected to be just over 100 MW. Such a park is expected to be able to obtain a CfD contract (feed-in tariff) of DKK 2-3 per kWh, which makes it interesting to work with wave energy in the UK.



Wave Dragon with windmills

WaveStarEnergy could be an up to 250 m long bottom-fixed structure that can be placed in a depth of 20 m, with multiple floats it will be able to produce up to 6 MW.

KNSwing is investigating incorporation of the OWC system into floating structures. In collaboration with DTU investigating using active control valves for increased one way absorption.

IEC Standards - Dansk Standard is the Danish partner under the international collaboration on standards IEC TC 114: Marine energy – Wave, tidal and other water current converters. In 2024 it was published:

- Specification DS/IEC TS 62600-100:2024 Marine energy – wave, tidal and other water current converters – Part 100: Electricity producing wave energy converters – Power performance assessment (integrating previous publication 102 into its annex).
- Specification DS/IEC TS 62600-101:2024 Marine energy – Wave, tidal and other water current converters – Part 101: Wave energy resource assessment and characterization

TECHNOLOGY DEMONSTRATION

Existing open sea test sites

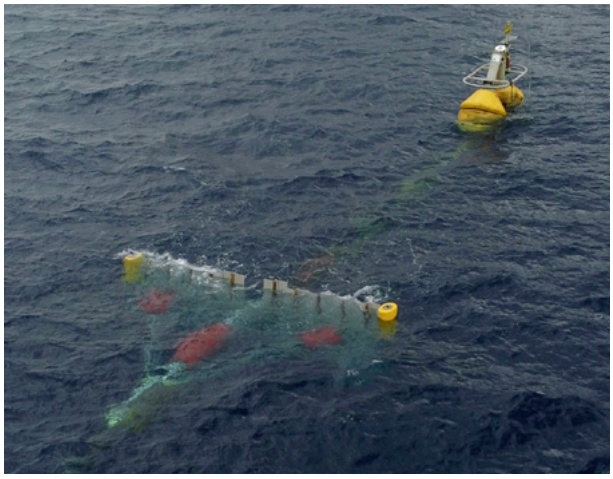
Windy weather, good water depth, good wave conditions and a competent service industry make the Port of Hanstholm an obvious place for testing wave energy. The Danish test site for Wave Energy "DanWEC" was created in 2010 and received in 2024 a grant of DKK 1,5 million (€ 200k) from the Danish Government to support upgrading of equipment. The funds have been used to upgrade DanWEC's two wave rider buoys and the moorings and the marking buoys of the test area located 2 km from the Port of Hanstholm. In 2024 the administration of the test site has been transferred to Port of Hanstholm.

Location of the test site DanWEC at Hanstholm

Port of Hanstholm

Projects in the water

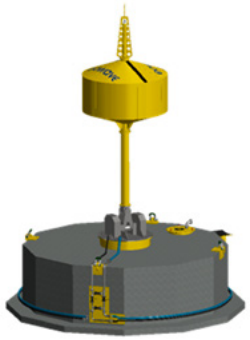
Wavepiston is testing and demonstrating at full-scale at the PLOCAN test site in Gran Canaria. The project contains various tests of components in the sea such as the moorings, the water hydraulic pumps, the sails, and the pipe connecting the WEC system to the fixed platform – where desalination and power production takes place. Furthermore, the site will be used as an offshore test bench for improved versions of Wavepiston's energy collector that is currently being developed in the two research projects SHY and COHSI-WEC (mentioned earlier). This will enable the acceleration of commercialisation.



Wavepiston v1 being tested in Gran Canaria

Projects planned for deployment

250 MW wave power in the Danish North Sea by 2030 – phase 1 is led by Exowave and the first phase will demonstrate the operation of a 40 kW prototype placed in 14 meter water depth at the test site in the North Sea at the Port of Hanstholm. The ExoWave power plant will supply hydraulic power, where the medium is seawater, to a water turbine that stands on the shore and drives a generator that converts the hydraulic power into electrical power.



Prototype of EXOWAVE to be installed at the test site in Hanstholm

Crestwing is concluding its final testing of the optimized Tordenskjold prototype in Kattegat by year-end. At the same time, they are preparing for the manufacturing and certification of their utility-scale 2.5 MW C-WEC.

CrestWing prototype

SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

The Danish Wave Energy developers are all open to international collaboration.

Wavepiston is active in the Canary Islands, as well as the Caribbean, with project development ongoing in Martinique and Barbados. Working with local partners is essential for the success of these projects. Wavepiston is collaborating with YS Energies Marines Developpement for a pilot plant in Martinique and has together with Export Barbados (BIDC) recently finalised a pre-feasibility study for the deployment of wave energy farms in Barbados. Both partners are planning the next steps in the project's development. Wavepiston has also signed a co-location collaboration agreement for an offshore wind and wave farm with Ørsted, one of the largest offshore wind developers worldwide. Although the project is planned for Danish waters, it shows the interest and willingness to collaborate, not only from the wave energy developers but more importantly, from global players in the renewable energy sector.

RELEVANT NATIONAL EVENTS

During 2024 there are two national events in wave energy that are planned again for 2025: "Bølgeenergiens dag" (wave power day) and Folkemødet på Bornholm (27 March 2025)

Folkemøde på Bornholm 2024

EUROPEAN COMMISSION

REPORT PREPARED BY:
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OVERVIEW

The European Commission is supporting the development of the ocean energy sector through an array of activities: the Green Deal, the Energy Union and the SET-Plan in particular, and also by stimulating a sustainable blue economy in the EU[1].

In October 2023, the European Commission presented a communication **'Delivering on the EU offshore renewable energy ambitions'**[2]. It proposes to increase Europe's offshore wind capacity, including floating wind, to at least 111 GW by 2030, which is nearly twice as high as the ambition set out in the Offshore Renewable Energy Strategy published in November 2020. For ocean energy it adjusted the timeline stating that 100 MW of ocean energy capacity is achievable by 2027 and 1 GW by the end of the decade or early 2030's. The Commission published as well a revised SETplan[3] addressing cross cutting issues, like digitalisation, circularity, clean energy materials, societal needs and skills to accelerate the clean energy transition.

The European Commission cooperates closely with its Member States to increase support for ocean energy and to encourage them to include trajectories for marine renewable energies in their 2030 National Energy and Climate Plans.

The European Commission continued to support ocean energy development via their EU funding programmes. The Horizon Europe programme has launched new calls in 2024. The Innovation Fund support programme has been launched in 2020 and published new calls in 2024 for projects on net zero technologies with deadlines in 2025 (24 April 2025). Ocean Energy is listed as a net zero technology.

As part of the Clean Energy Technology Observatory the Joint Research Centre of the European Commission has published the report 'Ocean energy in the European Union - 2024 Status Report on Technology Development, Trends, Value Chains and Markets'.[4]

SUPPORTING POLICIES FOR OCEAN ENERGY

European strategy

The European Commission presented the European Green Deal in 2019. It is the most ambitious package of measures that should enable European citizens and businesses to benefit from sustainable green transition. The Green Deal has led to several communications and directives in the following years to achieve its targets.

The Offshore Renewable Energy Strategy is the key policy initiative released in 2020 to support the development of ocean energy in the EU. It places significantly emphasis on the need to continue the cost-reduction of ocean energy technologies to enable for the uptake of wave and tidal energy technologies in the EU energy system. In October 2023 the Commission states in its new communication 'Delivering on the EU offshore renewable energy ambitions'[i] that the EU has made good progress in ocean energy development since the launch of the Offshore Strategy. This has been achieved notably with EU funding for R&I (Horizon Europe/Innovation Fund). However, progress

1 https://ec.europa.eu/oceans-and-fisheries/ocean/blue-economy/sustainable-blue-economy_en
2 COM(2023) 668 final
3 COM(2023) 634 final
4 https://setis.ec.europa.eu/publications-and-documents/clean-energy-technology-observatory/ceto-reports-2024_en

is needed in many areas such as design and validation of ocean energy devices, logistics and marine operations. 100 MW of ocean energy capacity is achievable by 2027 and 1 GW by the end of the decade or early 2030's.

REPowerEU is a plan for 1) saving energy, 2) producing clean energy and 3) diversifying their energy supplies. The plan sets out a series of measures to rapidly reduce dependence on Russian fossil fuels and fast forward the green transition, while increasing the resilience of the EU-wide energy system. It is backed by financial and legal measures to build the new energy infrastructure and system that Europe needs. It is confirming that renewables are the cheapest and cleanest energy available, and can be produced domestically, reducing our need for energy imports. REPowerEU will speed up the green transition and spur massive investment in renewable energy. We also need to enable industry and transport to substitute fossil fuels faster to bring down emissions and dependencies.

Following REPowerEU the European Commission proposed the Net-Zero Industry Act (NZIA) in March 2023. The NZIA entered into force on 29 June 2024 (Regulation (EU) 2024/1735) and is now due to be implemented. It creates the necessary conditions to facilitate investments in net-zero technology manufacturing projects and makes it easier for project promoters to build up net zero industrial manufacturing. It does so by addressing the core drivers of net-zero technology manufacturing investments through measures such as i) lowering the administrative burden for net-zero manufacturing projects by streamlining administrative requirements and facilitating permitting, ii) ensuring access to information, iii) facilitating access to markets in public procurement procedures and auctions, as well as schemes aimed at supporting private demand by consumers and iv) supporting innovation through regulatory sandboxes. The EU aims to strengthen its domestic manufacturing capacities of key clean technologies and to increase the competitiveness and resilience of its industry.

Also revised the Commission the Renewable Energy Directive and proposed to have an indicative target of at least 5% of all new installations by 2030 to come from innovative renewables, such as ocean energy technologies. The Commission encourages Member States to include targeted policies to support the deployment of ocean energy technologies in the revised National Energy and Climate Plans (NECPs). The national plans outline how the EU Member States intend to address energy efficiency, renewables, emissions reductions, interconnections, and research and innovation. The European Commission has invited all Member States to deliver revised/updated plans in 2023, but only Portugal provides an indicative target of 0,2 GW for the development of ocean energy to contribute to the objective of 1 GW of ocean energy by 2030. Member States are encouraged now to include the missing trajectories, thorough planning and targeted installed capacities for deployment of renewable technologies for the next 10 years, with an outlook to 2040, in their final NECPs.

As part of the Clean Energy Technology Observatory the Joint Research Centre of the European Commission has published the report 'Ocean energy in the European Union - 2024 Status Report on Technology Development, Trends, Value Chains and Markets'. It provides an evidence-based analysis feeding the policy making process and hence increasing the effectiveness of R&I policies for clean energy technologies and solutions. It monitors EU research and innovation activities on clean energy technologies needed for the delivery of the European Green Deal and assesses the competitiveness of the EU clean energy sector and its positioning in the global energy market.

Maritime spatial planning (MSP) is a necessary tool to allocate sea space for different uses of the sea using an ecosystem-based approach and to ensure long-term co-existence and preservation of the ecosystems. The Commission has established an EU MSP Platform for sharing knowledge and experiences, prepared guidance on managing tensions with sectors in competition with ORE and issued best practice for multi-uses of space and cross-border cooperation.

Competitiveness has become a focus for EU policy, including with regard to net-zero technologies. Conclusions of the European Council of April 2024 urged to strengthen the EU's competitiveness[5]. The new Competitiveness Compass sets out a set of measures to strengthen the EU's competitiveness in the coming years, building directly on the in-depth analysis from the Draghi report[6]. The Dra-

5 European Council (2024), Conclusions from the special meeting of the European Council (17 and 18 April 2024); European Council (2024), Budapest Declaration on the New European Competitiveness Deal (7-8 November 2024).
6 COM(2025) 30 final.

ghi report emphasises the economic opportunities clean technologies represent for the EU, as an innovation leader in clean technologies[7]. At the same time, the report highlights the main barriers holding back the EU's competitiveness and calls for an aligned and targeted strategy, taking into account differences between industries. Additionally, the 2025 progress report on competitiveness of clean energy technologies notes that specific attention is needed to increase the economic viability and to bring innovative technology to the market.

Since in 2024 there were elections for the European Parliament and a new Commission has been inaugurated on the 1st December 2024, there were hardly any new policy initiative. This will most likely be different in 2025.

Market incentives

In 2020 the European Commission launched the Innovation Fund succeeding the NER 300. The Innovation Fund is one of the world's largest funding programmes for the demonstration of innovative low-carbon technologies and it will provide more than EUR 10 billion of support over 2020-2030 for the commercial demonstration of innovative low-carbon technologies, aiming to bring to the market industrial solutions to decarbonise Europe and support its transition to climate neutrality. The Innovation Fund improves the risk-sharing for projects by giving more funding in a more flexible way through a simpler selection process and is also open to projects from energy-intensive industries. The Innovation Fund focuses on highly innovative technologies, such as ocean energy, and big flagship projects within Europe that can bring on significant emission reductions.

The Commission supports the ocean energy sector via BlueInvest. This programme aims to boost innovation and investment in sustainable technologies for the blue economy, by supporting readiness and access to finance for early-stage businesses, SMEs and scale-ups. The BlueInvest pilot initiative managed by the European Investment Fund, provides financing to underlying equity funds that strategically target and support the innovative blue economy. This sector can play an important role in the transformation to a carbon-neutral economy by 2050, an ambition announced in the European Green Deal. The programme is backed by the European Fund for Strategic Investments, the financial pillar of the Investment Plan for Europe.

Public funding programmes

Horizon Europe is the successor of Horizon 2020 and the total budget for Research and Innovation is 95.5 billion EUR. The programme started in 2021 and includes topics on ocean energy development under the Climate, Energy and Mobility subprogramme.

In 2022 a call for projects was opened for the demonstration of sustainable tidal energy farms (EU funding budget 40 million Euro). Two projects have been selected for funding (SEASTAR and EURO-TIDES).

In 2023 a call was opened for the demonstration of wave energy farms (EU funding budget 38 million Euro). The call was closed in January 2024. 2 projects were invited for grant preparation, but till now only one has succeeded to successfully complete these preparations. A call for the development of critical technologies for future ocean energy farms was opened in 2024 with a closing date in 2025. Projects could focus on innovative materials, technologies for operation and monitoring, use of artificial intelligence and subsea infrastructure (EU funding budget 8 million Euro). It is expected that 2 projects will be funded under this call.

The Innovation Fund launched in the end of 2024 a call for net-zero technologies with a total budget of 2.4 billion EUR. Ocean energy is acknowledged as one of these technologies. If the project is successful, the proposed technology should move to the next stage of a large-scale demonstration or first-of-a-kind commercial production. This specific call seems suitable for further development of ocean energy towards the market.

The European Maritime, Fisheries and Aquaculture Fund (EMFAF) is the follow-up of the EMFF programme and runs from 2021 to 2027 and supports the EU common fisheries policy (CFP), the EU maritime policy and the EU agenda for international ocean governance. It provides support for developing innovative projects ensuring that aquatic and maritime resources are used sustainably.

The InvestEU Programme will bring together under one roof the multitude of EU financial instruments currently available and expand the successful model of the Investment Plan for Europe, the Juncker Plan. With InvestEU, the Commission will further boost investment, innovation and job creation.

7 Mario Draghi, *The future of European competitiveness*, 2024.

RESEARCH & DEVELOPMENT

An overview of awarded Horizon 2020 and Horizon Europe R&D projects in the last four years and which are still ongoing or just finished, is presented in the table below, focusing on the objective of the newly announced projects. One wave energy farm project started in 2024 with the aim to demonstrate the array at least 2 years in the lifetime of the Horizon Europe project, but also to continue afterwards minimum 8 years to show the survivability and reliability of the farms building trust in the technology and to attract investors. Also, in 2024 three projects were funded with the focus of development of a PTO for wave energy devices. As indicated by the IEA-OES's MTIR framework it is important to invest in infrastructure. A project has been funded to develop an integrated Research Infrastructure for offshore renewables.

Information about projects in previous years can be found in earlier IEA-OES annual reports or in the CORDIS database https://cordis.europa.eu/projects.

TABLE 1. HORIZON 2020 AND HORIZON EUROPE R&D PROJECTS IN THE LAST FOUR YEARS

Year	Acronym	Title	Technology developer	Focus
2024	**ONDEP**	Ondas De Peniche	AW Energy	The project aims to establish a 2MW wave energy farm in Peniche, Portugal, featuring four WaveRoller® units.
2024	**MegaWavePTO**	Modular Electrical Generator PTO system for Wave Mega PTO Wave	CGEN CETO Wave Energy Ireland Mocean Energy	Through this project, an innovative, scalable, reliable, and easily maintainable all-electric modular PTO system for wave energy devices, ranging from kW to MW capacities, will be developed. The project will provide a system that will be adaptable to various sea conditions at different installation sites and able to continue operating even in the event of a partial failure.
2024	**SHY**	Seawater Hydraulic PTO using dynamic passive controller for wave energy converters	Wavepiston A.S.	The project is aimed at advancing wave energy by developing key components of a seawater hydraulic PTO system, coupled with an advanced control strategy. This dual focus aims to reduce LCOE while concurrently minimising the environmental impact.
2024	**UR4energy**	UR4energy: Underwater Robots for efficient ocean energy harvesting	Norwegian University of Science and Technology	The project will tap into vortex wake energy source by developing an efficient way to harvest it by using Underwater Robots.
2024	**POHOWEP**	Performance Optimization of a Hybrid Offshore Wind-Wave Energy Platform	N/A	Aims to combine a FOWT with Oscillating Water Columns (OWCs) to harness both wave and wind energies
2024	**MARES**	Marine Reciprocating Superconducting Generator (RSG)	Several companies	Aims at developing a next generation of ultra-high force Superconducting Direct Drive PTOs for wave energy conversion.

2024	**MARINERG-i_PP**	Marine Renewable Energy Distributed Research Infrastructure - Preparatory Phase	University College Cork	Development of a plan for an integrated European Research Infrastructure, an independent legal entity, designed to facilitate the future growth and development of the Offshore Renewable Energy sector.
2023	**EURO-TIDES**	EUROpean Tidal energy pilot farm focused on Industrial Design, Environmental mitigation and Sustainability	Orbital Marin Power Ltd (UK)	The project aims to deliver a 9.6 MW farm of four 2.4 MW Orbital tidal energy devices of the same series. The farm will operate for >10 yrs, expected to be deployed in 2027.
2023	**SEASTAR**	Sustainable European Advanced Subsea Tidal Array	Nova Innovation Ltd	The project will deliver a 4 MW array of 16 tidal stream turbines at the EMEC test site - the world's first large tidal farm considering the number of tidal turbines.
2023	**off-coustics**	Minimisation of the offshore wind and tidal turbine acoustic footprint on marine life	Universidad Politecnica de Madrid	The project combines numerical simulations and experiments to provide insights into the physics governing the aero/hydro-acoustic generation and propagation for offshore wind and tidal farms.
2023	**GreenH2Wave**	Producing Green Hydrogen Using Power of Ocean Waves	Wave To Energy	The main objective is to boost the TRL of the novel Concept of Floating Dual Chamber Oscillating Water Column (FOWC) device. The generated electricity is used to produce green Hydrogen from the sea water. The produced Hydrogen is stored inside the internal tanks of the device to be used as the "clean fuel" by the next generation of ships.
2022	**MAXBLADE**	Maximising tidal energy generation through Blade Scaling & Advanced Digital Engineering	FMC Technologies	The project will specifically focus on delivering a 70% increase in rotor swept area of the technology by addressing design, reliability, condition monitoring, maintenance and control issues relating to tidal turbine blades.
2022	**SUREWAVE**	Structural Reliable Offshore Floating PV Solution integrating circular concrete floating breakwater	SINTEF	The project will develop and test an innovative concept of Floating Photo-Voltaic (FPV) system consisting of an external floating breakwater structure acting as a protection against severe wave-wind-current loads on the FPV modules, allowing increased operational availability and energy output.
2022	**PLOTEC**	Tested Optimised Floating Ocean Thermal Energy Conversion Platform	PLOCAN	The project aims to achieve a successful demonstration of the novel designs and materials for an OTEC platform capable of converting solar heat energy stored in the oceans surrounding the Overseas Countries and Territories of the EU, Small Islands and Developing States, and the Asian and African continent into reliable, baseload power with an economical cost model.

2022	**NATURSEA-PV**	Novel Eco-Cementitious materials and components for durable, competitive, and bio-inspired offshore floating PV structures	Tecnalia	The main objective of the project is to improve the overall lifetime, reliability, and maintainability of marine substructures for offshore floating PVs and thus reduce its LCOE.
2022	**WEDUSEA**	Wave Energy Demonstration at utility Scale to Enable Arrays	New Wave Technologies Ltd (Ocean Energy)	The project aims to demonstrate a grid connected 1 MW OE35 floating wave energy converter (known as the OE Buoy) at EMEC test site.
2021	**EU-SCORES**	European Scalable Complementary Offshore Renewable Energy Sources	Corpower	This project will present the benefits of continuous energy production with small space requirements via complementary energy sources (wind, sun and waves). An offshore photovoltaic system will be installed in Belgium co-located with a bottom-fixed wind farm, and a wave energy array in Portugal co-located with a floating wind farm.
2021	**FORWARD-2030**	Fast-tracking Offshore Renewable energy With Advanced Research to Deploy 2030MW of tidal energy before 2030	Orbital Marine Power	This project will develop a multi-vector energy system that will combine predictable floating tidal energy, wind generation, grid export, battery storage and green hydrogen production.
2021	**EuropeWave**	Bridging the gap to commercialisation of wave energy technology using pre-commercial procurement	Several wave energy developers	The project will build on the work of Wave Energy Scotland to help Europe's wave energy innovation community transition to commercial viability. An innovative 'pre-commercial procurement' approach is used to identify and fund the most promising wave energy technologies from developers across Europe.
2021	**IMPACT**	Innovative Methods for wave energy Pathways Acceleration through novel Criteria and Test rigs	VGA Srl	To validate in relevant environment (TRL5) a next generation testing approach for wave energy converters
2020	**VALID**	Verification through Accelerated testing Leading to Improved wave energy Designs	AVL List GmbH	To demonstrate in relevant environment (TRL6) a new platform for accelerated hybrid testing that can be used across the wave energy sector to improve the reliability and survivability of components and subsystems

An overview of awarded Innovation Fund projects is presented in the table below. These projects will become significant milestones for the ocean energy sector. Due to its nature the actual deployment of the innovative demonstrators/arrays may take several years. The NH1 and FLOWATT projects have been invited for grant preparations, with their likely start date in 2025.

TABLE 2. AWARDED INNOVATION FUND PROJECTS

Year	Acronym	Title	Technology developer	Focus
2025	**NH1**	Raz Blanchard project	Normandy Hydroliennes	Installation of four x 3 MW underwater tidal turbine to generate electricity for a total output of 12 MW at Raz Blanchard.
2025	**FLOWATT**	Construction of a first-of-a-kind pilot tidal energy farm pilot with capacity of 17 MW in French waters at Raz Blanchard that contains 80% of EU's tidal Stream Energy	Hydroquest	Construction of a first-of-a-kind pilot tidal energy farm pilot with capacity of 17 MW in French waters at Raz Blanchard that contains 80% of EU's tidal Stream Energy.
2024	**SAO***	The Saoirse Wave Energy Project	Corpower ocean	5 MW wave energy conversion array of approximately 15-16 wave energy units, to be located off the west coast of Clare. Expected to entry into operation by Q1/2030.
2024	**SEAWORTHY****	Sustainable dispatchable Energy enabled by wAve-Wind OffshoRe plaTforms with onboard Hydrogen	Floating Power Plant (DK)	Mid-size prototype demonstration project aiming to demonstrate dispatchable renewable power supply through smart integration of wave energy converters, a wind turbine, and a full hydrogen system (electrolyzer, storage, and fuel cells) in a single semisubmersible platform. It will be tested in Spain and xpected to entry into operation by Q3/2028.

*SAO - https://ec.europa.eu/assets/cinea/project_fiches/innovation_fund/101133237.pdf

**SEAWORTHY - https://ec.europa.eu/assets/cinea/project_fiches/innovation_fund/101133097.pdf

The European Maritime and Fisheries Fund (2014-2020) aims to promote a growth and job-based recovery in Europe's Blue Economy. This fund supports coastal communities in diversifying their economies, financing projects that create new jobs and improve quality of life along European coasts and makes it easier for applicants to access financing. The fund has financed several smaller projects in the past years focussing on environmental aspects, supporting ocean energy technology development.

TABLE 3. OCEAN ENERGY EMFF/EMFAF PROJECTS AWARDED SINCE 2020

Year	Acronym	Title	Technology developer	Focus
2022	**FLORA**	FLORA (Floating Radar) is an autonomous, in-situ ocean station powered by wave energy and designed for continuous, long-term operational oceanography including bird tracking	Wedge	The core energy system is based on a wave energy of point absorber type integrated with battery storage. The major innovation of the project will be the technical compatibility that we will enable between the existing system and a 3D bird radar as well as the associated telemetry.
2020	**Wavefarm**	WaveRoller Wave Farm Scale-Up - Preparing to deploy the world's first commercial wave energy farm	AW-Energy (Finland)	This project was completed in 2024.
2020	**SafeWave**	Streamlining the Assessment of environmental efFEcts of WAVE energy	CorPower, GEPS, Wello Oy	This project was completed in 2024.

More information can be found via the EMFF datahub:
https://ec.europa.eu/easme/en/european-maritime-and-fisheries-fund-0

RELEVANT PUBLICATIONS

Communication on the Green Deal
https://commission.europa.eu/publications/communication-european-green-deal_en

Communication Delivering on the EU offshore renewable energy ambitions
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2023:0668:FIN

Communication Revision of the Strategic Energy Technology (SET) Plan
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2023:0634:FIN

Communication Net Zero Industry Act
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:52023PC0161

https://eur-lex.europa.eu/eli/reg/2024/1735/oj/eng

Directive promotion of energy from renewable sources
https://energy.ec.europa.eu/topics/renewable-energy/renewable-energy-directive-targets-and-rules/renewable-energy-directive_en

https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32023L2413

Report on Progress of clean energy competitiveness
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52025DC0074&qid=1740650518877

Clean Energy Technology Observatory: Ocean energy in the European Union - 2024 Status Report on Technology Development, Trends, Value Chains and Markets
https://setis.ec.europa.eu/publications-and-documents/clean-energy-technology-observatory/ceto-reports-2024_en

EU Blue Economy Report 2024
https://op.europa.eu/en/publication-detail/-/publication/ef90077b-1e82-11ef-a251-01aa75ed71a1

FRANCE

REPORT PREPARED BY:
Christophe Maisondieu, IFREMER

OVERVIEW

The 2024-2030, *Stratégie Nationale Mer et Littoral*, which sets out the main guidelines for strategic planning of maritime and coastal areas, identified marine renewable energies to help achieve carbon neutrality by 2050 and plans to support the research and development of new marine renewable energies, in particular marine tidal power.

The demonstrator at scale ¼ of the Seaturns wave energy converters was tested for over a year on IFREMER's open sea test site.

New studies for an accurate assessment of the tidal resource were conducted at the regional level in Brittany and Normandy.

SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy

Stratégie Nationale Mer et Littoral (SNML)

The National Strategy for the Sea and Coastline (SNML) is a joint initiative of the French government, local authorities and the various stakeholders in the sector, including associations, users, trade unions and scientists. The SNML is drawn up every 6 years, and sets out the main guidelines for strategic planning of maritime and coastal areas, which is applied to France's maritime façades and ultramarine basins. It is the reference framework for public policies concerning the sea and coast, and is linked to all existing sectoral strategies.

The development of marine renewable energies to help achieve carbon neutrality by 2050 is one of the 18 objectives identified in the SNML 2024-2030. While this objective relies heavily on the development of offshore wind power, the SNML plans to support the research and development of new marine renewable energies, in particular marine tidal power. Main identified actions regarding ocean energy include:

- identify potential areas for OEs, in particular tidal turbines
- identify which of these zones could be occupied by several technologies
- Support research and development of new OEs, particularly marine turbines
- Promote short circuits and develop offshore service stations
- Take into account the specificities of the coastal and maritime environment in the government's strategy.

Public funding programmes

For over a decade, the French government has provided strong support for the development of Marine Renewable Energies, both through feed-in tariffs and by backing R&D for MREs. The Plan d 'Investissement d'Avenir and the France 2030 program provide ongoing support for innovation in MRE. Nearly a billion euros have been earmarked for innovation and support for the industrialization of renewable energy production facilities via France 2030. This has led to the implementation of a €75 million support program for the FLOWATT project to deploy a pilot tidal turbine farm in the Alderney Race (see below).

RESEARCH & DEVELOPMENT

An important effort was made at the regional level to accurately assess the tidal resource.

In Normandy, a mapping of the resource for the development of tidal turbines was elaborated. The mapping that

was proposed following public debate shows a potential of about 4.750 GW, mainly located in the Alderney Race area. Final confirmation of this mapping as a reference should be given early 2025.

A similar study was carried out by the Brittany Region to characterize its tidal resource. This assessment allowed identification of a potential of the order of 500 MW for the development of commercial farms, spread over three distinct areas: the Fromveur passage, as well as two new zones to the west of the island of Ouessant and in the Raz de Sein.

Optile project

The design of power systems for isolated sites and micro-grids fed by marine renewable energy converters is to be optimized to cover needs at a realistic cost. The aim of the OPTILE project, led by France Energies Marines, is to improve the traditional approach based on matching production and consumption, by introducing optimization criteria from a variety of disciplines: reliability, machine position, power grid, carbon dioxide estimation, consumption control, cybersecurity and electrical stability.

TECHNOLOGY DEMONSTRATION

Existing open sea test sites

OPEN-C Foundation joins the THeoREM Research Infrastructure

Since 2023, the OPEN-C Foundation coordinates, develops and manages offshore test sites for floating offshore wind, tidal power, wave energy, offshore hydrogen and floating photovoltaics.

In March 2024, the OPEN-C Foundation joined the national Research Infrastructure THeoREM, a network of hydrodynamic and mechanical test facilities, built in 2017 to carry out research activities and collaborative projects with French and international companies, mainly in the field of Offshore Renewable Energy.

THeoREM brings together the test sites operated by the OPEN-C Foundation and the facilities operated by IFREMER, Centrale Nantes and Université Gustave Eiffel, and has now the capacity to support and follow the development of ocean energy systems at all stages of development from the proof of concept (TRL 1-2) to the pre-industrial production stage (TRL 8-9).

OPEN-C Foundation test sites

Credit: O. Dugornay, Ifremer

Seaturns

A demonstrator at scale ¼ of the Wave Energy Converter developed by Seaturns was deployed between October 2023 and September 2024 on the IFREMER Sainte-Anne du Portzic open sea test site. This test campaign allowed to:

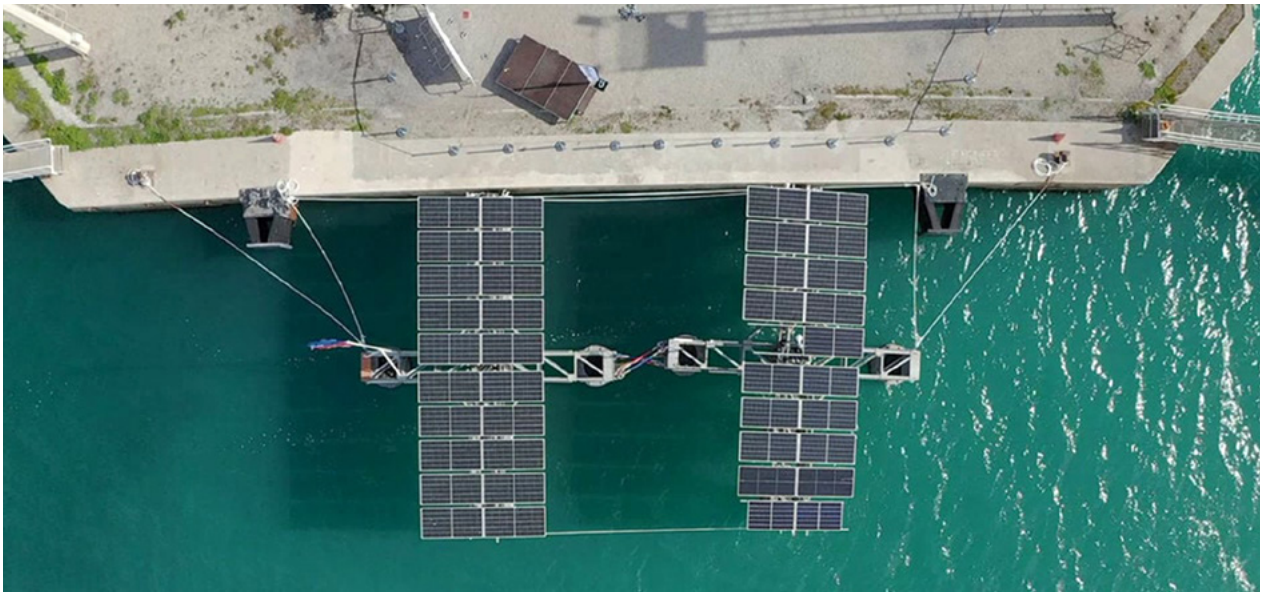
- Confirm the good level of production
- Validate the power export concept
- Study the response of the dynamic cable

A second leg of testing was started in October 2024 and is due to end early February 2025. Deployment of a full-scale demonstrator (9 m in length, 6 m in diameter, power: 200 kW) is planned at the SEMREV open sea test site operated by Foundation Open-C, later in 2025.

Projects in the water

Sun'Sète and Mega-Sète Projects

The Sun'Sète project developed by SolarInBlue, was launched on March 17, 2023. It is the first offshore photo-



SOLARINBLUE Sun'Sète project

voltaic farm (300 kWp) in France. The energy generated by the solar panels, transmitted via a submarine cable, will supply renewable electricity to the infrastructures of the port of Sète-Frontignan on the Mediterranean Sea. Production is estimated at 400 MWh/year.

In June 2024, SOLARINBLUE announced they secured a 6 million Euro grant (France 2030 funding programme – ADEME) for the development and deployment of the Mega-Sète 1 MWp pre-commercial demonstrator.

D10 Tidal turbine

In October 2024, Inyanga Marine Energy Group announced that it was taking over the D10 tidal turbine originally developed by SABELLA, and that it had secured all the authorizations to operate the tidal turbine until August 2028. The D10 tidal turbine, deployed in the Fromveur Passage, can inject up to 250 kW of clean electricity into the isolated power grid on the island of Ouessant, and has been operating continuously since its last deployment in early 2022.

Projects planned for deployment

The partners of the **FLOWATT** project, the independent producer of renewable energy Qair, the developer of vertical axis tidal turbines Hydroquest and the shipyard CMN announced the deployment of a pilot 17.5 MW tidal farm in 2028. Six 2.8 MW vertical axis tidal turbines will be deployed in the Alderney Race. The FLOWATT project received a 75 million euros financial support from the French government, as part of the France 2030 national investment plan and will also benefit from a preferential feed-in tariff for the electricity produced. Flowatt also received support from the EC through the Innovation Found, funding programme for innovative low-carbon technologies.

Further, **Normandie Hydroliennes**, the winner of the Innovation Fund for their NH1 project, aims at deploying by 2028 in the Alderney Race a 12 MW pilot tidal farm composed of 4 AR3000 horizontal axis tidal turbines developed by Proteus.

Legendre, developer of the DIKWE wave energy converter for port areas and breakwaters, announces the development of a 360-kW demonstrator and its installation onto the breakwater protecting the port of Boulogne-sur-Mer in the north of France. Legendre is also conducting studies for the installation of a 1 MW Dikwe pilot system in the port of Bilbao and the installation of a 2 MW pilot system in the port of Viana do Castelo (Portugal).

SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

Several bilateral/regional cooperation initiatives have been developed during 2024.

RELEVANT NATIONAL EVENTS

The **Seanergy Conference** is the main conference and exhibition in France addressing ocean energy. In 2024 it was held in Nantes (June 26-28) and addressed both offshore wind energy and ocean energy and gathered over 3,500 visitors from the industry and academia, as well as representatives of public authorities. Seanergy 2025 exhibition and conference will be held in Paris (June 17-18).

A special event of the 3rd United Nations Conference on the Ocean, the **One Ocean Science Congress**, will be held in Nice, France (June 3-6, 2025). The objective of this congress is to provide Heads of State and Government, all participants in the Third United Nations Conference on the Ocean (UNOC3) and society with comprehensive scientific information on the health, dynamics and future trajectory of the ocean, its conservation and sustainable use, and the services it provides to humanity.

INDIA

REPORT PREPARED BY:
Dr. Purnima Jalihal, National Institute of Ocean Technology (NIOT)

OVERVIEW

The vast Indian coastline offers opportunities for extracting ocean energy, for both grid and off grid applications. The National Institute of Ocean Technology (NIOT), under the aegis of the Ministry of Earth Sciences (MoES), Government of India, is tasked with developing technologies to harness these ocean energy resources. Recent initiatives, such as Deep Ocean Mission of MoES and call for proposals from the Ministry of New and Renewable Energy (MNRE) and DST (Dept. of Science and Technology), have provided momentum to the development and demonstration of ocean energy devices, including renewable energy powered desalination. NIOT is actively engaged in executing projects as part of the ocean energy and freshwater vertical under the Deep Ocean Mission (DOM), along with establishing an OTEC-powered desalination plant.

SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy

The Ministry of New and Renewable Energy (MNRE) is the nodal Ministry of the Government of India for all matters including tariff fixation and policy formulation relating to new and renewable energy. NIOT-MoES works towards technology development of ocean energy devices. A national committee on Marine Energy Conversion Systems (ETD-54) of Bureau of Indian Standards (BIS) has been tasked to formulate standards towards development of ocean energy in India.

Market incentives

Various small scale developmental projects related to marine energy under Deep Ocean Mission programme have been awarded by MoES. MNRE and DST (Dept. of Science and Technology) are also funding few proposals in the area of marine renewable energy and desalination.

Public funding programmes

As part of the vertical on Energy and freshwater of the Deep Ocean Mission funded by MoES, a detailed project report (DPR) for 10 MW closed cycle OTEC and 5 MLD capacity open cycle OTEC powered desalination plant is being carried out by NIOT with the help of a private firm. An Expression of Interest was invited for a new pilot scale demonstration plant towards generation of energy and freshwater on a floating platform in more than 1000 m water depth utilizing ocean thermal gradient. With several Indian players in the fray, works towards necessary approvals and floating RFP is underway.

Works towards implementation of an OTEC powered desalination plant of 100 m3/day capacity at Kavaratti Island in UT Lakshadweep is currently under progress by NIOT. Process components including open cycle turbine were fabricated and currently being transported to the site for erection. Structure for the plant is also under construction

Indian National Centre for Ocean Information Services (INCOIS) under MoES has published an 'Integrated Ocean Energy Atlas' of the Indian EEZ, which showcases the vast potential of ocean energy resources on Septem-

ber 13, 2024. The Atlas identifies areas with high potential for energy generation and will serve as a reference for policymakers, industry and researchers for harnessing the rich energy resources available in the Indian EEZ.

RESEARCH & DEVELOPMENT

Energy from ocean thermal gradient

- Design for process equipments and layout of the offshore platform is under progress for the preparation of DPR for 10 MW closed cycle OTEC and 5MLD capacity open cycle OTEC powered desalination plant. Concept development for the offshore components for the demonstration of a pilot scale floating OTEC-Desalination plant has been carried out. Deep draft buoy and flat bottom barge mounted plant were studied.
- Plant automation using AI/ML techniques are being studied for optimization of the OTEC plant performance at OTEC-Desalination laboratory at NIOT.

Wave Energy

A customized IoT enabled wave powered fairway buoy funded by Kamarajar port Ltd. (KPL) has been fabricated for usage at KPL in Chennai by NIOT. Andaman & Nicobar Administration, Chennai port and other ports in India have shown interest in installation of these buoys at their premises.

Collaborative projects under DOM

Various projects related to numerical and experimental studies on floating OTEC platform, conduits, green hydrogen, studies on salinity gradient, ocean thermal gradient-based desalination, etc. are under progress by academic and R&D institutes in India under the aegis of collaborative work with NIOT under DOM. A laboratory scale technology project 'Blue Energy from Salinity Gradient' aimed at demonstrating energy generation through salinity gradient using novel Pressure Retarded Osmosis technology has taken up by IIT-Bombay.

SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

- MoES and MNRE hosted a 7th task force on Blue Economy for sustainable development on 6 December in New Delhi.
- NIOT and M/s PCCI consortium signed a contract for commencement of United State Trade Development Agency (USTDA) funded project on Engineering Design and costing of 16 MW and 5 MW floating Ocean Thermal Energy Conversion (OTEC) power plant for Andaman & Nicobar Islands.
- India led by NIOT participated in its 1st Plenary Meeting of International Electro-Technical Commission (IEC) TC 114 on Marine energy during 17-19 April 2024 in Republic of Korea.
- A World Ocean Science Congress (WOSC-2024) conference with focus on advancements in ocean technologies, sustainability and marine renewable energy was organized during 28-29 February 2024 by NIOT.
- An International Workshop on Optimizing Engineering Design with AI: A focus on Ocean Energy Systems (OEDAI-2024) was held on 17-20 Nov 2024 at IIT Madras in collaboration with NIOT.

Lab set-up for studies on salinity gradient at IIT-Bombay

OTEC-Desalination laboratory set-up at NIOT

IRELAND

REPORT PREPARED BY:
Forest Mak and Emer Dennehy, Sustainable Energy Authority of Ireland (SEAI)

OVERVIEW

Ireland has one of the best offshore renewable energy resources in the world with a sea area of 490,000 square kilometres which is approximately seven times the size of the country's landmass[1].

Ireland has committed to halving greenhouse gas emissions by 50% by 2030 and reaching net zero by 2050. The third update to the Climate Action Plan (CAP 24) was released in December 2023 consolidated the measure and actions to deliver on Ireland's carbon budgets and sectorial emissions ceiling. CAP 23 set an ambitious target to progress offshore energy in Ireland with a target to achieve 5 GW offshore wind by 2030, with an additional 2 GW for green hydrogen production. Under the CAP 24, the electricity sector has been set one of the smallest carbon budget allocations and the steepest trajectory (-75%) across all sectors. Offshore wind will be a key driver for Ireland to meet its second carbon budget with electricity emissions ceiling of 20 MtCO2eq. for 2026-2030 and setting the country on a long-term trajectory for a net zero electricity system. Beyond offshore wind, there currently aren't any specific targets for wave, tidal or any other ocean energy technologies in Ireland.

SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy

Policy development for Marine Consenting

In response to the requirements of the EU Directive 2014/89/EU, the Irish government established the National Marine Planning Framework (NMPF) during 2021. The NMPF brings together all marine-based human activities, outlining the Government's vision, objectives, and marine planning policies for each marine activity. The NMPF sets out the proposed future approach to the adoption of spatial designations for marine activities including offshore renewable energy development, whilst taking account of the existing network of designated European sites under the Birds and Habitats Directives[2].

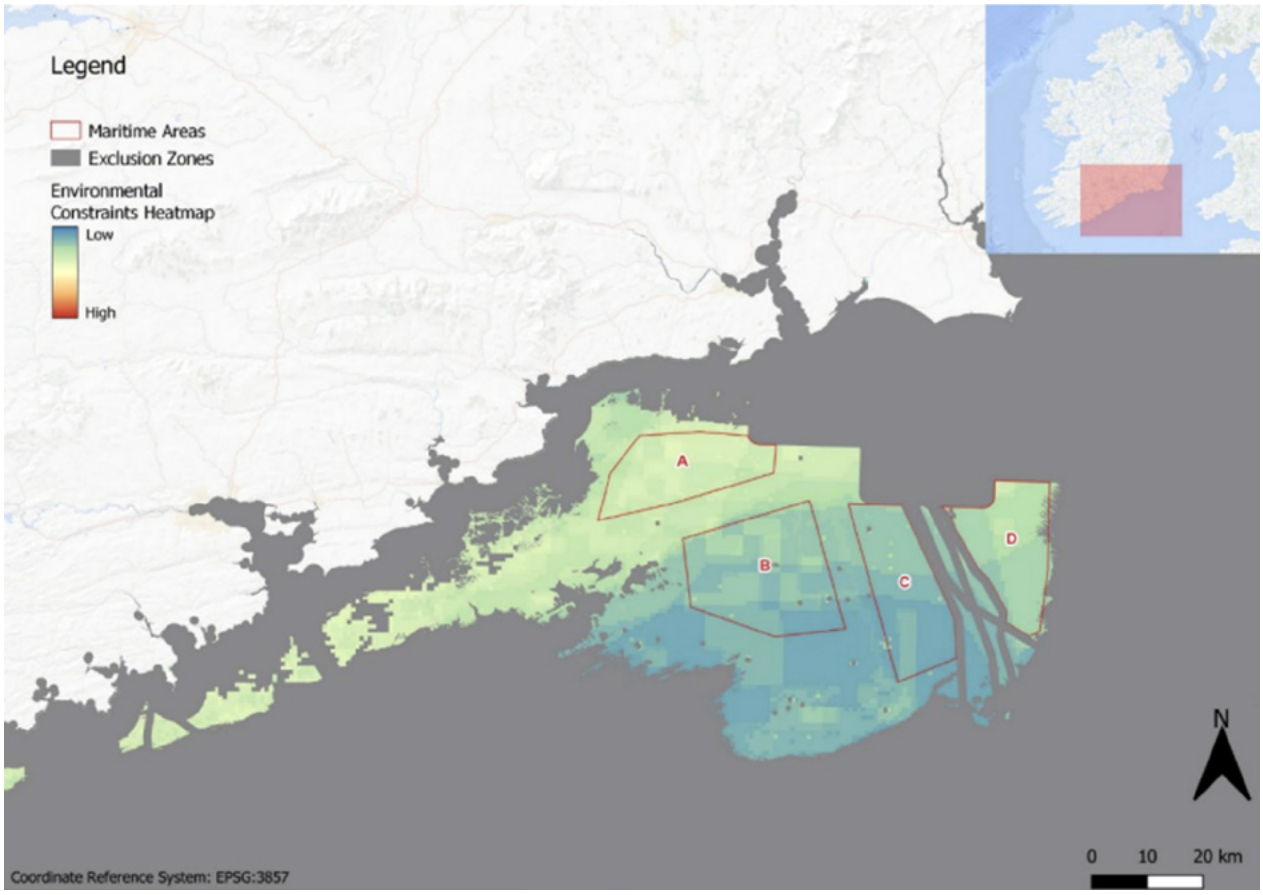
As part of the NMPF and set out in the Maritime Area Planning Bill, an Offshore Renewable Energy (ORE) Designated Maritime Area Plan (DMAP) has been established to set out Ireland's future development for ORE. The DMAPs will develop a multi-activity area plan which will promote the co-existence and co-location of offshore renewable activity with other marine usages and activities.

In 2023, the first DMAP has been proposed at the south coast of Ireland which will initialise the geographical area for future offshore renewable development to take place. In 2024, the south coast DMAP was approved by the Oireachtas (Houses of the Irish Parliament) which has identified four sites for the future development of offshore windfarms off the south coast of Ireland. The second offshore auction is due to run in 2025 for development of a 900 MW offshore wind farm in the first site, site A in the figure below, also known as Tonn Nua.

The Marine Area Planning Act 2021

The Marine Area Planning (MAP) Act of 2021 established into law a new marine planning system, which is underpinned by a statutory Marine Planning Statement, and guided by the NMPF. It consists of a development management regime from the high-water mark to the outer limit of the State's continental shelf administered by An Bord Pleanála (the Irish planning authority) and the coastal local authorities.

1 https://www.gov.ie/en/press-release/07331-transition-of-offshore-renewable-projects-announced/
2 https://www.gov.ie/en/publication/a4a9a-national-marine-planning-framework/



South Coast DMAP consisting of four sites for development of offshore wind. Site A an Tonn Nua will be the first site for ORE development under the plan-lead regime

The MAP Act streamlined procedures using a single consent principle: one State consent known as a Maritime Area Consent (MAC), that enables occupation of the Maritime Area and one development consent, with a single environmental assessment. The Act established a new independent agency, the Maritime Area Regulatory Authority (MARA) and the agency came into operation on 17th July 2023[3].

Offshore Wind Delivery Taskforce

A cross-Departmental Offshore Wind Delivery Taskforce was established in August 2022 to accelerate and drive delivery and capture the wider and longer term economic and business opportunities associated with the development of offshore renewables in Ireland. The challenge is to bring these together in a coherent whole of government plan that provides the necessary structures, governance, project management and delivery supports to ensure the medium term, 2030 and post-2030 targets will be delivered. Many of the challenges that will be resolved for offshore wind will also aid in the deployment of other offshore renewable energy technologies.

Offshore Renewable Energy technology roadmap

The Offshore Renewable Energy Technology Roadmap maps the pathway to harnessing Ireland's ORE potential. It is an advisory report published by the Sustainable Energy Authority of Ireland (SEAI) in 2024 to inform strategic planning and policy development. It captures the frameworks for ORE delivery in Ireland, recommending areas for further consideration, informed by international best practice and industry expertise[4]. While the report does conclude that fixed and floating offshore wind would play a dominant role in delivering clean energy from our ocean, wave energy has been considered a technology

3 https://www.gov.ie/en/press-release/9c75f-minister-obrien-announces-maritime-area-regulatory-authority-mara-establishment-day-and-new-ceo/
4 https://www.seai.ie/sites/default/files/publications/ORE-Technology-Roadmap.pdf

that can have an impact. This is considered under an ORE deployment scenario where advancements are made to the TRL/CRI and the technology achieves the significant cost reductions necessary to play a significant role in Ireland's energy system.

Future Framework for Offshore Renewable Energy

The Future Framework for Offshore Renewable Energy launched by the minister of Environment, Climate & Communication in May 2024 is a long-term model and vision for offshore renewable energy (ORE) in Ireland. The policy statement sets out the pathway Ireland will take to deliver 20 GW of offshore wind by 2040 and at least 37 GW in total by 2050. Critically, it also provides the evidence base for Ireland's ambitious ORE targets[5].

The Future Framework includes 29 key actions to develop on Ireland's strategic long-term approach and national ambition. Seven of those which are considered as priority actions includes:

- Provide the structures and supports necessary to establish a future DMAP roadmap.
- Explore the feasibility of implementing a competitive MAC framework.
- Explore the possibility of a roadmap for future ORE development.
- Design and develop a successor support scheme to ORESS.
- Maximise capacity from alternative routes to market.
- Align infrastructure efficiencies to consider generation, grid, and route to market.
- Assess the potential to deploy floating offshore wind at scale in Irish waters.

Ocean Knowledge 2030

A draft of Ireland's strategy for Marine Research, Knowledge & Innovation for the period 2025-2030 has been prepared by the Marine Institute. It will guide the coordination at national level of marine research and innovation investments, programming and policy, helping to optimise impact, enable the sustainable use of ocean space, and develop a sustainable climate-neutral blue economy[6]. Further to this, it will align and integrate with a broader suite of sectoral and Research and Innovation strategies and policies at both national and EU level. Ocean Knowledge 2030 is also designed to advance the Impact 2030 action to 'position Ireland as a leader for marine research and technology'.

Market incentives

The Renewable Electricity Support Scheme (RESS) provides support to renewable electricity projects in Ireland. It is an auction-based process where renewable energy projects compete against each other by bidding their lowest price offer to win contracts to provide electricity at the bid price for a twenty-year period. With a primary focus on cost effectiveness, the RESS delivers a broader range of policy objectives, including:

- Providing an Enabling Framework for Community Participation through the provision of pathways and supports for communities to participate in renewable energy projects.
- Increasing technology diversity by broadening the renewable electricity technology mix.
- Delivering an ambitious renewable electricity policy to 2030.
- Increasing energy security, energy sustainability and ensuring the cost effectiveness of energy policy[7]

In 2023, Ireland ran its first ever Offshore (ORESS) auction which procured just over 3GW of capacity from four offshore wind projects which will deliver over 12 TWh of renewable electricity per year. The average bid price from the auction was €86.05/MWh making it the lowest prices paid by an emerging offshore wind market in the world[8]. An additional two merchant fixed offshore wind projects are also progressing to the planning stage.

The second offshore auction (ORESS 2.1) is expected to commence in 2025 after the approval of the inaugural south coast DMAP under the new plan-led regime. One bidder will be successful in the auction for an Tonn Nua site. It is expected that the development of the offshore wind farm from ORESS 2.1 will be contributing to-

5 https://www.gov.ie/en/publication/0566b-future-framework-for-offshore-renewable-energy/
6 https://www.marine.ie/site-area/research-funding/marine-research-ireland/ocean-knowledge-2030
7 https://www.gov.ie/en/publication/36d8d2-renewable-electricity-support-scheme/
8 https://www.gov.ie/en/press-release/f2ac5-minister-ryan-welcomes-hugely-positive-provisional-results-of-first-offshore-wind-auction/

wards Ireland's 2030 7GW of installed capacity target along with ORESS 1[9].

Public funding programmes

SEAI Research, Development and Demonstration Fund

The SEAI National Energy Research Development and Demonstration (RD&D) Funding Programme invests in innovative energy RD&D projects which contributes to Ireland's transition to a clean and secure energy future. The key programme objectives include the following:

- Accelerate the development and deployment in the Irish marketplace of competitive energy-related products, processes, and systems.
- Support solutions that enable technical and other barriers to market uptake to be overcome
- Grow Ireland's national capacity to access, develop and apply international class RD&D
- Provide guidance and support to policy makers and public bodies.

SEAI/LIR NOTF Industry access programme

The Sustainable Energy Authority of Ireland (SEAI) and LIR National Ocean Test Facility (NOTF) in UCC fund an industry access programme to enable the testing and progression of ORE technologies through the early development stages in advance of open sea testing. Funded by SEAI, the industry access fund is open to any type of ORE technology (wave, wind, tidal, floating solar) that can be tested at the Lir NOTF. In 2024, the programme opened a fourth call for applications of ORE technologies that are eligible to test their scaled-down physical model at the test site. A total of eight projects, five wave one tidal and two component applications were successful from the competitive process.

RESEARCH & DEVELOPMENT

The Irish government is taking major steps towards making Ireland carbon neutral by 2050. One of the key steps that have been taken since 2023 is the continuous support for the development of the national testing facilities and funding the research and development for Ocean Energy.

Key national research activities

SEAI has supported many Ocean Energy projects through Government funded grant support to Irish research institutions and Enterprises. In 2023, three ocean energy projects were funded through the programme. An additional three ocean energy projects were successful in the 2024 call. Further details about funded projects on the SEAI national energy research database10. Projects that started in 2024 include:

LOGistical and Industrial Codesign for TIDal Energy

LOGIC-TIDE will assess key practical requirements for tidal energy devices in the priority areas of industrial manufacture, installation, operations, and maintenance that will be critical for developing cost competitive and reliable projects. The survivability and robustness of critical components will be demonstrated in a high-precision laboratory setting.

DeepCData: DEtailEd material Performance Characterisation and DATA generation for tidal energy

The DeepCData project focuses on testing novel composite materials used in tidal turbines to explore variations in blade loading, design life and performance.

Advancing Tidal Energy Applications and Moorings (A-TEAM)

The goal of the A-TEAM project is to accelerate the commercialisation of a high-potential cross-flow tidal energy turbine with a capacity of up to 2MW, to provide clean, predictable energy in support of Ireland's and Europe's decarbonisation and enterprise development efforts.

9 https://www.gov.ie/en/press-release/f6070-consultation-opens-on-first-auction-to-supply-electricity-from-offshore-wind-under-the-renewable-electricity-support-scheme-oress-1/

10 https://www.seai.ie/data-and-insights/seai-research/research-database/

Note that the database includes all energy related research in Ireland, including funding by other agency (such as the Marine Institute, Geoscience Ireland, Science Foundation Ireland, the Irish Research Council, etc.) not only SEAI funded projects.

Ocean R,D&D projects funded by other Irish organisations include:

LEAP HI: U.S.-Ireland R&D Partnership: Control Co-Design for Ocean Wave Energy Conversion (Funded by Research Ireland)

Control Co-Design for Ocean Wave Energy Conversion

Maximising the power capture from cyclorotor wave energy converters (Funded by Research Ireland)

Cyclorotor-based wave energy devices are a promising type of wave energy device. The MaxRotorWEC project provides a new control strategy that can significantly improve the performance of cyclorotor-based wave energy devices, reducing costs, maximising energy produced and extending the device's lifespan. This new technology also has commercial applicability for cyclorotor-based wind and tidal turbines, cyclocopters, and propellers.

Ocean Energy projects that Irish partners participated in during 2024 through European-funded programmes include:

H2020, MUSICA: Multiple Use of Space for Island Clean Autonomy will provide a full suite of Blue Growth solutions for a small island including three forms of renewable energy: wind, photovoltaic and wave, innovative energy storage systems on the Multi-Use Platform, smart energy system for the island, desalinated water and green support services for island's aquaculture. Irish Partner is MaREI-UCC.

H2020, IMPACT: Innovative Methods for wave energy Pathways Acceleration through novel Criteria and Test rigs aims to develop and demonstrate a next-generation testing approach for Wave Energy Converters. At the end of the project a novel platform for all the wave energy converter types will be delivered, contributing to a drastic acceleration in their progress through laboratory tests and leading to a rapid advancement from TRL 3 to TRL 5. Irish Partner is MaREI-UCC.

H2020, VALID: Verification through Accelerated testing Leading to Improved wave energy Designs aims to develop and validate a new test rig platform and procedures for accelerated hybrid testing that can be used across the wave energy sector to improve the reliability and survivability of the components and subsystems that form Wave Energy Converters (WECs). Aquatera sustainability Ireland Ltd are the Irish partners of the project.

H2020, EU-SCORES: European Scalable Offshore Renewable Energy Source will demonstrate the combination of offshore wind with wave- and offshore solar PV energy. This will pave the way for bankable multi-source offshore parks across Europe by 2025. These multi-source parks will use offshore space more efficiently and balance the electricity grid to achieve a resilient and cost-effective 100% renewable energy system. Exceedence Ltd are the Irish project partners.

H2020, FOWARD2030: Fast-tracking Offshore Renewable energy With Advanced Research to Deploy 2030MW of tidal energy before 2030 aims to accelerate the commercial deployment of floating tidal energy. The project consortium seeks to develop a multi-vector energy system which will combine predictable floating tidal energy, wind generation, grid export, battery storage and green hydrogen production. Irish partners are MaREI-UCC.

HORIZON EUROPE, WEDUSEA: Wave Energy Demonstration at Utility Scale to Enable Arrays will demonstrate a grid connected 1MW OE35 floating wave energy converter (known as the OE Buoy) at the European Marine Energy Test Site (EMEC) in Orkney, Scotland. Ocean Energy and University Cork College are the Irish project partners.

HORIZON EUROPE, SEETIP Ocean: SEETIP supports the activities of both the European Technology & Innovation Platform for ocean energy (ETIP Ocean) and the Strategic Energy Technology plan (SET Plan) Ocean Energy Implementation Working Group. SEAI are project partners of SEETIP.

HORIZON EUROPE, SEASTAR: In the SEASTAR project, coordinator Nova Innovation (Nova) leads a world-class team to deliver a 4 MW array of 16 tidal stream turbines at the EMEC Fall of Warness tidal site in Orkney - the world's first large tidal farm, which will contain more tidal turbines than are currently deployed worldwide. Irish partners include Nova Innovation Limited, Wood Group Kenny Ltd, Ocean Wave Venture Ltd.

HORIZON EUROPE, MEGA WAVE PTO: The MEGA PTO Wave project aims to provide an enabling technology to transform ocean waves into clean, reliable energy. Through this project, a smart, scalable system will be created that adapts to changing conditions and keeps working even if a part of the system experiences a fault. Pure Marine Gen Ltd and CETO Wave Energy Ireland Ltd are the Irish partners of the project.

HORIZON EUROPE, SHY: The SHY project will develop a composite linear pump and controller valve that use sea-

water as the working fluid and enable the use of a dynamic passive controller to maximise the power capture. National University of Ireland Maynooth are the Irish partner.

EMFAF, SAFEWave: Streamlining the Assessment of environmental efFEcts of WAVE energy addresses environmental monitoring of ocean energy devices, specifically wave energy deployments. The project aims to assist in overcoming non-technological barriers that could hinder the future development of one of the main pillars of the EU Blue Growth strategy: wave energy. MaREI UCC are the Irish project partners.

ERC, HIGHWAVE: Wave breaking represents a key physical process that affects the evolution of ocean waves and the interaction between the overlying atmosphere and the underlying ocean. HIGHWAVE aims to develop an innovative approach to include accurate wave breaking physics into coupled sea state and ocean weather forecasting models, but also to obtain improved criteria for the design of ships and coastal/offshore infrastructure; to quantify erosion by powerful breaking waves. MaREI UCC and UCD are the Irish project partners.

Innovation Fund, SAO: The Saoirse Wave Energy Project is a first-of-a-kind 5 MW wave energy development located 4 km offshore from County Clare, Ireland. The project will deploy and demonstrate the CorPack, a pre-commercial wave energy array using the CorPower Ocean wave energy converter (WEC) technology. By accelerating wave energy roll out, Saoirse Wave Energy will enable others to implement wave energy farms, contributing to the delivery of the European Commission's Green Deal deployment targets for tidal and wave energy. It will demonstrate wave energy levelised-cost-of-energy (LCOE) reduction towards the EU SET Plan's target of €150/MWh.

TECHNOLOGY DEMONSTRATION

Existing open sea test sites

Ireland aims to provide test sites that facilitate the testing and development of wave, tidal and offshore wind energy technology at all technology readiness levels (TRL). Ongoing improvement and expansion of Ireland's test and demonstration facilities are key to the Ocean Energy goals in Ireland. Planned facilities that cover all Technology Readiness Levels (TRLs) from 1 – 9 are detailed below:

Lir National Ocean Test Facility

The Lir National Ocean Test Facility (NOTF) is a world-class centre for renewable energy and marine research, located in the UCC Beaufort Building in Ringaskiddy, Co. Cork. Lir is a custom-designed test facility that features upgraded and expanded tanks and equipment for the testing of small-scale Ocean Energy renewable devices with TRL ranging from 1 to 4. Lir is an essential part of Ireland's Ocean Energy research and testing infrastructure and provides a significant launch pad for both national and international marine renewable energy developers. Testing infrastructure includes:

- A Deep Ocean Wave Basin (circa 1:15 scale testing).
- The Open Ocean Emulator, an ocean wave basin with a sophisticated 2-sided paddle system and a two-sided absorption system (circa 1:50 scale testing).
- A wave and current flume with coastal/tidal testing capabilities (circa 1:50 scale testing) and a wave demonstration flume.
- Mechanical and electrical workshops.
- Electrical testing infrastructure, including a smart grid and a series of linear and rotary rigs used to test power take-off and energy storage.

SmartBay Marine and Renewable Energy Test Site

The test site aims to facilitate open sea deployment of a quarter to half scaled prototypes of Wave Energy Converters (WEC's) with TRL ranging from 4 to 6.

Atlantic Marine Renewable Energy Test Site (AMETS)

The Atlantic Marine Energy Test site in Belmullet Co. Mayo is being developed by SEAI to test full scale pre-commercial offshore energy technologies with TRL ranging from 7 to 9[11].

11 https://www.oceanenergyireland.com/test-facilities/atlantic-marine-energy-test-site/index.xml

Planned deployments

There were no additional planned deployments of ocean energy projects in Ireland in 2024. The Saoirse wave energy project is continuing for planned deployment in 2029.

SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

Atlantic Maritime Strategy - Pillar III Marine Renewable Energy

The main objective of the European Commissions' Atlantic Action Plan 2.0 is to unlock the potential of blue economy in the Atlantic area while preserving marine ecosystems and contributing to climate change adaptation and mitigation. The plan includes four pillars that are interconnected and trans-regional by nature and address key challenges and aim to foster sustainable blue growth and contribute to greater territorial cooperation and cohesion in the EU Atlantic area. Pillar III Marine Renewable Energy sets one specific goal; namely to promote carbon neutrality through marine renewable energies in the Atlantic area. It sets out a number of actions to encourage innovation and foster collaboration between the four Member States to help them achieve the goal.

In July 2024 the third term of Pillar III commenced with Ireland reappointed Pillar lead for Marine Renewable Energy.

European Maritime Day

European Maritime Day 2025 will take place in Cork, Ireland, on the 21-23 May 2025. It is the annual event during which Europe's maritime community meet to network, discuss and outline joint action on maritime affairs and sustainable blue economy. It is also the place where 'Ocean Leaders Meet'. It provides an engaging and interactive experience to catch up on the current state of play on a broad range of issues concerning the blue economy and the marine environment and to discuss ways of moving forward.

RELEVANT NATIONAL EVENTS

Events in 2024

Marine Renewables Industry Association: The MRIA represents and promotes development and implementation of policy for Marine Renewables Emerging Technologies. MRIA hosted the 2024 Marine Renewables Emerging Technologies Industry Forum. Ireland's ORE policy developments, emerging technologies and innovations in ocean energy were presented.

Centre for Ocean Energy Research: The COER is an active international research centre in Maynooth University involved in fundamental and applied research relating to ocean energy. A series of seminars have been hosted as in-person and online events presenting research on the technical aspects of ocean energy systems.

Ocean Knowledge 2030: The Marine Institute held the Ocean Knowledge 2030 conference in Dublin on 20th - 21st November 2024. The conference was held to bring together a diverse national ocean community including academic and public research bodies, government departments, state agencies, ocean business and civil society.

Annual Marine Economics and Policy Research Symposium: The Socio-Economic Marine Research Unit in the University of Galway organised the annual Marine Economics and Policy Research Symposium held in Portershed, Galway City on 3rd December 2024. The event provided participants with an update and discussion on socio-economic research related to a broad range of marine policy topics.

Events in 2025

Marine Renewables Industry Association: The MRIA represents and promotes development and implementation of policy for Marine Renewables Emerging Technologies. The annual MRIA Forum will take place in February 2025.

European Maritime Day will take place in Cork City Ireland from 21-23 May.

The SEAI National Energy Research Conference will take place in September 2024.

ITALY

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OVERVIEW

In the wake of the past years, 2024 was also characterized by a reduced rhythm of marine projects development. Nevertheless, some relevant advances concerning ocean energy occurred, especially regarding projects with an already defined development path, which continued their way towards technological maturity. From a strategic point of view, relevant preparatory work has been carried out for the implementation of new public funding plans, considering both capital grants and market incentives, also including NRRP resources. These changes are described in the report, together with the annotation of the most relevant 2024 events.

SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy

NECP 2024

In 2024 an updated version of the National Energy and Climate Plan (NECP) was presented, defining national strategy towards 2030 targets. Although the largest contributions in the electricity sector are expected from photovoltaic and wind energy, all energy sources should play an important role. In NECP it is highlighted that energy resource deriving from the sea (marine energy) has great potential both for the amount of power available globally and for its power density, estimated to be over 20 times that of the wind resource, and its greater predictability. In Europe, the availability of marine energy resources is greatest along the Atlantic coast (Ireland and Scotland). However, the Mediterranean Sea also offers interesting opportunities for both energy production and technology development. From ENEA assessments it emerged that the areas with the highest wave energy potential are the western coasts of Sardinia and the Sicily Channel, where the average energy flow fluctuates between 10 and 13 kW/m. Strengthening the role of energy from the sea in the Mediterranean now appears more of a necessity than a choice, as evidenced by the growing interest of local authorities (e.g. the Italian ANCIM - National Association of Minor Island Municipalities). A great effort is therefore underway by the national scientific community to develop devices for converting wave motion into electrical energy, following shared methodologies for the evaluation of their level of technological maturity (TRL) and converging towards a limited number of optimal solutions that avoid the dispersion of funding and skills. Research and development activities are supported by financing instruments that operate on two levels: (i) basic research for innovative technologies and (ii) the development of pilot and demonstration projects. The objectives of national research and development activities are in line with those established by the "Ocean Energy" working group of the European Strategic Plan for Energy Technologies (SET-Plan). In this context, Italy, represented by ENEA, presides over the collaborations between the Member States interested in energy from the sea. The R&D activities are also in line with those proposed by the Joint Research Program Ocean Energy of the European Energy Research Alliance (EERA).

NRRP

The National Recovery and Resilience Plan (NRRP), the national plan functional to access the funds allocated in the Next Generation EU area, aims at giving a strong impulse for a rapid restart after the pandemic impact on country society and economy. Within NRRP, a specific investment (Green Islands) provided dedicated resources to the development of innovative plants and solutions, including marine energies.

Finally, the cluster "Blue Italian Growth" (BIG), led by the Italian National Research Council (Consiglio Nazionale delle Ricerche - CNR), has continued its progress towards the establishment of an open structure for the aggregation of all the national actors involved in all the different sectors of the Blue Economy, including Marine Renewables. Sectoral Action Plans have been developed.

Market incentives

The RES 2 Ministerial Decree 06/19/2024 was issued to support the production of renewable electricity from innovative technologies or with high generation costs, through the definition of incentives that stimulate their competitiveness and allow them to contribute to achieving the 2030 decarbonisation objectives. The objective of the RES 2 is to build 4.6 GW of plants by 31 December 2028 using a series of technologies, including energy plants from tidal energy, wave motion, other forms of marine energy and offshore floating PV, with a dedicated quota of 200 MW. The first competitive procedure for such technologies is expected in 2025.

The Directive 2014/89/EU on Marine Spatial Planning is also relevant for the specific Blue Energy Sector, as it establishes a framework for the implementation of maritime spatial planning and integrated coastal management by Member States, aimed at promoting the sustainable growth of maritime economies, the sustainable development of marine areas and the sustainable use of marine resources. The Directive has been transposed into the Italian legislation via D. 201/2016.

Public funding programmes

The "Green Islands Program" was launched from the Ministry of the Environment and Energy Security. The Program has a budget of 200 million Euros provided by Investment 3.1 of the National Recovery and Resilience Plan (PNRR), Mission 2 Component 1. The Program is aimed at promoting the improvement and strengthening, in environmental and energy terms, the Municipalities of the 19 smaller non-interconnected Islands, through the promotion of renewable energies, the implementation of integrated energy and water efficiency projects, sustainable mobility, waste cycle management and circular economy. The Program is aimed at the 13 Municipalities of the 19 non-interconnected smaller islands. Among the projects presented by the municipalities in April 2022, the installations of systems for the production of renewable energy from wave motion are planned on two islands. In September 2022, through a directorial decree a formal approval was given to the presented projects, which will have to be realized in the upcoming years.

RESEARCH & DEVELOPMENT

Research activities and infrastructures

RSE

Ricerca sul Sistema Energetico SpA, has always been engaged in analyses, studies and research applied to the entire energy sector. Through the funding of the Ricerca di Sistema fund, which supports the research and development activity aimed at technical and technological innovation of general interest to the electricity sector in Italy, RSE has been carrying out activities about ocean energy since 2012. The main focus is the mapping of marine energy resources along the Italian coastline which can be retrieved from the Integrated Atlas for the National Energy System and Renewable Sources[1]. In addition, RSE has developed the WAVESAX concept, a wave converter within the OWC category described later. In 2023 the activities were carried out in the project INFER (Energy from renewable sources and land integration[2]) and concerned the development of mathematical models for single WAVESAX device characterization and the study of optimal configurations of a set of devices (park analysis) for their use in offshore locations.

ENEA

The national agency for alternative energies, has long been involved in ocean energy research. ENEA has developed two innovative models to estimate the production of energy from the sea thanks to high-resolution forecasts of waves and tidal currents in the Mediterranean:

MITO: capable of providing forecasts on the temperature, salinity and speed of sea currents with spatial detail ranging from 2 km up to a few hundred meters as in the case of Straits of Gibraltar, the Dardanelles and the Bosphorus;

1 https://atlanteintegrato.rse-web.it/
2 https://www.rse-web.it/progetti/energia-da-fonti-rinnovabili-e-integrazione-nel-territorio/

WAVES: the wave prediction system that guarantees resolution up to 800 meters in marine and coastal areas with high energy potential.

In the Mediterranean sea, the areas with the highest potential for wave energy are the western coasts of Sardinia and Corsica, but also the Strait of Sicily and the coastal areas of Algeria and Tunisia, where the average energy flow fluctuates between 10 and 13 kW/m. In addition to the waves, a novelty has been introduced in the model: local tides and those transmitted from the Atlantic through the Strait of Gibraltar have been included.

In Italy, tidal energy can be extracted mainly in the Strait of Messina. Together with the Strait of Gibraltar, this area shares the record as the most promising site in the Mediterranean: in fact, thanks to the exploitation of its currents that reach speeds of over 2 meters per second, the production of energy could reach 125 GWh per year, an amount sufficient to meet the energy needs of cities like Messina itself.

In Italy, attention is growing for the exploitation of energy from the sea, in particular from waves since the extraction of energy from the tides is limited to a single geographical area and WEC technology appears to be more promising for the Mediterranean environment. Initiatives in this sector are multiplying, but the most significant at public level concern the Research of the Electricity System and the recent establishment of the **Blue Italian Growth National Technology Cluster (BIG)** which sees in the development of marine renewable energies a driving force for economic growth and for the relaunch of the shipbuilding industry in our country. ENEA, together with the Polytechnic of Turin, is responsible for the activities related to marine renewable energy at the Technical Scientific Council of the Cluster-BIG. ENEA has launched the first national survey of new technologies for exploiting energy from tidal currents and sea waves in 2021, as part of a campaign conducted together with Ocean Energy Europe (OEE), European Energy Research Alliance (EERA) and ETIP Ocean.

CNR - National Research Council

The National Research Council is the largest research body in Italy, a network of 88 Institutes under 7 departments covering multi-disciplinary areas. The Department for Engineering, Energy, Transport and IT is actively involved in multi-disciplinary research in the Offshore Renewable Energy (ORE) sector. A key contribution is given by the Institute of Marine Engineering (Istituto di Ingegneria del Mare, CNR-INM). The Institute was founded in 2018 integrating the expertise, experience, and history of three CNR institutes: the Marine Technology Research Institute (formerly INSEAN, established 1927), the Genoa and Palermo branches of the Institute of Intelligent Systems for Automation (ISSIA), and the Institute of Acoustics and Sensors "Orso Mario Corbino" (IDASC). Expertise in the modelling, testing, demonstration of marine transport and offshore structures is applied to studies for the sustainable exploitation of marine renewable energy sources.

CNR-INM is internationally recognized for the experimental research carried out in hydrodynamics testing infrastructures among the largest globally for applications to the ORE sector. Cross-cutting research topics include underwater acoustics and robotics, materials and structures, energy system management and grids. The research approach is multi-disciplinar by taking advantage of collaborations with other CNR institutes working on the environmental and societal implications of the maturation of the ORE sector. Support to the development of ORE technologies is also given by participation to international committees (ITTC, ISSC, IEA-Wind, IEC) and networks (EERA, OEE), and in education and training by collaboration with national and international academic Institutions. At national level, CNR-INM contributes to the Blue Italian Growth National Technology Cluster (BIG).

MOREnergy Lab

The MOREnergy Lab is a research centre of Politecnico di Torino, Italy, active in all areas of offshore renewable energy, notably wave energy and floating offshore wind. The MOREnergy Lab allows to deepen the study of all marine energy sources, investigating not only wave motion but also offshore wind and offshore solar. The MOREnergy Lab is based at Politecnico di Torino, but triangulates with two important Eni structures: the Marine Virtual Lab (at the HPC5 supercomputing centre in Ferrera Erbognone) and the offshore test area in Ravenna, where the pre-prototype phase of the ISWEC wave converter (the world's first hybrid and distributed wave and photovoltaic power generation plant). In addition to Piedmont, Lombardy, Emilia Romagna also in Sicily, the laboratory collaborates with the Polytechnic site in Pantelleria. Within Pantelleria, the MOREnergy Lab has a sea area in permission for experimental testing; moreover, being the regional partner of the Clean energy for EU islands secretariat, the MOREnergy lab Lab has redacted the Energy Transition agenda for the decarbonisation of the Island, currently in its second

phase of implementation. The MOREnergy Lab has developed an open-access web-based platform[3], dubbed MORE-EST that gives users access to wave and wind energy resources in any location in European seas and oceans, as well as some maritime spatial planning information and examples of productivity evaluation. It has been designed to support maritime stakeholders in the exploitation of wave and wind energy resources, offering wave data for the period 2010 to 2019, as well as the power matrix of different wave energy converters.

MORE Lab Stewart Platform

To validate numerical models concerning the dynamics of systems and subsystems, the subject of study in the MORE Lab, a six-degree-of-freedom motion platform, also called the Stewart Platform, is available. The platform comprises six linear electro-mechanical actuators combined to make a hexapod capable of realising the motion trajectories. The need for such instrumentation lies in simplifying experimental testing, which, in the most general case, would involve the floating device and its subsystems and related experimentation in naval tanks or relevant environments.

MOST is a collaborative effort between the MORE Energy Lab and the WEC-Sim developers at Sandia National Laboratories and the National Renewable Energy Lab. MOST (Matlab for Offshore Simulation Tool) functions within the WEC-Sim environment to simulate various offshore structures, including floating wind turbines, hybrid wind-wave energy converters, and platforms with multiple turbines.

SEAPOWER SCRL

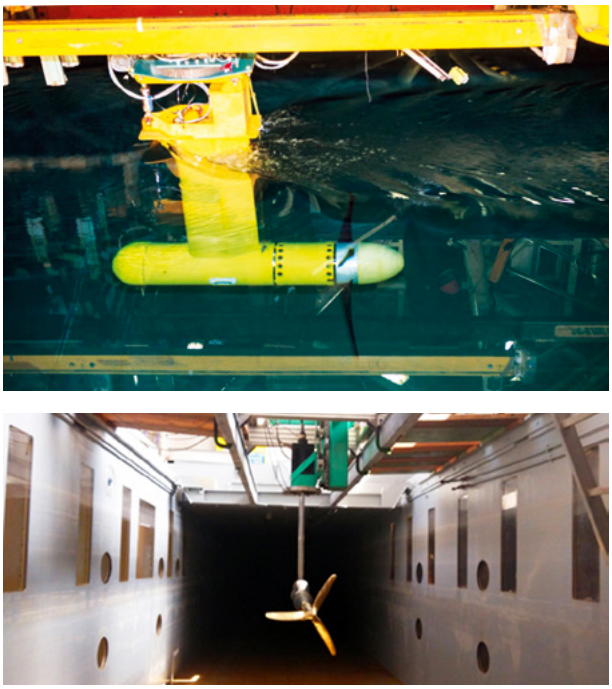
SeaPower (www.seapowerscrl.com) is a non-profit research center participated by University of Naples Federico II. Founded with the aim of developing systems for spreading the distributed generation of renewable energy from fluid sources, the company develops systems for ocean energy (tidal and wave), rivers, small/medium wind turbines and develops projects for large PV and wind plants for private customers. It participates at European research projects for floating offshore wind turbines and performs experimental test campaigns for both ocean and wind devices at reduced scale level (towing and wave tank, wind tunnel) as well as at full scale in real field condition. Worth to mention GEMSTAR, a tethered submerged system to harness tidal stream energy, PIVOT hinged wave energy converter originally developed for nearshore application and recently extended to offshore use and HYDRASPAR an innovative patented floating platform to be employed by offshore floating wind turbines.

CNR-INM flume and towing tanks

CNR-INM headquarters in Rome offer world-class research infrastructures for the development, assessment and demonstration of marine renewable energy systems. This includes:

- "Pugliese" calm water towing tank, one of the largest globally for studies on offshore renewable energy. The tank is equipped with a towing carriage powered by 4x92 kW motors that can achieve a maximum speed of 15 m/s,
- "Castagneto" wave-towing tank, with towing carriage maximum speed of 15 m/s, equipped with a single-paddle wavemaker to generate regular as well as random sea states.
- Circulating Water Channel, one of the largest depressurized flume tank globally hosting research and consultancy projects on offshore renewable energy.

These infrastructures are used to test large-scale models of concepts with TRL up to 5 and allow the simulation of real operating conditions at sea, accounting for the combined effects of winds, currents and waves.



Tidal stream turbine testing at CNR-INM: PTO response during wave-towing tests on a 1.5 m model

3 http://www.morenergylab.polito.it/more-est-platform/

University of Naples Wave/Towing Tank

The Naval Tank of the Department of Industrial Engineering (DII) – of University of Naples Federico II allow to test relatively large models and to obtain very good tank-sea correlation. Resistance and powering characteristics have been conducted both for conventional ship and for fast planning hulls. Furthermore, multi hull configurations like catamaran, trimaran and pentamaran ship models have been subject of research during last years.

VGA

VGA srl founded in 2011 is as an engineering company specialized in the design, development and operation of test rigs, energy storage solutions, actuation systems and high-tech equipment. VGA started in 2018 their activities in the ocean renewable energy sector, exploiting their knowledge in test rigs applied to wave energy conversion technologies. In particular, during 2024 VGA was involved into three different projects:

IMPACT (Horizon 2020): led by VGA, aimed at developing the next-generation testing platform and methodologies for wave energy converters. It ended in June 2024 with the issue of a public report describing the novel methodology framework and testing approach. The successfully developed rigs will continue to be used as part of the SWEET Lab at VGA's facilities.

EuropeWave (Horizon 2020): VGA, working as subcontractor of the project lead CETO Wave Energy Ireland, tested a belt for characterization and endurance purposes and provided support in the drafting of the CETO technology drivetrain test plan and setup.

MORE (Clean Energy Transition Partnership): the "Next Generation Marine Materials for Resilient Offshore Renewable Energy Devices" project focuses on harmonizing small- and large-scale multi-degradation rigs, to create a fast track for validation of materials and subcomponents used in the offshore renewable energy sector. VGA provided support in the design of the multi-degradation rigs that are currently being developed.

SWEET Lab

The Structured Wave Energy Equipment Test Laboratory (SWEET Lab) was inaugurated in April 2024 at VGA facilities in Deruta during the IMPACT Wave Energy Rig Testing Workshop. The laboratory integrates two different test rigs targeting the development of wave energy converter technologies. The drivetrain test rig, originally developed as part of the EU-funded IMAGINE project for testing a linear Power Take Offs (PTOs), has been furtherly upgraded so that it is now able to host either linear or rotary for PTOs from different types of wave energy converters (WECs) and simulate their interaction with the electrical grid. The SWEET Lab was also included within the Horizon Europe RISEnergy project.

SWEET Lab drivetrain test rig

Marine Renewable Energy Lab (MaRELab)

Marine Renewable Energy Lab (MaRELab) is the first onshore/offshore infrastructure financed by Ministry for environment and energy safety (MASE), for testing full and model scale prototypes aimed at harvesting energy from marine renewable sources. It is a real environment testing site located in the port of Naples, in proximity of the final part of San Vincenzo artificial breakwater. The laboratory covers an area of about 4 km^2, including 40 meters along the breakwater, and moving 300 meters in the seaside from this. Just few meters from the breakwater, it is possible to reach about 30 meters deep, allowing the correct scaling of the behaviour of platforms in deep and intermediate waters. Due to its facilities, MaRELab enables to test different kind of devices. On the breakwater area, for example, is currently installed the OBREC device (Overtopping BReakwater for Energy Conversion), that exploits the overtopping phenomenon in order to produce energy.

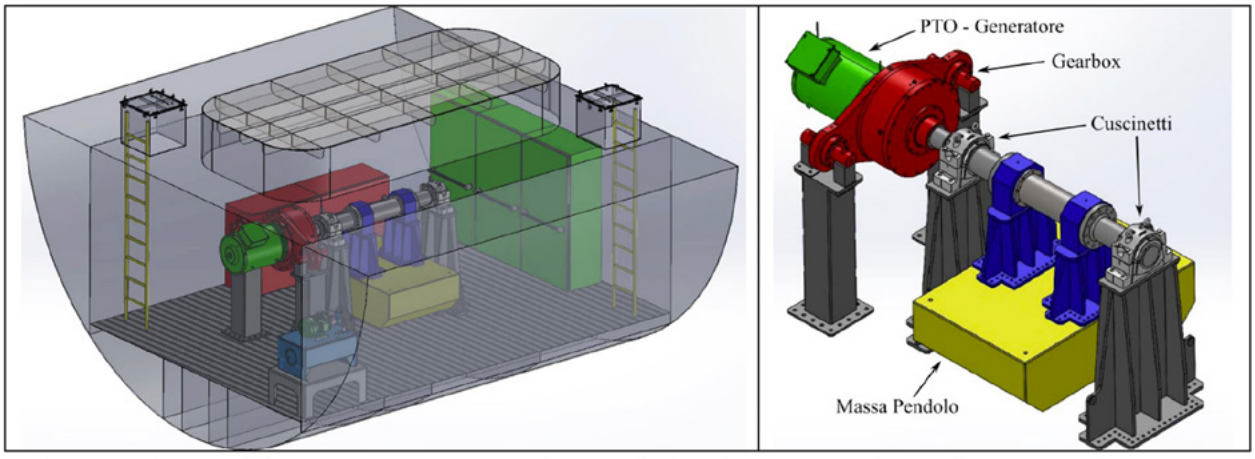
Innovative converters

MEGA WAVE PTO

The mission of the European research project entitled "MODULAR ELECTRICAL GENERATOR PTO SYSTEM FOR WAVE" is to create a smart and scalable system that adapts to changing marine conditions, continuing to operate even if part of the system fails. The consortium includes two Italian companies: Cheros Srl and the Institute of Mechanical Intelligence of the Sant'Anna School of Pisa.

PeWEC

The new and improved version of PEWEC (Pendulum Wave Energy Converter), being developed by Italy's national agency ENEA and the MOREnergy Lab of Politecnico di Torino, could prove to be an ideal solution for small and medium-sized islands across the Mediterranean as they transition to net-zero future. PEWEC 2.0 features some technological improvements compared to the previous version. The Politecnico di Torino university has developed fast and reliable numerical models in conjunction with genetic optimization algorithms to identify device geometries and characteristics that minimize the system's energy costs. Between 2022 and 2024, the team designed a PEWEC prototype for installation at the test site off Pantelleria. The developed prototype features an electric generator with a nominal power of 50 kW, a hull length of 7.5 meters, a width of 6.5 meters, a height of 3.6 meters, and a total weight of 86 tons.



Preliminary design of the PEWEC prototype to be installed at the test site of Pantelleria

SWINGO

A novel wave energy converter that incorporate an innovative gyropendulum system within its hull. SWINGO overcomes the issue of directionality by activating the gyropendulum system regardless of the incoming wave direction. The gyropendulum system introduces a hybrid device functioning as both a gyroscope and a pendulum, adapting to the wave's direction relative to the hull. As a result, this innovation represents a progression from WECs exclusively based on pendulum or gyroscope technology. In October 2023, a comprehensive test campaign of a 1:20 prototype was conducted at Oregon State University to evaluate the system's energy conversion capability under varying directions.

PIVOT Wave Converter

Pivot is part of one of the Seapower patents and is an innovative system for generating clean energy from sea waves, born in 2015. In its first nearshore version, the system consists of a fixed structure and a floating body. The buoy, hinged on the fixed structure, captures the wave energy and transforms it into usable energy through the Power Take-Off (PTO) system, developed by Umbra Group. The mechanical energy contained in the waves is then transformed into electrical energy, ready to be fed into the grid or used to charge a battery bank. The entire system, in its first version, must be anchored to a fixed structure such as a platform, breakwaters or piers. After two phases of successive tests in the laboratory, a large-scale model was manufactured and tested in the port of Civitavecchia, which gave excellent results and a new development of the technology for offshore applications has been patented and it is currently under development.

Pivot first generation-nearshore version tested in Civitavecchia

RivGen Power System by ORPC

During 2024, demonstration trials of a full-scale crossflow hydrokinetic turbine were carried out at the calm water towing tank at CNR-INM. The device was representative of the RivGen Power System developed by the ORPC company for installation in both tidal sites and rivers. The activity was partially funded by the EU-H2020 CRIMSON project (2021-2024), and represented a first-of-its kind testing program, tested during 3 months in the tank. Innovative solutions for materials, system design and manufacturing were investigated, and the turbine performance was characterized over a full range of operating conditions. The testing program delivered new knowledge to enhance reliability and profitability in the tidal energy sector. The feasibility of testing high TRL devices in large towing tanks to de-risk marine renewable energy project was stressed.

TECHNOLOGY DEMONSTRATION

In Italy, there is an increasing interest in the exploitation of wave and tidal energy converters. In particular, wave converters integrated into conventional breakwaters have gained more and more interest among the port managers, as they offer the opportunity of energy self-sufficiency for the infrastructures in conjunction with a limited increase in costs and with ease of maintenance. Italian companies engaged in the supply chain for wave and tidal energy converters detain long-term experience and innovation capacity, which can support all the specific, high-tech steps of the design and production process.

The following map shows a historical list of the Italian locations where research infrastructures for marine energy have been developed in recent years (such as marine tanks) or devices have been tested in the sea.

Locations where marine projects have been developed in last years

Wave converters

WAVESAX

RSE S.P.A. (Ricerca sul Sistema Energetico), in collaboration with Tuscia University, developed WAVESAX (TRL 5/6), an innovative wave converter within the OWC cate-

gory, registered by the European Patent Office[4]. This device has been conceived for its integration into coastal structures. The article "Modeling and optimization for arrays of water turbine OWC devices" has been published in the journal Ocean Engineering. In March 2024, the Sicilian Region and RSE signed a three-year MoU to facilitate the definition of policies aimed at achieving the objectives established at European, national and regional level in terms of energy transition and sustainable development and to support the drafting of the regional strategy on the efficient, economic and effective management of energy produced from renewable sources.

REWEC3

The Mediterranean University of Reggio Calabria has been developing the REsonant Wave Energy Converter (REWEC3), which is a particular type of Oscillating Water Column (OWC) incorporated into a traditional vertical breakwater of monolithic reinforced concrete structure type. This activity is being carried out in cooperation with Wavenergy.it – an Academic Spin-Off of the Mediterranean University. The REWEC3 has already been installed in the port of Civitavecchia (Rome) and the famous architect Renzo Piano plans to insert it in the new port of Genoa. It will soon also be built in the Port of Salerno and Roccella Ionica (Reggio Calabria) and its installation will be evaluated both in the Principality of Monaco and in Belgium to defend the artificial islands. About the first full-scale prototype built in the port of Civitavecchia, the Port Authority of Civitavecchia decided to upgrade its infrastructure and adopted the REWEC3 technology for the realization of 17 new caisson breakwaters. Each REWEC3 caisson is 33.94 m long and includes 6-8 independent chambers. The total length of REWEC3 caissons is 578 m. A first Wells turbine of 20 kW has been installed. With all the caissons equipped with turbines, the total capacity would be 2.5 MW.

SiZable Energy - Spar buoy platform

In March 2024 it is recorded that the development of a hydroelectric storage system (Spar Buoy) is planned, a particular type of buoy characterized by excellent stability against wave motion. These Buoys were used by SiZable energy during experimental tests conducted in the sea of Reggio Calabria. Their purpose was to keep the floating tank of the miniaturized floating electric storage system in place. Already in 2021, a platform was positioned in the same place, as part of a multifunctional European project for aquaculture applications with on-board electricity generation from renewable sources. A series of studies were started, acquiring further skills and expanding the initial delivery area of the laboratory also in the open sea.

Positioning of the SiZable Energy platform on the Reggio Calabria seafront

Overtopping BReakwater for Energy Conversion (OBREC)

The first OBREC device was built into the Port of Naples's San Vincenzo rubble mound breakwater in 2015. It was the world's first overtopping device wave energy converter (WEC) built into an existing coastal defense structure. With a completely new PTO, a medium-term monitoring campaign is starting. The goal is to enhance the capacity factor and to develop the very-low-head saltwater-turbine sector.

Inertial Sea Wave Energy Converter (ISWEC)

The Polytechnic of Turin developed ISWEC (TRL 7), a pitching point-absorber wave energy converter suitable for mild climate seas such as the Mediterranean. It is based on the gyroscopic technology already used in marine applications for roll stabilization, except that the direction of energy transfer is reversed, with the gyroscopic torque induced by the incoming waves being exploited by the electrical PTO. Research activities started 15 years ago and led to the development of the technology industrialized by Wave for Energy, a spin-off of the Polytechnic of Turin. A unit of 250 kW was installed off Pantelleria in the early 2023 and the project is currently ongoing.

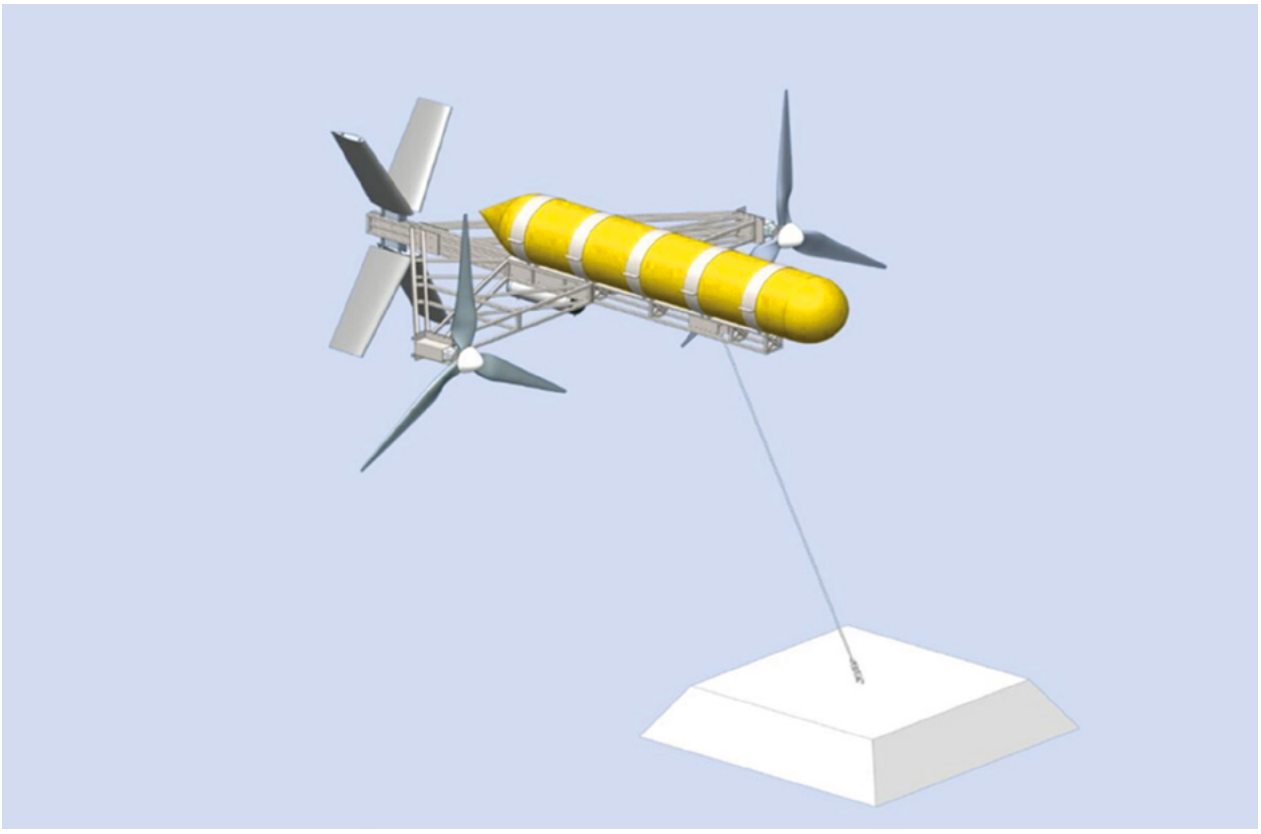
4 Patent Document N. 2 848 802 B1, European Patent Bulletin 2016/23

ISWEC installation

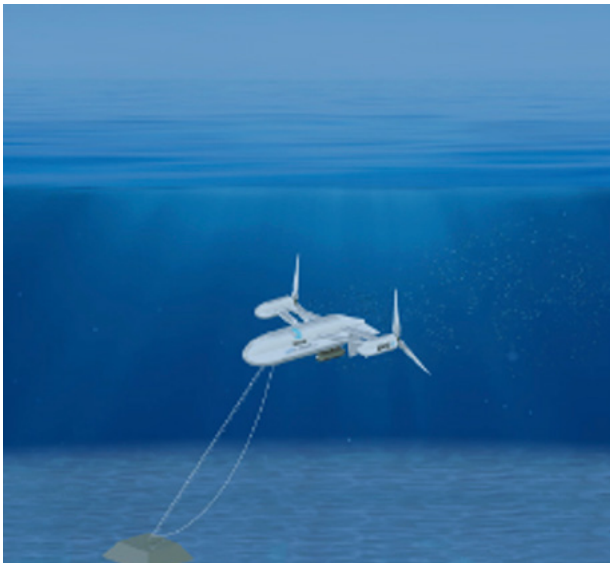
Tidal turbines

MECS

MECS (Multi Energy Compensator System) is the new project of Seapower; the project has as its general objective the development of a complex system (microgrid) capable of integrating and managing the energy produced by multiple systems that exploit different renewable sources, such as wind, sun and tidal currents, optimizing overall costs, efficiency and reliability.



The functioning of the Multi Energy Compensator System



Gemstar second generation project

GEMSTAR

SeaPower s.c.r.l. designed Gemstar, a system for converting the kinetic energy of water such as tidal currents, marine currents or the motion of rivers, into electrical energy. Gemstar represents the second generation and the evolution of the first prototype of the project, which has been developed since 2005. It consists of a tethered system of two marine turbines connected to a submerged floating body that is tied to the seabed by a cable. Seapower aims to install the next full-scale 300 kW prototype in the Strait of Messina.

SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

The final version of the NECP, transmitted to the European Commission in July 2024, provides that regional cooperation on RES with neighbouring countries (Malta, Croatia, Austria, Greece and France) could also be based on the sharing of offshore plant development projects (offshore wind, tidal, wave motion) and the related maritime shipbuilding industry, on the opening of support mechanisms, on electricity interconnections, gas pipelines and natural gas supplies.

RELEVANT NATIONAL EVENTS

Events 2024

- **12 April 2024 Perugia:** Wave Energy Rig Testing Workshop: Bridging the Gap between Research and Deployment, Horizon 2020 "IMPACT" project
- **5-8 November 2024 Rimini:** Ecomondo 2024 The Blue Economy, a strategic resource for the future
- **6 December Venice:** International Conference on Nautical and Maritime Culture
- **12 December 2024 Naples:** MARMED project final meeting
- **13 December 2024 Rome:** National Observatory for the Protection of the Sea: a day dedicated to offshore renewable energy and the Sea Cluster

Events planned for 2025

- **Rimini from 5th to 7th March 2025:** KEY - The Energy Transition Expo 2025

MONACO

REPORT PREPARED BY:
Jérémie Carles, Head of the Climate and Energy Division - Department of Environment - Monaco

SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy

On the instigation of H.S.H. Prince Albert II, the environment and subjects related to sustainable development are among the most important political priorities in the State of Monaco, on both a national and international level. The actions of the Princely Government take into account the topics of biodiversity, preservation & management of natural resources and the reduction of greenhouse gases emissions and also a specific policy towards the establishment of a sustainable city.

The Principality of Monaco joined the OES in June 2013. This action was part of the Government targets for combating climate change and recognizing the relevance of international cooperation.
Monaco is a coastal country with 2,08 km² of area, bordered by the Mediterranean Sea, with a coast length of 3829 m.
The Government pursues a sustainable development policy aimed at achieving full compliance with the Principality's undertakings.

According to the National Determined Contribution, in line with the provisions of the United Nations Framework Convention on Climate Change and the Paris Agreement, Monaco is committed to reduce the greenhouse gas emissions by 55% in 2030 compared to the reference date of 1990 and to achieve carbon neutrality in 2050.

In 2022, the GHG emissions decreased by 34,5% compared to 1990 (last published data).

Public funding programmes

Within the framework of the Paris Agreement, a National Green Fund has been created and is financed by:

- a contribution generated through the sale of electricity;
- the Government budget.

This fund is dedicated to finance actions in favour of the reduction of the GHG emissions and the energy efficiency, the development of renewable energies and the clean mobility.

Furthermore, the Government holds 100% of the shares of a venture capital firm, known as "Société d'Aide à la Création et au Développement d'Entreprise" (SACDE), the aim of which is to support innovative Monegasque companies.

In parallel, the Government and the SMEG (Monegasque electricity and gas company) jointly created MER (Monaco renewable energies) to develop renewable energy production projects, particularly photovoltaic and wind energy, outside Monaco. The objective is to cover the needs of the Principality with renewable electricity production capacities.

TECHNOLOGY DEMONSTRATION

Projects in the water

In Monaco, the sea is used as a renewable energy source for the development of a heat pump system. The first seawater heat pump in Monaco dates back to 1963. 80 seawater heat pumps produce 17% of the energy consumed in the Principality (about 191 GWh/year).
Many buildings located on the coast benefit from this reversible system, for heating in winter and air-conditioning in summer.

Projects planned for deployment

Two new heating and cooling networks connected to seawater heat pumps has been put into service and the buildings are being connected. They should supply 3500 homes and eliminate 6ktCO2eq of GHG emissions (approx. 8% of the total emissions of Monaco).
These networks will produce around 26 000 MWh of completely decarbonized energy.

THE NETHERLANDS

REPORT PREPARED BY:
Netherlands Enterprise Agency (RVO)
Dutch Marine energy Center (DMEC)
Energy from Water Agency (EWA)

OVERVIEW

SeaQurrent's Tidal Kite™ underwent successful offshore testing near the Dutch Wadden Isle of Ameland, demonstrating its potential in real-world conditions. Similarly, SlowMill Sustainable Power continued its dry testing, refining its technology for future deployments. The Wave Energy Collective (Weco) also made progress with tests conducted in a wave flume. Additionally, Symphony Wave Power achieved a major milestone by completing the assembly of its prototype and establishing a dry testing facility, setting the stage for upcoming sea trials.

On the investment front, the Dutch tidal and wave energy sectors have attracted significant financial support, with more than 15 million euros invested by both public and private entities. Notable companies such as Equinox Ocean Turbine, SeaQurrent, and WaveHexaPod have benefited from these investments.

SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy

National Ocean Energy Policy

The Netherlands has no specific policy on Ocean Energy Systems (OES) besides the offshore wind policy which includes possibilities for combinations with solar or other kinds of sustainable energy solutions such as wave, H2 and storage. However, our government does support innovations on OES through several innovation programs in different stages of development. For example, the **DEI +** (abbreviation for Demonstrating Energy Innovation) which is an investment subsidy (pilot and demonstration). The **SDE++** (abbreviation for Subsidy Sustainable Energy) is a feed-in tariff subsidy scheme capped at 400 €/ton avoided CO2. The SDE++ supports the implementation of new sustainable energy solutions and can be combined with DEI+ (within the boundaries of state aid). Generic funding programmes are available for all relevant types of renewable energy. Projects compete with each other and have a general condition that cost reductions must be achieved by innovation. The Ministry of Economic Affairs and Climate initiated a number of grants via generic **R&D instruments** such as TKI as well as the Waddenfonds.

These are also available for ocean energy research:

- Study on the significant ocean energy potential in Waddengebied by TNO.
- Dynamic Tidal Power (DTP) validation study by Deltares to support governmental review of subsidy mechanisms.
- Feasibility study on Delta21-concept by CE Delft and Horvat & Partners and governmental commitment to further research.
- Marine Spatial Planning Policy; The Netherlands has adopted the North Sea Programme 2022-2027, including the Maritime Spatial Plan describing the policy for bolstering the ecosystem, the transition to sustainable food supply and the transition to sustainable energy provision. The programme explicitly mentions the inclusion of wave and tidal energy in these plans with the target to identify most suitable zones for these technologies. https://maritime-spatial-planning.ec.europa.eu/countries/netherlands

The latest area passport for the Hollandse Kust Noord wind farm can facilitate the permitting of ocean energy systems integrated into the wind zone area.

Market incentives

The above mentioned subsidy programs supported by our Ministry of Economic Affairs include market incentives.

Public funding programmes

Besides the above mentioned subsidy programs supported by our Ministry of Economic Affair, there are different kinds of public funding (equity, loans, guarantees) by:

- Regional development agencies
- InvestNL, the national promotional bank
- Municipalities
- Export subsidies

RESEARCH & DEVELOPMENT

In 2024, new R&D projects were initiated:

ORESA: The Offshore Renewable Energy Sustainability Alliance (ORESA) is a consortium of multiple partners from industry, government and research institutes, spanning five NWE countries. Coordinated by DMEC, the ORESA accelerator shares expertise across the offshore sustainability sector and between its regions.

Offshore proof: This project addresses key barriers to adopting innovative Offshore Renewable Energy (ORE) by establishing a network of accredited offshore test sites across North-West Europe. Dutch partners include Campus@Sea, Deftiq and North Sea Farmers.

TidalKite 2.0 project: The project focuses on realizing and demonstrating (sub-system) design improvements, simplifying and optimising energy production from Sea-Qurrent's TidalKite. Through Dutch collaboration with RUG, TCNN, and the engagement of local suppliers, the local innovation ecosystem will be strengthened, which can result in the development of new value chains.

SHY project: The SHY project aims to unlock the potential of wave energy by developing key components of a seawater hydraulic power-take-off (PTO) system and an advanced control strategy. Together with Dutch partner Marine Systems Modelling, this approach seeks to reduce the levelized cost of energy (LCOE) and minimize environmental impact.

Mid-Fidelity Numerical Modeling Approach for Two-Stage Ocean Current Turbines: Equinox is set to introduce a two-stage turbine design for efficient power generation at low water velocities. This design reduces power take-off (PTO) costs and simplifies mooring solutions. However, current modelling tools cannot directly analyze or optimize this unique design due to its complex interactions between the main rotor and tip turbines. This project aims to adapt and refine mid-fidelity modelling tools, such as OpenFAST and associated libraries, to accurately capture these interactions and develop a robust modeling approach.

OFFSET: Offshore Floating Storage of Energy and Transfer: Supported by the Dutch Government, Dutch developer SwitcH2 is aiming to launch a new open-sea project in northern Portugal utilizing CorPower Ocean's wave energy technology.

SlowMill Validation Scheveningen project: focused on offshore testing of the improved SlowMill WEC technology. The project will validate its previously tested WEC at the Texel offshore test site. Improvements in the design with regard to fatique, mooring and remote control will lead to longer life span and better performance. In collaboration with Campus@Sea, North Sea Farmers and engineering companies.

Weco EKOO project: Drone charging at sea. Supported by the Topsector Energiesubsidie of the Ministry of Climate Policy and Green Growth, this funding enables Weco to advance the development of E-Sea Charging, an offshore charging station for autonomous vehicles powered by renewable energy sources such as solar and wave energy. The project addresses the growing need for sustainable energy solutions for unmanned vehicles, including drones, USVs (Unmanned Surface Vessels), and AUVs (Autonomous Underwater Vehicles).

These projects were also ongoing throughout 2024:

Blue-X is a Horizon Europe project focused on utilizing satellite data to optimize and expedite renewable energy projects across all phases—from planning and construction to operation and decommissioning. The project's primary aspect involves a cloud-based IT network combining Earth observation and MetOcean data streams. These streams are integrated into a decision support tool tailored for each project phase. As project partner, DMEC will pilot this tool across various developers, including SeaQurrent and Oceans of Energy.

Offshore for Sure: Five developers of promising offshore energy solutions are joining forces in the Offshore For Sure (O4S) project, coordinated by BlueSpring, supported by specialists from Belgium and the Netherlands. These projects represent innovative solutions from technology developers with a proven track record in the fields of tidal energy, wave energy, offshore floating solar energy, and energy storage.

EU FLORES project: Together with an international consortium two Dutch companies, Bluespring and Deftiq, continue their leadership in the field of developing education and training content for the sector under the ERASMUS funded project FLORES: Forward Looking at the Offshore Renewables. The project aims to improve upskilling opportunities for a new offshore renewable energy workforce.

EU SCORES is a H2020 project coordinated by the Dutch Marine Energy Centre.. EU SCORES will pave the way for bankable hybrid offshore parks across Europe from 2025. The project will build on two demonstrations: (1) A 1.2 MW grid-connected wave energy array in Portugal co-located with an offshore wind farm and; (2) A 3 MW grid-connected offshore solar PV system in Belgium co-located with a bottom fixed wind farm. As a major milestone for the EU-SCORES project and the entire marine energy sector, EU-SCORES project partner CorPower Ocean has installed its first commercial scale wave energy converter in northern Portugal in 2023.

NL-MARINERG-i is a consortium backed by the Dutch Ministry of Economic Affairs and Climate Policy (EZK). It brings together research institutes and test facilities with an aim to accelerate offshore renewable energy research actions. Led by DMEC, the Dutch consortium includes Deltares, Maritime Research Institute Netherlands (MARIN), HZ University of Applied Sciences, Royal Netherlands Institute for Sea Research (NIOZ), TNO, Netherlands Aerospace Centre (NLR), DNW German-Dutch Wind Tunnels, Technical University Delft and Wageningen University & Research. NL-MARINERG-i aims to provide research and test support to achieve the European targets for offshore renewable energy and key priorities such as the Green Deal. The NL-MARINERG-i is part of the European MARINERG-i consortium, which has been selected as one of the eleven key priorities of the European research roadmap ESFRI 2021.

TECHNOLOGY DEMONSTRATION

Existing open sea test sites

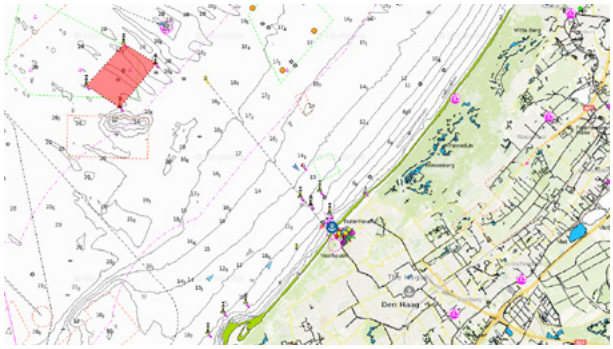
Proeftuin op de Noordzee

Off the coast of The Hague, just outside the port of Scheveningen, the Municipality of The Hague, KPN, Delft University of Technology, TNO, Sailing Innovation Centre, Svašek Hydraulics, and the Watersportverbond are collaborating on an advanced test area of 10 x 10 nautical miles. It provides startups and SMEs in this sector a space to test and demonstrate their innovative products outside the traditional laboratory, in real practical conditions on the water, and with end users. The test site is specifically designated for short-term ('live') tests of new technologies, including energy generation, data collection and others. Technology developers can make use of the area for tests in the range of multiple hours, with the limitation of all components to be removed before the end of the day.

Source: https://proeftuinopdenoordzee.nl/

North Sea Farmers - Offshore Test Site

Located 12 km off the coast of Scheveningen, the OTS is an innovation hub covering 6 km² of the North Sea area. In six plots the test site offers developers of offshore energy technologies, food production, nature-inclusive design and other innovations the opportunity for long-term testing. The site is consented (Waterwet) until 2028. Next to testing the OTS also aims to provide broader support as an incubator for start-ups and scale-ups stepping into the offshore environment or planning to upscale. As the OTS is located within the Proeftuin, a combination of testing activities in both zones is possible.

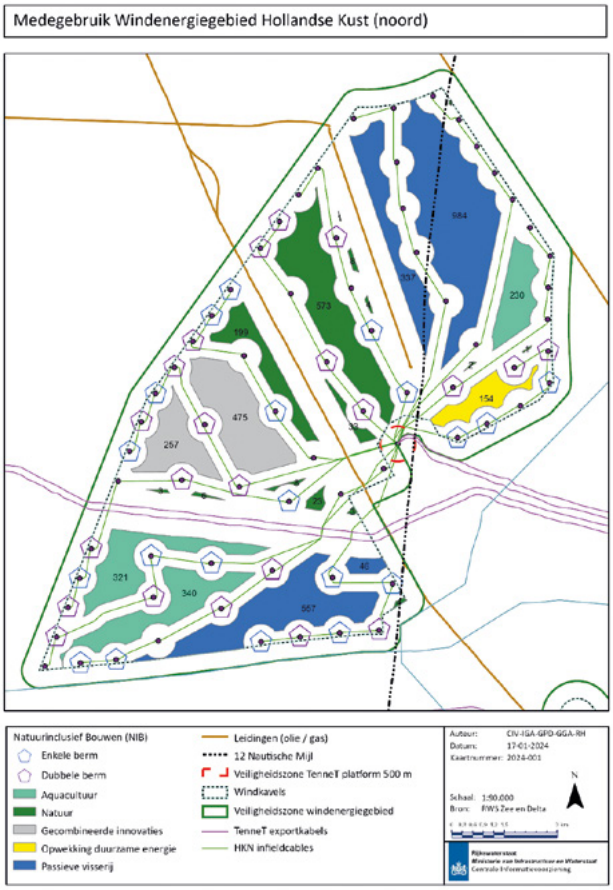


Ameland - Borndiep

The grid-connected site will serve as a testing ground for SeaQurrent's full-scale TidalKite device.

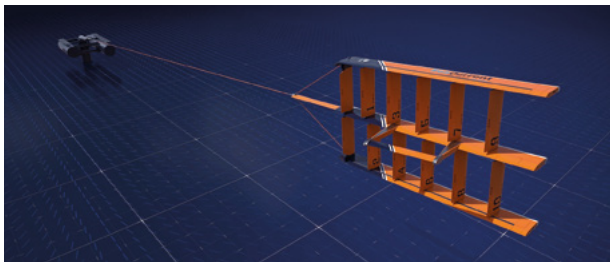
Offshore wind farms

Ocean energy developers can apply for the necessary permits to deploy as a 'multi-use' activity in offshore wind farms. Since 2020, area passports guide the assignment of preferred multi-use options to the various plots of the offshore wind farms and a legal framework in which multi-use developers can submit a permit application.



Projects in the water

The TidalKite is anchored to a monopile in the seabed with a tether and flies underwater across the current. The traction force generated by the kite is converted into electricity in a power take-off system comprising a hydromotor, which in turn drives a generator, generating green electricity. As part of Seaqurrent's TIDALKITE 2.0 project, offshore tests have been successfully conducted at the grid-connected test site near Ameland. Further testing is scheduled for next year.



Wave Energy Collective (Weco) performed a series of offshore tests with their Kaizen WEC in the Deltares wave flume and offshore at Scheveningen. Future testing at the offshore test site (OTS) in Scheveningen aims to validate a fully functional system (TRL 6).

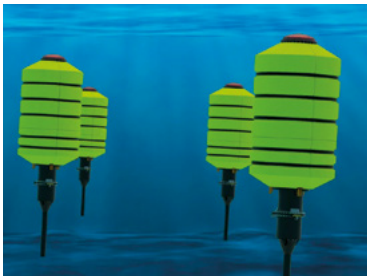
REDstack continues to generate Blue Energy from the difference in salinity between river water and seawater at the Afsluitdijk since 2014, exploring applications in natural and industrial settings. Their automated manufacturing line in Heerenveen is expected to be completed by the end of 2025.

Water2Energy's vertical axis turbine was reinstalled for new tests within the Offshore For Sure Project. The improved pitch control technology has since been patented.

Projects planned for deployment

Slow Mill Sustainable Power designed a novel wave energy device for moderate wave climates. Their 40 kW WEC is undergoing dry testing before being deployed at the offshore test site (OTS) in Scheveningen. This testing series aims to validate a fully functional system (TRL 6). After five years, their 50-ton concrete wave energy anchor has been safely recovered and will be repurposed as a backup anchor for this next demonstration.

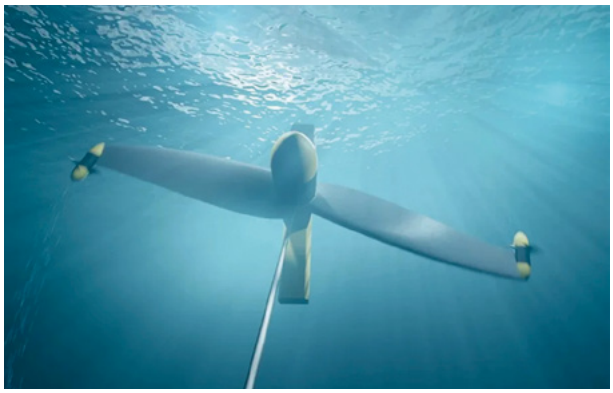
Symphony Wave Power completed their prototype assembly and dry testing facility and will test the functionality and efficiencies before heading to sea trials with their 40 kW prototype point absorber.



Dutch Wave Power has prepared the offshore demonstration at the OTS in Scheveningen, scheduled for 2025. Dutch Waver Power generates electricity with a cylindrical float that lies at sea level. The waves moving up and down cause the float to rotate and the rotation is converted into electricity by a generator built into the float.

AE WaveHexaPod will deploy two pods on a submersible off the coast of The Hague. This deployment aims to demonstrate the potential of the WaveHexaPod system with 2 x 500 kWp over a six to twelve-month period. The offshore deployment follows from the onshore testing stage at Dordrecht, where 6 repurposed robots at the bottom simulate the waves.

Equinox has moved into new headquarters and is developing a prototype turbine in 2025. Together with NREL, a modeling approach is created that captures interactions between Equinox' two turbine stages.



RELEVANT NATIONAL EVENTS

Relevant events in 2024

Amsterdam RAI, November 2024; Offshore Energy Exhibition & Conference 2024

On 26 & 27 November 2024, the Offshore Energy Exhibition & Conference (OEEC) again opened its doors in Amsterdam. The OEEC is Europe's leading event for the entire offshore energy industry, connecting the maritime and offshore world for sustainable solutions. Dutch and international marine energy companies showcased their developments to the offshore sector, including DMEC's pavilion and conference session on how to best include innovations such as ocean energy in offshore wind tenders.

Offshore Experience 2024, Den Helder

The annual event focusses on relevant developments around the offshore blue economy. With an inspiring keynote speech and panel discussion and various in-depth master classes, including on the topic of ocean energy hosted by EWA.

Oceanovation Festival, The Hague

The Oceanovation Festival, held on the 19th and 20th of June at the Fokker Terminal in The Hague, was a gathering of ocean enthusiasts, innovators, policymakers, and investors from across the globe.

Relevant events planned for 2025

- Amsterdam RAI, November 2025
- Offshore Energy Exhibition & Conference 2025
- Oceanovation Festival, The Hague

NEW ZEALAND

REPORT PREPARED BY:
Alona Ben-Tal, Vladislav Sorokin, Millan Ruka, Armin Howard, Martin Knoche and Craig Stevens
from Aotearoa Wave and Tidal Energy Association (AWATEA)

OVERVIEW

Azura Wave Power has signed Memoranda of Understanding to deploy 200 kW and 100kW Wave Energy Converters in Australia and in French Polynesia, respectively.

The Waves and Dynamics Research Group at the University of Auckland has deployed and tested two small-scale marine energy devices for aquafarms.

The "Ruka Marine Turbine" project by Mana Wairua Energy 1999 Ltd, has been approved for the Callaghan Innovations Arohia Seed Fund program. A "demonstrator" is now completed on the workshop floor and a non-disclosure agreement has been signed with a Raiatea Island delegation from French Polynesia.

The Waves and Dynamics Research Group at the University of Auckland in collaboration with AWATEA prepared a report for Ara Ake (New Zealand's future energy centre) about the potential of marine energy in New Zealand.

AWATEA members participated in the following conferences: the 2024 Offshore Renewable Energy Forum held on March 20–21 in Hāwera, New Zealand, and the International Conference on Ocean Energy, hosted in Melbourne, Australia, from September 17–19, 2024.

SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy

New Zealand has a renewable energy strategy, but sadly ocean energy is not a main priority for the Government.

Market incentives

There are no significant market incentives for ocean energy in New Zealand. However, aquafarming is growing fast in New Zealand, with increasing energy demand and interest in renewables. In addition, there are Government-encouraged initiatives for offshore wind which will have implications for ocean energy development (Hale et al. 2024).

Public funding programmes

There are no funding programmes specifically for ocean energy. There are several public funding programs (Ara Ake, Callaghan Innovation, Smart Ideas) that could potentially support ocean energy development, however, funding in these programs is limited and highly competitive. Some of the opportunities are reviewed in Stevens (2024).

RESEARCH & DEVELOPMENT

The **Waves and Dynamics Research** Group at the University of Auckland, in collaboration with Aquafarming Marine Energy Solutions New Zealand Ltd, is currently developing and ocean testing short-term at marine farms two small-scale (100 W) marine energy devices, one harvesting wave energy, another tidal energy.

Ruka Marine Turbine (RMT) is a floating surface-operating turbine, elongated in design that harnesses tidal and river currents. It will produce revolutions and torque to a PTO shaft onboard that will be able to drive most types of machinery including - desalination plants, electricity generators, irrigation pumps, and hydrogen production units. In February 2024, the RMT project has been approved for the Callaghan Innovations Arohia Seed Fund program and a demonstrator is now completed on the workshop floor.

More information about this project can be found here: https://youtu.be/8Xv7Wmd0kfU?si=HVHZ47awuNijDagD

A recent interview with Millan Ruka, can be found here: https://www.youtube.com/watch?v=xfxwBaPDX0M&t=1911s&pp=ygUVa2F0aGVyaW5lIG1pbGxhbiBydWth

TECHNOLOGY DEMONSTRATION

Projects in the water

Devices by the Waves and Dynamics Research Group at the University of Auckland were deployed short-term at aquafarming sites in 2024.

Projects planned for deployment

- Azura Wave Power has signed a Memorandum of Understanding with Southern Ocean Mariculture to deploy a 200 kW Wave Energy Converter enabled micro-grid system at their Abalone aquaculture facility in Port Fairy, Victoria, Australia.
- Azura Wave Power has signed a Memorandum of Understanding with French marine energy project developer, *YS Energies Marines Developpement*, to deploy a 100 kW Wave Energy Converter, as part of a marine energy demonstrator off the coast of the French Polynesian island of Tahiti.
- Devices by the Waves and Dynamics Research Group at the University of Auckland and Aquafarming Marine Energy Solutions New Zealand Ltd will continue to be deployed short-term at aquafarming sites in NZ.
- In 2025, subject to funding availability, RMT "proof of concept", capable of no less than 50 to 250 kW output to the PTO shaft, will be built and deployed.

SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

The International Conference on Ocean Energy (ICOE2024), 17-19 September 2024, Melbourne, Australia, was a good regional opportunity for NZ. The goal of the conference and exhibition was to share recent experiences from research and demonstrate efforts. Ara Ake was a sponsor and there were several NZ-focused talks and posters including several invited NZ syntheses and impacts talks. A University of Auckland student won an award for the best poster. The social activist Catherine Murupaenga-Ikenn (Ngāti Kurī) was well received in terms of her call for social justice. In addition, Azura Wave was name-checked throughout the conference.

Members of AWATEA participated in online seminars organised by the Blue Economy CRC (a Cooperative Research Centre under the Australian Government's CRC Program).

In December 2024, a 40-person delegation from Raiatea French Polynesia visited the RMT project in Whangarei, NZ. A non-disclosure agreement has been signed.

RELEVANT NATIONAL EVENTS

2024 Offshore Renewable Energy Forum, 20-21 March, 2024, Hāwera, New Zealand.

PUBLICATIONS

Hale R, Thompson D, Brough T, Kregting L, Hayden M (Ngāti Huia ki Poroutāwhao, Ngāti Raukawa ki te Tonga, Te Ātiawa ki Whakarongotai, Ngāti Toa, Ngāti Pākeha), Parsons D, Nodder S.D., Beaumont J., Anderson O., Stevens, C. (2024). Environmental implications of future offshore renewable energy development in Aotearoa New Zealand, Jour. Royal Society of New Zealand, pp. 1–34. https://doi.org/10.1080/03036758.2024.2406829

Stevens C. (2024). Marine Renewable Energy Research and Development in New Zealand in the Pre-Offshore Wind Era, NZ Science Review, 79, pp. 47-54. doi:10.26686/nzsr.v79.8251.

PORTUGAL

REPORT PREPARED BY:
Ana Brito e Melo, WavEC

OVERVIEW

Throughout 2024, the progression and planning of Portugal's offshore renewable energy initiatives largely depended on the anticipated approval of the Renewable Energy Allocation Plan (PAER). However, due to a government transition, the approval of this essential framework was postponed until January 2025, significantly influencing the development pace. This delay adjusted the timeline for critical activities, including the initial auction for offshore wind projects, which has now been rescheduled to 2025. The advancements in offshore wind energy in Portugal could set a positive example for the development of wave energy. While the upcoming auctions are expected to be technology-neutral, they are likely to attract primarily wind projects due to the higher Technology Readiness Level (TRL) of offshore wind compared to ocean energy technologies. This initial focus could pave the way for broader inclusion of wave energy as it matures.

SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy

Portugal's energy sector policy aims to decarbonise the energy supply and reduce energy import dependency primarily through broad electrification and a rapid expansion of renewable electricity generation, along with increased energy efficiency. The Directorate-General for Energy and Geology (DGEG), within the Ministry for the Environment and Climate Action, has the main responsibility for developing and implementing Portugal's energy policy.

In January 2022, the government introduced Decree-Law No. 15/2022, outlining the operational guidelines for the National Electric System (SEN). This decree-law established a Technology Free Zone (ZLT) offshore Viana do Castelo , a dedicated space for testing and demonstrating new technologies in a real-world environment, subject to specific legislation and continuous oversight by regulatory bodies. It also designated DGEG (General Directorate for Energy and Geology) as the managing entity of energy related ZLTs. This approach aims to expedite experimental and research activities through streamlined legal mechanisms. Covering 7.63 km^2, this ZLT is designed to foster innovation and development projects for generating electricity from marine renewable energy sources. It is strategically located near the Windfloat Atlantic project, Europe's pioneering floating wind farm.

In 2024, the approval of the Renewable Energy Allocation Plan (PAER) was expected, and it was published in early 2025 as Resolution of the Council of Ministers No. 19/2025. This initiative forms a part of the National Energy and Climate Plan 2030 (PNEC 2030), aiming to achieve a target of 2 GW of offshore wind capacity and 0,2 GW of wave energy by the end of the decade. Originally scheduled for 2023, the initial auction was postponed due to technical complexities and is now planned for 2025.

The approval of PAER will facilitate marine renewable energies in Portugal as it will automatically update and integrate into the National Maritime Spatial Planning Situation Plan (PSOEM), which defines areas for different activities within the national maritime space. According to the latest statements from the Minister of the Environment, an offshore wind energy auction will proceed in two phases. The first phase will offer seabed rights for area studies, followed by a Contracts for Difference (CfD) auction to set energy purchasing prices and injection capacity.

The auction framework, enabled by PAER is expected to pave the way for the development of wave energy.

National Strategy for the Sea 2021-2030

The National Strategy for the Sea 2021–2030, released by the government in 2021, aims to enhance the contribution of the ocean to Portugal's economy and promote a healthy ocean that increases the welfare of the Portuguese people. It centers around 10 objectives, including combatting climate change, decarbonize the economy and promoting renewable energy, stimulating scientific knowledge, technological development and blue innovation. The corresponding Action Plan contains concrete measures to execute until 2030, for each area, including relevant actions for Marine Renewable Energies. In 2022, the first report monitoring the National Strategy for the Sea was prepared, presenting statistics for the services and value of the blue economy.

More information at:
https://www.dgpm.mm.gov.pt/enm-21-30

Atlantic Strategy Committee (ASC)

Portugal, Spain, Ireland and France are represented in the Atlantic Strategy Committee. The ASC is the governing body of the Atlantic Maritime Strategy adopted in 2011 by the European Commission in response to repeated calls from stakeholders for a more ambitious, open and effective cooperation in the Atlantic Ocean Area. In this context, the Atlantic Action Plan 2.0 was approved aiming to unlock the potential of the sustainable Blue Economy in the Atlantic area while preserving marine ecosystems and contributing to climate change adaptation and mitigation of environmental hazards. The new action plan includes four pillars, one of which is on Marine Renewable Energy. Progress, activities and results are presented in the recent published Atlantic Action Plan 2.0 Implementation Report 2024 (AAP 2.0). The report concludes with important lessons learned, recommendations for future actions, and insights intended to shape ongoing strategy and enhance the impact of AAP 2.0 in advancing a sustainable blue economy in the Atlantic region.

More information at:
https://atlantic-maritime-strategy.ec.europa.eu/en/atlantic-strategy-glance/atlantic-strategy

European Marine Energy Board (ENB)

The European Marine Board is the leading European think tank in marine science policy. It provides a platform to advance marine research and to bridge the gap between science and policy. The European Marine Board is a unique strategic pan-European Forum for seas and ocean research and technology. As an independent, self-sustaining, non-governmental advisory body, the European Marine Board transfers knowledge between the scientific community and decision makers, promoting Europe's leadership in marine research and technology.

The European Marine Board released a report titled "*European Offshore Renewable Energy: Towards a Sustainable Future*". This report was prepared by a working group formed by members from Greece, Ireland, UK, Italy, France, Norway and Portugal (represented by WavEC). The report emphasizes the urgent need for responsible and sustainable management of the offshore renewable sector, providing a comprehensive overview of the technical, environmental, and socioeconomic aspects of the offshore renewable sector, with a specific focus on the European context.

Marine spatial planning policy

National Maritime Spatial Plan (PSOEM)

The Maritime Spatial Plan (PSOEM) identifies existing and potential uses/activities and exclusion areas. This plan is also the instrument that allows the attribution of a Permit of Private Use of the National Maritime Space.

The right to private use of the national maritime space is granted by concession, license, or authorization, formalized in the form of 'permits of private use of the maritime space', briefly TUPEM. The authority responsible for TUPEM approval is DGRM, which ensures the consultation of other public services and bodies.

Whenever TUPEM is associated with the use or activity related to geological resources, energy resources and renewable energy, including their infrastructure, the Directorate-General of Energy and Geology (DGEG) is the coordinator of the all licensing process. The request for TUPEM is submitted online at DGRM website (https://www.dgrm.mm.gov.pt).

Public funding programmes

Foundation for Science and Technology (FCT)

The Foundation for Science and Technology (FCT) is a national funding agency under the responsibility of the Ministry for Science, Technology and Higher Education whose mission is to boost Portugal's RD&D capabilities in all scientific fields. FCT provides RD&D funding through several programmes, including tenders for RD&D projects, grants, scholarships, support of public-private RD&D collaboration and direct funding of public research institutions.

FCT became a participant in the inaugural Co-funded call of the **Sustainable Blue Economy Partnership** (SBEP). This initiative involves 36 funding organizations across 23 countries, collectively supporting research and innovation actions in the blue economy, with financial support from the European Commission. Its strategy takes into consideration the R&I agendas of the sea basins (Mediterranean, Black Sea, Baltic and North Sea) and the Atlantic Ocean and builds on lessons learned from previous initiatives (e.g. OCEANERA-NET).

National Innovation Agency (ANI)

The National Innovation Agency (ANI) is a state-owned agency supporting technology and business innovation to strengthen Portugal's competitiveness in global markets. The ANI's responsibilities include stimulating private RD&D investment, promoting partnerships between Portugal's RD&D entities and industry, and increasing the participation of Portugal's RD&D entities and industry in international RD&D programmes.

ANI also runs the Interface Programme that certifies and funds Technological Interface Centres in several areas including renewable energies, using *FITEC - Innovation, Technology and Circular Economy Fund* that aims to support policies to enhance scientific and technological knowledge and its transformation into innovation.

RESEARCH & DEVELOPMENT

Key R&D institutions

WavEC Offshore Renewables

WavEC is a private non-profit organization created in 2003 with a strong research and innovation component and a broad spectrum of specialized services in Marine Renewable Energies and Engineering Solutions for the ocean economy, incorporating technological, economic, environmental, social and legislative aspects. Its mission is to accelerate the energy transition in an economical, safe and sustainable way and promote the growth of the blue economy.

WavEC's activities are internationally recognized through its extensive network of contacts, with a wide experience in working with international consortiums, being involved since 2003 in 60 R&D public-funded projects on marine renewable energies. WavEC is further responsible for the secretariat and communication of the IEA-OES.

WavEC is formally recognised by the National Innovation Agency (ANI) as a **Technology and Innovation Centre (CTI)**. CTIs are entities dedicated to the production, dissemination and transmission of knowledge, aimed at companies and economic value creation, contributing to the pursuit of public policy objectives, within the framework of priority specialisation areas, whether national or of the regions in which they operate.

IST Instituto Superior Técnico

Two groups were active on ocean energy at Instituto Superior Técnico (IST), University of Lisbon:

- Institute of Mechanical Engineering (IDMEC) with a decades-long history in wave energy conversion studies - following previous years, the activity at IDMEC has

been concentrated on wave energy conversion, especially the development of new types of oscillating water column converters (OWCs) and self-rectifying air turbines. An important area of research at IDMEC is latching control of floating and fixed-structure OWC converters, taking advantage of new types of air turbines fitted with fast valves.

- Centre for Marine Technology and Engineering (CENTEC) whose involvement in ocean energy is more recent - Ocean energy is a major area in the diversified activity of CENTEC/IST. The activities at CENTEC in ocean energy involved a wide range of topics covering waves, tidal currents and offshore wind. The characterization of the wave energy resource (and to a much lesser extent tidal and offshore wind energies) at various oceanic locations in the world has been one of the dominant topics. The study of ocean energy conversion, focused mainly on wave energy converters, with numerical theoretical/modelling and model testing of several types of devices and arrays, and also PTOs (namely hydraulic-circuit PTOs) and moorings.

FEUP – CIIMAR (Marine Energy and Hydraulic Structures Research Group)

The Marine Energy (ME) team's main topics of research revolve around the development, design, and optimization of technologies to harness marine renewable energy resources as well as the engineering design of coastal and maritime structures to cope with marine environmental actions, using either numerical modelling (BIEM, RANS, SPH) or physical model testing in experimental facilities (wave basin and/or wave-current flume). The ME group is strongly committed to the research and innovation of cross-cutting, sustainable and advanced technologies or solutions to harness and withstand marine blue energy, mitigate climate change effects and support the societal transition to a low carbon sustainable economy. Current research activities focus on: the development and testing of ocean technologies, hydrodynamic modelling, dynamics of floating structures, moorings, wave energy converters, offshore wind foundations, resource assessment and characterization, risk assessment and extreme events prediction, met-ocean data statistical modelling, reliability analysis, breakwater and harbour design, wave-structure interaction, coastal and offshore aquaculture, energetic sustainability, among others.

University of Coimbra - LHRHA

The University of Coimbra, through its Laboratory of Hydraulics, Water Resources and Environment (LHRHA), is actively engaged in ocean energy research, particularly in the development and testing innovative wave energy devices.

INESC TEC – Institute for Systems and Computer Engineering, Technology and Science

INESC TEC plays a significant role in research, development, and demonstration of marine renewable energy systems, particularly in control systems, electrical integration, and offshore monitoring technologies. The institute has contributed to several national and European ocean energy projects, working closely with industry and academia.

INEGI – Institute of Science and Innovation in Mechanical and Industrial Engineering

INEGI is a leading R&D institution in Portugal with active involvement in marine renewable energy projects, particularly through its expertise in mechanical engineering, structural design, materials, and system optimization. INEGI supports the development of ocean energy technologies by contributing to prototype design, fatigue and corrosion analysis, and mechanical testing.

Key R&D projects

Key R&D projects in Portugal are conducted by consortia, predominantly at a European level, involving international cooperation and supported by European funding. This overview presents a selection of key relevant projects, representing a non-exhaustive list that highlights significant initiatives within the sector.

Funded by the Horizon Europe programme:

- The **ONDEP** project, with total funding of €19M aims to establish a 2MW wave energy farm in Peniche, Portugal. This project utilizes four WaveRoller units, benefiting from over a decade of development and two years of full-scale demonstrations. Coordinated by Queen's University of Belfast, ONDEP is set to run from October 2024 to March 2030. This project involves 14 leading organizations from nine countries. WavEC's role includes conducting large-scale monitoring and comprehensive assessments across technical, economic, social, and environmental dimensions, and managing necessary permission agreements for the deployment and operation.

- The **MEGA WAVE PTO** project, coordinated by WavEC and funded by Horizon Europe and UKRI (UK Research and Innovation) with a total budget of €4M (€2.1M from Horizon Europe and €1.9M from UKRI), focuses on developing a highly modular Power Take-Off (PTO) system. Running from May 2024 to April 2028, this system features innovative axial flux magnetic gear and electrical generator technologies, along with adaptable power electronics, enhancing the efficiency, eco-friendliness, and ease of manufacturing, transport, installation, maintenance, and recycling of the energy production process.
- **PLOTEC** was initiated in November 2022 and will run until 2025, with the overall objective to achieve a successful demonstration of the novel designs and materials for a floating OTEC platform to be tested in Canary Islands. **WavEC** will assess and quantify the impacts of this project on the sustainability of the technology and on the socio-economic added value and thus validate the solution based on economic, environmental, and human-centered needs, enabling rapid adoption of the solution.
- **EU-SCORES** was initiated in September 2021 aiming at demonstrating and unlocking the large-scale potential of multi-source, offshore renewable energy farms across different European sea basins. This will be achieved through two demonstrations: (1) An offshore solar PV system in Belgium co-located with a bottom fixed wind farm and; (2) A wave energy array in Portugal co-located with a floating wind farm. The demonstrations in EU-SCORES aim to showcase the benefits of continuous power output by harnessing complementary power sources including wind, sun, and waves. The full-scale demonstrations are intended to prove how the increased power output and capacity installed per km^2 will reduce the amount of marine space needed, thereby leaving more space for aquaculture, fisheries, shipping routes, and environmentally protected zones. The project has 18 partners and it is led by the Dutch Marine Energy Centre (DMEC). From Portugal, **WaVEC**, **INESC TEC** and **EDP Labelec** are participating.
- **Ocean Tribology Center (OTC)** – A pan-European network of Ocean Tribology (COST Action CA23155), coordinated by University of Ghent, Belgium. It aims to create a pan-European-wide network of countries with a strong offshore affiliation for promoting collaboration and knowledge-sharing towards the development of sustainable, reliable and energy efficient ocean systems. This action started in October 2024 and is driven by the ambition to realize sustainable and energy-efficient systems that can withstand the harsh ocean conditions with minimal ecological impact on the aquatic environment. **UPORTO (FEUP)** is represented in the Management Committee.

Funded by the European programme INTERREG Atlantic Area:

- **HYDEA** – Boosting the Hydrogen transition in the Atlantic Area Ports: aims at accelerating deployment and use of green hydrogen-based technologies in the Atlantic Area (AA) ports. Therefore, it will assess, develop and promote the integrated use of those technologies with marine and other renewable energies in ports to boost their transition towards an energy efficient and decarbonised model. This project is coordinated by EnergyLab (Spain), includes 7 Pilots of H2-based Technologies in AA ports, and started in October 2023. **UPORTO (FEUP)** is responsible for characterizing the ccurrent scenario and identifying opportunities in AA ports as well as for the development and testing of solutions and pilots of H2-based technologies for Port of Leixões (Portuguese case study).

Funded by the National Foundation for Science and Technology (FCT):

- **POSEIDON** – conducted by **CIIMAR**, the project has the overall objective of extending and validating dynamic scour protections for complex marine renewable energy foundations, with several applications, including a strong focus on wave energy converters combined with offshore wind energy infrastructures.
- **SAGE MIT Portugal Project** is a project conducted by Instituto Superior Técnico with funding from the MIT Portugal Programme through FCT, to design, manufacture and assemble a new purpose-built turbine-generator set to equip wave-powered monitoring buoys. This is critical for electricity generation and storage to enable continuous data acquisition under longer-term deployment periods at the open sea. The current project aligns with the mid-term objective of deploying a fully functioning device at open sea. The project deals with important technological challenges in both mechanical and electrical engineering. In 2022, ***Instituto Superior Técnico*** built and dry-tested a 2.2 kW PTO system for off-grid OWC wave energy converters in a project funded by the Portuguese Foundation for Science. The research built upon the successful experi-

ence of the H2020 OPERA project and incorporated new aerodynamic, mechanical, and electrical designs in response to the requirements of stand-alone systems. Applications for this technology include autonomous remote sensing and vehicle battery charging. Further research includes wet-testing in IST's Spar-buoy OWC.

Funded by Ente Vasco de la Energía (EVE, Basque Country):

- Ente Vasco de la Energía (EVE) launched a Pre-Commercial Public Procurement Procedure in December 2022, detailed in the TurboWave Project challenge documentation, referenced as DIRTEC/22/06. The objective is to develop a replacement for the ageing air turbine technology in place in the Mutriku Wave Power Plant (MWPP), meeting challenging requirements in terms of Performance, Controllability, Reliability, Maintainability and Affordability.

  The TurboWave Challenge was addressed through collaborative efforts by two Lisbon-based entities with proven experience in the fields of wave energy and the type of wave energy conversion used in MWPP: Instituto de Engenharia Mecânica/Instituto Superior Técnico **(IDMEC/IST)** and Kymaner Tecnologias Energéticas, Lda **(KYMANER)**, forming the NOVATUM consortium. NOVATUM aims to enhance the MWPP energy delivery through the development and testing of a novel turbine-generator concept integrated into a Power Take-Off (PTO) unit. External expertise from Det Norske Veritas (DNV) and TECNALIA supported the consortium in technology qualification and techno-economic modelling, respectively. The consortium completed Phase 1 of the project in early 2024 and was granted funding for Phase II, which is expected to be finished by February 2025.

TECHNOLOGY DEMONSTRATION

Test sites

The government created an offshore Technological Free Zone (ZLT) offshore Viana do Castelo for innovation projects. It covers an area of 7,63 km^2 adjacent to the WindFloat Atlantic project.

Another test site is located offshore Aguçadoura, with an area of 5,6 km^2. The Swedish developer CorPower has made considerable progress in advancing its flagship wave energy project, HiWave-5, within this designated area. This site is managed by the private entity Companhia de Energia Oceânica (CEO) owned by INESC TEC and WavEC Offshore Renewables. In 2024, CEO became part of a new platform for offshore demonstrations in Europe, called High Power Test Sites (HiPoTeSis). The HiPoTeSis initiative is a cooperation platform for five demonstration sites in Europe, which aims to safeguard the interests of offshore testing at European level. The other entities involved in this initiative are the Biscay Marine Energy Platform (BiMEP) in the Basque Country, the Oceanic Platform of the Canary Islands, the OPEN-C Foundation in France and the Mari Energi Testcentre in Norway.

CorPower Ocean

CorPower Ocean achieved a significant milestone with the successful installation of its inaugural commercial-scale Wave Energy Converter off the northern coast of Portugal. The CorPower C4 device was initially launched at the port of Viana do Castelo before being towed to the Aguçadoura site, situated 4km offshore. Following its connection to a pre-installed UMACK anchor on the seabed, the device was connected to the Portuguese national grid through a subsea export cable. Subsequently, the system underwent a thorough commissioning program, during which its functions and operational modes were systematically verified. Additionally, Operations and Maintenance (O&M) methods for offshore service access, device retrieval, and tow-back to the on-land service base in Viana do Castelo were rigorously tested.

RELEVANT NATIONAL EVENTS

The WavEC Annual Seminar in 2024, held on December 3rd in collaboration with the Norwegian Embassy in Portugal, focused primarily on floating offshore wind while also exploring synergies with wave energy. This event brought together over 250 participants. Presentations are available at: https://www.wavec.org/en/seminar

Oceanic Renewables Summit

This event was organised by APREN on April 17, 2024, at the Champalimaud Foundation, with 350 participants. Presentations are available here: https://www.apren.pt/en/conferences/oceanic-renewables-summit-2024

The **16th European Wave and Tidal Energy Conference (EWTEC)** will be held between 7th– 11th September 2025 in Madeira, Portugal.

REPUBLIC OF KOREA

REPORT PREPARED BY:
Jin-Hak Yi, Korea Institute of Ocean Science and Technology

OVERVIEW

The Ministry of Oceans and Fisheries (MOF) remains a target for a carbon dioxide reduction by 2050 of 2.3 million tCO2 from the ocean energy sector. Many R&D projects are being carried out to support this ministry's carbon-negative target and ocean energy commercialization.

Korea Research Institute of Ships and Ocean Engineering (KRISO) has successfully constructed a 30 kW OWC WEC and is currently operating it and advancing the technology. In addition, a new R&D project is being conducted to build a wave farm composed of a number of OWC WECs with a total capacity of 90 kW or higher, and the construction of the OWC structure is scheduled to begin this year. KRISO is building a hydrogen production plant at 500 kW Yongsoo OWC WEC, and will produce green hydrogen with wave power for the first time in the world. Korea Institute of Ocean Science and Technology (KIOST) developed a 1 MW class horizontal axis tidal current energy converter, and installed and tested its power output performance at the Uldolmok tidal energy test site following the IEC TS 62600-200 specification.

The first ocean energy technical standard on terminology was published as KS C 0561-1 by harmonizing the IEC TS 62600-1 and additional terms related to the Ocean Thermal Energy Conversion (OTEC). Three additional ocean energy technical standards, harmonized from IEC TS 62600-100, 200, and 201, were investigated by energy board members of the Korea Agency for Technology and Standards, an official governmental organization, and will be registered in 2025 as new Korean Industrial Standards.

The IEC TC 114 Plenary Meeting was held in Jeju from April 15 to 19, and the Asian Offshore Wind, Wave, and Tidal Energy Conference (AWTEC) 2024 was held in Busan from October 10 to 24.

SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy

Within the 2030 Ocean Energy Development Plan, the ministry's action plan for developing and disseminating ocean energy systems, a strategic plan has been established in tidal and wave energy development. This plan is divided into four steps: (1) the expansion of R&D in ocean energy and the establishment of open-sea test sites; (2) the construction of large-scale ocean energy farms; (3) the entrance into the global market and the expansion of domestic supply; and (4) the establishment of an ocean energy certification system and supporting policies. This plan was revised for the carbon-negative in 2050, and the long-term roadmap was prepared.

Market incentives

The Renewable Energy Portfolio Standard (RPS) was established in 2012 to compel utility companies with a capacity greater than 500 MW to provide obligatory portions of their total electricity production from renewable energy, based on the Acts on the Development, Utilization, and Supply Promotion of Renewable Energy legislation. The market incentive plan, known as the tradable Renewable Energy Certificate (REC), supplements this RPS policy. The weighting value of REC is currently given as 2.0 for tidal current, 1.0 for tidal barrage with an embankment, and 2.0 for tidal barrage without embankment. In contrast, the value of REC for wave energy is not given at this moment, and it is expected to be set by analyzing the actual power output data from the demonstration project of WEC operated in Korea. The first REC was issued for the Uldolmok Tidal Power Pilot Plant in 2022 based on the records to generate electricity from tidal current energy.

Public funding programmes

MOF provides public funding for ocean energy R&D programs, including demonstration projects, and 17.6, 7.8, and 9.4 million USD in 2021, 2022, and 2023, respectively, were invested in developing ocean clean energy technologies and tidal energy systems. In 2024, 6.9 million USD was invested for developing green hydrogen production technology using ocean energy, for developing OWC wave power plant.

RESEARCH & DEVELOPMENT

In 2022, the R&D project to produce green hydrogen with wave power began, and a hydrogen production plant was built at the Yongsoo OWC WEC at sea in 2024, and it is currently being commissioned. The R&D project of the multi-moludes OWC WEC connected to the breakwater is underway, and the OWC structure construction is scheduled in 2025 after completing the design of the OWC structure.

For developing the national standards in the field of ocean energy systems, the technical specifications published by IEC TC114 were basically harmonized. In addition, the project is confirming whether it is applicable in Korean and Asian environments. The first ocean energy technical standard on terminology was published as KS C 0561-1 by harmonizing the IEC TS 62600-1 and additional terms related to the Ocean Thermal Energy Conversion (OTEC), and it was selected as one of the outstanding accomplishments among new Korean industrial standards in 2024. In 2023, three ocean energy technical standards, from IEC TS 62600-100, 200, and 201, were submitted to the Korea Agency for Technology and Standards, were investigated by energy board members in 2024, and will be registered in 2025 as the new Korean Industrial Standards. The standardization activities are expected to lead the advancement of ocean energy technologies in connection with existing R&D accomplishment, and technical standards and certification systems can activate the ocean energy industry.

TECHNOLOGY DEMONSTRATION

Existing open sea test sites

The KRISO-Wave Energy Test Site (WETS), located in the western part of Jeju Island, has been in operation since 2019. KRISO-WETS features 5 test berths, including the Yongsu OWC pilot plant, two berths at 15 m, one at 40 m, and one at 60 m water depth. Each berth supports a 4.5 MW maximum output capacity and 5 MW capacity in total, and there are plans to increase the capacity to meet the requests from floating offshore wind developers.

Projects at the KRISO-WETS. © KRISO

A dry-mate type connecter, ADCP and buoy type wave measurement instrument, and onshore and offshore substations are provided. Several small projects were conducted using the test site, such as wave energy devices developed by Jeju Univ. in 2020, a digital twin for WEC by KRISO. Also, unmanned underwater vehicles, radars, and lidars are being tested using this facility. From 2024, test site will support floating offshore wind and green hydrogen production projects. By 2025, marine green hydrogen will be produced using renewable energy from the OWC wave power plant and floating offshore wind turbines. By conducting more test projects, it will come closer to operating this facility without additional financial support from the Korean government.

KIOST has established and operates an open sea test site to support performance testing and evaluation of tidal energy converters and their components. To facilitate the strength evaluation of blades up to 12 m in length, the Tidal Energy Component Testing Laboratory was established at the KIOST Busan Headquarters in March 2021. Additionally, a 4.5 MW open sea test site was constructed in December 2023 at the Uldolmok Strait in Jindo, Jeollanamdo, to assess power performance and to measure mechanical loads under real-sea conditions. KIOST has also developed a 1 MW commercial-scale tidal energy converter. The structural strength of its blades was tested at the Tidal Energy Component Testing Laboratory, and the reliability of the structure is being validated through installation and testing at the Uldolmok Strait. KIOST plans to integrate digital twin technology to manage and operate the open sea test site. Furthermore, research will be conducted on the environmental impacts of tidal energy systems, focusing on fish collisions and noise.

Actuators for blade strength testing. © KIOST

Projects in the water

KRISO is conducting the world's first R&D project to produce green hydrogen by wave power at the Yongsoo OWC WEC located near Jeju Island in Korea. In 2023, the design and manufacturing of major facilities for the hydrogen production were completed, and the hydrogen production plant was installed at the Yongsoo OWC WEC at the end of 2024. The facility produces green hydrogen with PEMWE (Polymer electrolyte membrane water electrolysis) by the wave power and desalinates seawater to electrolyze it and apply a cooling method using seawater. The hydrogen production plant was designed to enable production despite the large variability of wave power by using power buffers and underwent sufficient tests on land before being installed at sea. It is currently in the commissioning stage and is expected to begin its full-fledged operation soon.

Installation of Hydrogen Production Plant on Yongsoo OWC WEC. © KRISO

In the KRISO-led R&D project to develop 30 kW wave energy converters applicable to breakwaters in remote islands, the Pilot Plant was built at the Mook-ri port in Chuja Island (Located between Jeju Island and the mainland) and is conducting performance evaluation and technology verification through long-term operation. This Pilot Plant adopts the OWC type wave power generation method and it is the second plant developed in South Korea. In order to install the plant on the slope of the breakwater, a slope-type OWC chamber was adopted. The TTP (Tetrapod) was removed from the front of the breakwater slope in Mook-ri Port and the OWC Chamber produced by the pre-cast method was installed. This attempt, which was applied to a micro-grid with the integration with the OWC power plant and ESS system, is a very effective

Overview of Mook-ri OWC Plant. © KRISO

way to utilize ocean energy in islands with narrow land and relatively large marine space and is expected to be widely applied.

A 1 MW class horizontal axis tidal current energy converter was developed using a direct-drive permanent magnetic synchronous generator, variable-pitch and fixed-yaw, and tripod steel gravity-based foundation. The combined efficiency of the generator and the power conversion system was tested using the internal back-to-back test because of the absence of dynamo equipment, and it was evaluated at about 90%. The tidal current energy converter was installed at the Uldolmok tidal energy test site, and the power performance was assessed following the IEC TS 62600-200 specification. The overall system efficiency of this system was evaluated as about 29.2%.

Tidal turbine installed at the Uldolmok tidal energy test site. © KIOST

Projects planned for deployment

KRISO is currently advancing a project focused on the development and deployment of OWC device for integration into newly constructed breakwaters. This aims to install three or more multi-module water chambers on these breakwaters, with a capacity exceeding 90 kW. Commencing in 2023, the project has selected Homigot Port in Pohang, located on the East Sea, as the target site. The consent process for the site is in its final stages. Manufacturing of the structural components and the power take-off (PTO) system is scheduled for 2025, with installation to be completed by 2026. A test operation phase will follow in 2027. The project seeks to evaluate the feasibility and scalability of large-scale OWC farms, thereby advancing the technology readiness level (TRL) of wave energy converters from Level 6 to Level 8. This progression will facilitate broader adoption in future wave energy distribution projects in Korea.

RELEVANT NATIONAL EVENTS

The 2024 IEC TC 114 plenary meeting was held in Jeju from April 15 to 19 for working group meetings, a plenary meeting, and a technical tour to KRISO-WETS. More than 60 experts from 11 countries participated, and a new working group on power performance assessment for OTEC was initiated. Several key items were also discussed and decided.

The AWTEC (Asia Offshore Wind, Wave and Tidal Energy Conference) 2024 was held in Busan from October 22 to 25. More than 200 researchers participated in the field of offshore wind, wave, and tidal energy sectors from 22 countries, and more than 200 presentations were prepared. Technical tours to BladeLab and PEB (Physical Experiment Building) at KIOST Busan HQs, DOERC (Deep Ocean Engineering Research Center) at KRISO Busan Office, and KRISO-WETS in Jeju were provided, and many participants attended these technical tours.

SINGAPORE

REPORT PREPARED BY:
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SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy

Singapore's national strategy on renewable energy focuses on diversifying and increasing the use of clean energy sources while ensuring the country's energy security and economic growth. Given Singapore's limited land area, its strategy places a strong emphasis on technological innovation and regional collaboration to overcome space constraints. Singapore raises climate ambition to achieve net zero emissions by 2050. In 2022, Singapore raised its climate ambition to achieve net zero emissions by 2050. To enable this transition to a low-carbon future, Singapore will raise the carbon tax levels progressively from 2024. Carbon tax will be raised to $25/tCO2e in 2024 and 2025, and $45/tCO2e in 2026 and 2027, with a view to reaching $50-80/tCO2e by 2030. Currently, nearly 95% of the country's electricity needs come from natural gas, aiming to increase the role that true renewable energy sources play. Another primary focus is reducing the emissions that local industries generate to combat climate change by tracking energy efficiency and applying a carbon tax.

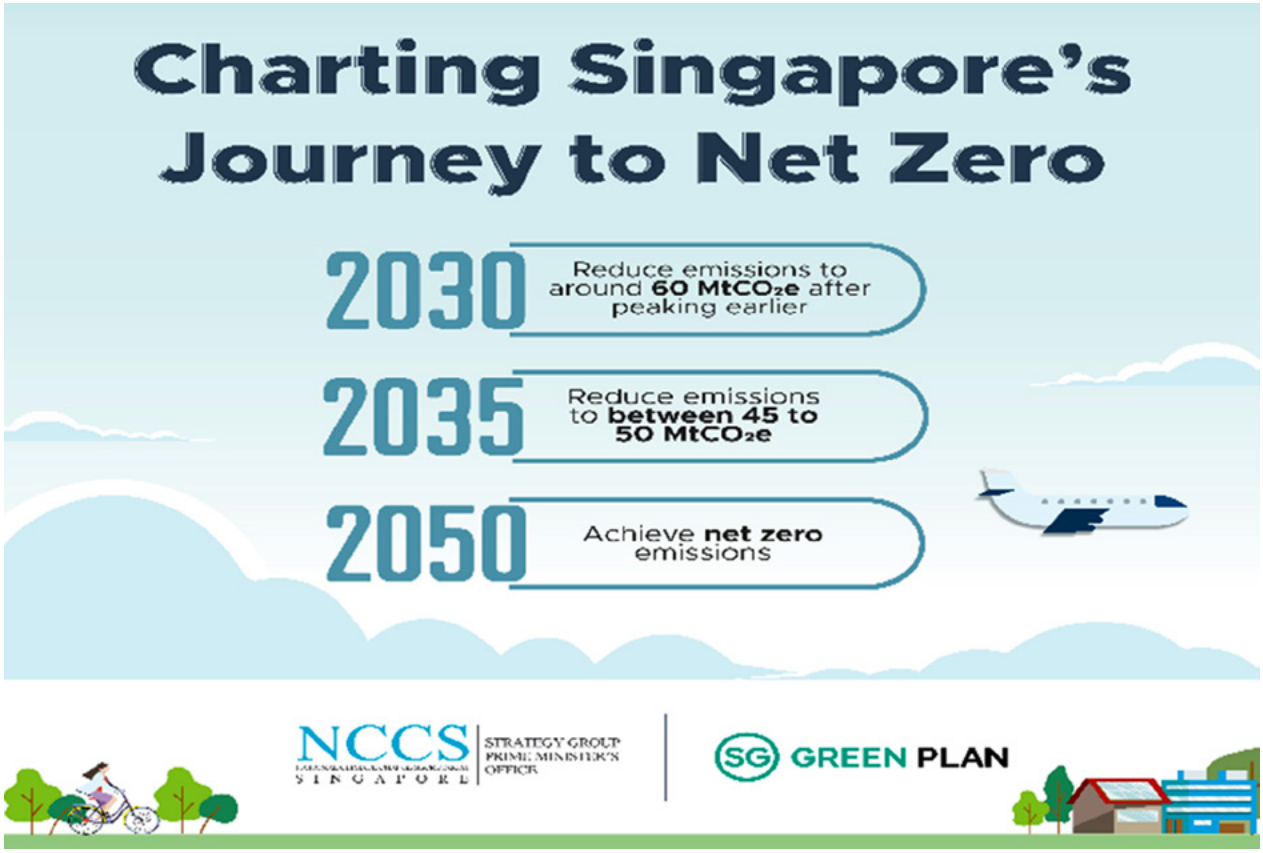


Figure 1: Singapore National Strategy

Market incentives

In Singapore, several government bodies, including the Energy Market Authority (EMA), Building and Construction Authority (BCA), and Economic Development Board (EDB), actively promote the adoption of renewable energy through various schemes and incentives. The Green-e Renewable Energy Standard is one such initiative, offering Green-e Energy certification to enhance renewable energy markets and provide consumers a clear way to support clean electricity. Rather than relying on subsidies, Singapore focuses on regulatory improvements and funding for R&D to develop commercially viable renewable technologies. Singapore Power Group (SP) plays a key role in this ecosystem, being the first in the Asia Pacific region to issue International Renewable Energy Certificates (I-RECs), which track renewable energy production and help companies meet sustainability targets.

Expanding on these national efforts, Singapore's MPA 2050 Net-Zero Blueprint sets out strategies to decarbonize its maritime sector, including transitioning port terminals to cleaner energy, shifting harbour craft to net-zero fuels by 2050, and developing multi-fuel bunkering for international shipping. The plan also aims for 50% of the Singapore Registry of Ships to be green by 2050 while advocating for global climate action. Investments in R&D, green financing, and carbon capture and storage (CCS) support these goals, with S$300 million committed to accelerating sustainable maritime practices.

Beyond maritime applications, Enterprise Singapore's TC114 working committee is also driving the adoption of clean marine energy for emerging industries such as aquaculture and tidal energy-powered data centres, reinforcing Singapore's broader commitment to renewable energy innovation across multiple sectors.

Public funding programs

Ocean renewable energy has been recognized as a key alternative energy source by ERI@N, especially for remote coastal and island regions, as part of its focused research initiatives. The government also encourages clean technology companies to utilize Singapore as a 'Living Lab,' allowing them to test and showcase innovative solutions before scaling them globally.

The Singapore Government has allocated over S$800 million in public funds to support research in energy, water, green buildings, and solutions for land scarcity. Additionally, $55 million has been granted to fund 12 projects focused on low-carbon energy technologies. The government is also ready to invest more than the estimated S$1 billion in carbon tax revenues generated during the first five years to help businesses adopt energy- and carbon-efficient technologies. Furthermore, the Maritime and Port Authority of Singapore (MPA) has teamed up with several major industry players, creating a $90 million decarbonization fund to enhance efforts in reducing emissions in the maritime sector.

RESEARCH & DEVELOPMENT

ERI@N, primarily funded by the EMA, concentrates on sustainable energy, energy-efficient infrastructure, and the socio-economic aspects of energy research. Its goal is to serve as a hub of excellence for pioneering research, development, and demonstration of innovative solutions that have a significant regional and global impact. The institute possesses substantial expertise in offshore energy, including wind, wave, floating solar, and tidal energy, along with complementary technologies such as energy storage, microgrids, and smart energy systems. Together, these areas provide a comprehensive set of skills, from materials design and synthesis to device fabrication, modelling, and systems integration and optimization.

The Renewables and Low Carbon Generation (RLCG) research program at ERI@N focuses on enhancing performance, reducing costs, and speeding up the deployment of offshore renewable technologies, particularly in tropical regions where there are distinct technological challenges. The program supports the advancement of technology development and commercialization through early collaboration with industry partners. ERI@N works closely with government bodies to address regional requirements and with both local and international renewable energy companies to pinpoint technology gaps. ERI@N has also developed a hybrid - tidal and solar powered mooring buoy system for low flow tropical waters of Singapore to support ocean environment and seawater quality monitoring.

Additionally, ERI@N is playing an active role in the development and adoption of marine energy standards in Singapore with Enterprise SG as part of IEC TS 62600. 4 Marine Energy standards (TR IEC TS 62600 series) has been customized and adopted as Singapore standards.

A Memorandum of Understanding (MOU) has been signed between Nanyang Technological University, Singapore and National Ocean Technology Centre, China

for joint collaborative research on Next Generation Tropical Marine Renewable Energy Technologies towards Singapore-China Carbon Neutral Goals which was facilitated by Energy Market Authority in Singapore on October 2024. This MoU was also signed between Deputy prime minister of Singapore and Deputy prime minister of China on Beijing in Nov 2024.

TECHNOLOGY DEMONSTRATION

Test sites

Sentosa – ERI@N Tidal Site

The Sentosa Tidal Test Site is a joint collaboration between Sentosa Development Corporation (SDC) and ERI@N, funded by the Ministry of Trade and Industry's Core Innovation Fund. This project aimed to showcase tidal energy extraction as a feasible and sustainable energy generating technology in Singapore and to provide opportunities to develop local technologies to harness the energy available in the narrow channel between Singapore and Sentosa.

Recent developments on the test site include the deployments of customized tidal turbines supported from the floating barges. Also, novel concepts such as floating solar system, anti-biofouling coatings are being evaluated for better field performance. The power developed was used for electric lighting on the boardwalk. This was further developed towards floating tidal turbine system. For feasible power capture, tidal generators are preferably located at natural coastal features which can converge and amplify water flow, such as channels and estuaries. The test bed benefits from amplified flow due to the narrowed channel between Singapore and Sentosa islands and bridge piers which provides manmade flow convergence.

ERI@N collaborated with Mako, a tidal turbine company, to evaluate the performance of a tidal energy turbine in Singapore's tropical waters. Singapore was selected due to its strong government support for renewable energy, suitable tidal flow conditions, and proximity to Asian markets. The ERI@N tidal site was used for the demonstration, with ERI@N actively involved in deployment and performance evaluation, including studies on the impact of the tropical environment on turbine operation.

In the next phase, Mako, in collaboration with Sentosa Development Corporation, Enterprise Singapore, ERI@N, and other industry partners, demonstrated a tidal turbine integrated with a Sentosa Boardwalk pylon.

Figure 2: ERI@N developed Tidal turbine system

Figure 3: Industrial Tidal turbine Demonstration at Singapore waters

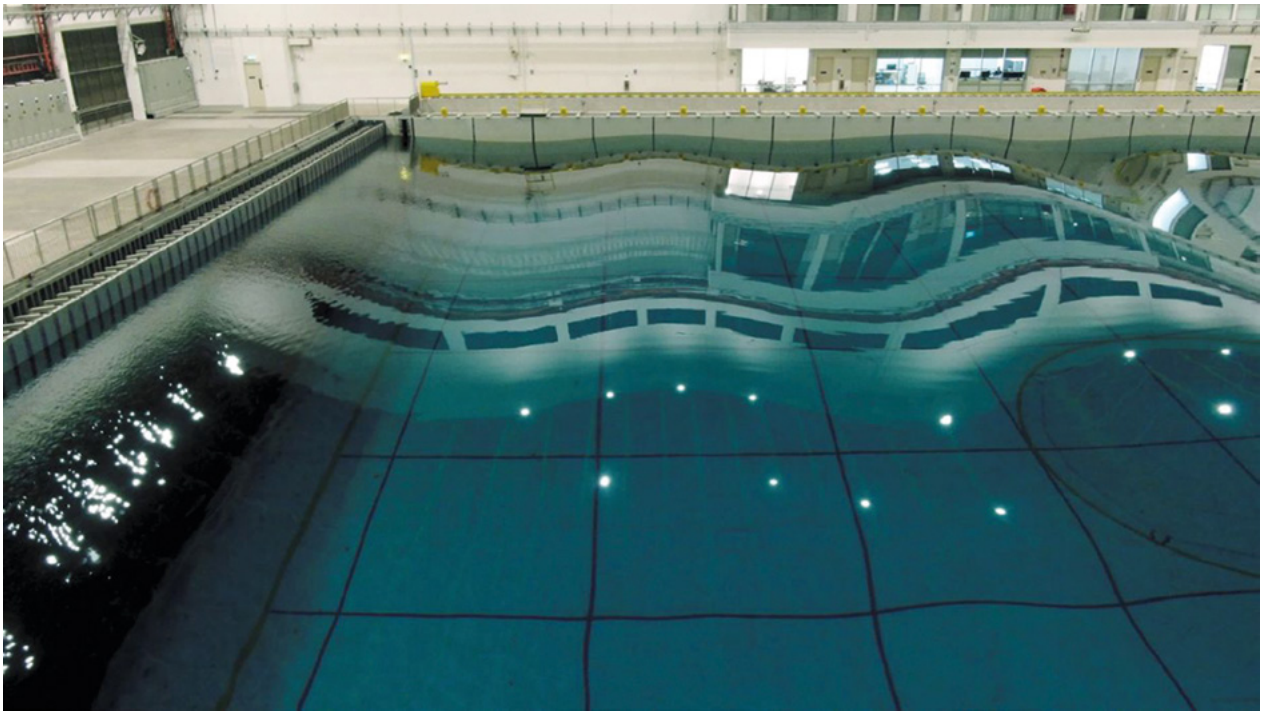


Figure 4: TCOMS – Ocean basin Facility

Ocean Basin Facility – TCOMS

The Technology Centre for Offshore and Marine, Singapore (TCOMS) is a national research and development hub focused on the Marine & Offshore and Maritime industries. TCOMS combine research and industry knowledge to develop innovative ideas and solutions to tackle real-world problems. A key component of TCOMS is the state-of-the-art Deepwater Ocean Basin research facility, which features advanced systems for generating waves and currents to replicate the challenging ocean environments in which marine platforms and vessels operate. Additionally, TCOMS benefits from the high-performance computing resources of the National Supercomputing Centre (NSCC) Singapore. These resources enable researchers to refine coupled numerical and physical modelling and simulation techniques, recreating complex operational conditions to help companies improve the design and functionality of their solutions. TCOMS is a collaborative initiative between the Agency for Science, Technology and Research (A*STAR) and the National University of Singapore (NUS).

TMFT - ERI@N Wave Energy Convertor Site

The Tanah Merah Ferry Terminal (TMFT), located in Changi, Singapore, is a key maritime facility featuring a floating pontoon that serves as a boarding platform for passengers and a loading/unloading platform for cargo. The pontoon is designed to move vertically with tidal changes while remaining horizontally stable.

A pontoon-type Wave Energy Converter (WEC) was integrated into the ferry terminal pontoons to assess its feasibility for energy generation. The system successfully demonstrated an output of 330 Wp at low wave heights, showcasing its potential for harnessing wave energy in sheltered coastal environments. This innovation is documented under PCT number SG11201708101PA.

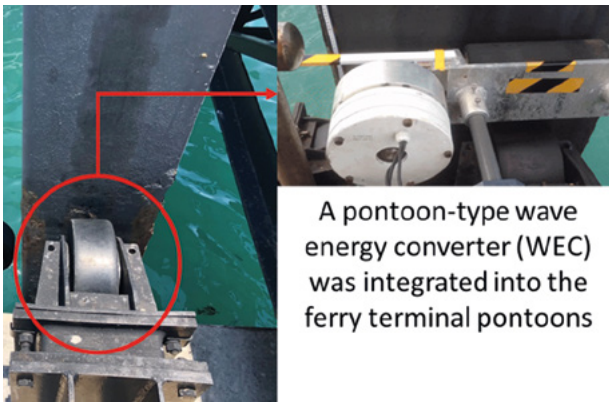


Figure 5: WEC Rollers at Floating Pontoons

Electrification and Power Grids Centre – EPGC

Located on Jurong Island, which home to Singapore's petrochemical hub, the Electrification and Power Grids Centre (EPGC) houses one of the largest and most comprehensive integrated energy facilities in the region. EPGC enables equipment manufacturers and system integrators to test their technologies at actual power before deployment.

Figure 6: MW testing facility at Electrification and Power Grids Centre

Planned deployments

Ocean Renewable Energy Farm

A renewable energy farm may be developed in the waters surrounding Raffles Lighthouse, with a feasibility study scheduled to commence in the fourth quarter of this year. The Maritime and Port Authority of Singapore (MPA) has identified a 30-hectare area around the island and is considering the installation of solar panels on the water's surface and tidal turbines below. Experts suggest that this could be Singapore's first large-scale facility combining solar and tidal energy. The farm's energy would likely be used to charge electric harbour craft, aligning with future efforts to reduce emissions in the maritime industry. Starting in 2030, all new harbour craft in Singapore must be fully electric, compatible with cleaner biofuels, or ready for net-zero fuels like hydrogen. This initiative is part of the country's broader plan for the maritime sector to achieve net-zero emissions by 2050. On July 24, MPA launched a tender for the feasibility study of a floating solar and tidal energy farm. The study will evaluate the environmental impact of the farm and help create strategies to address any potential concerns.

Figure 7: Raffles Lighthouse in Pulau Satumu

Figure 8: Renewable system deployed in Kusu Island, Singapore to meet the energy needs of the island

Deployment of Clean Energy Powered water generation system in Southern Islands of Singapore

The southern islands of Singapore are popular tourist destinations, and their energy and water consumption are primarily driven by tourism and various government facilities located there. These islands feature accommodations like bungalows and campsites for visitors, as well as attractions such as temples, beaches, fishing spots, and picnic areas, alongside government infrastructure. Currently, the islands rely on diesel-powered electricity and water delivered from the mainland. To address the growing demand for water and energy, the Energy Research Institute @ Nanyang Technological University (ERI@N), with support from the Singapore Land Authority (SLA), has implemented a clean energy-based water generation system and renewable energy solutions on one of these islands. The deployment of this renewable-powered water generation system has been successfully completed on Kusu Island, and there are plans to expand this initiative to other southern islands. Pulau Hantu Besar is the next island to adopt similar technology.

Figure 9: Floating Solar system planned in Kranji Reservoir

Floating Solar System Deployment

- Construction for a new large-scale floating solar farm is set to commence at Kranji Reservoir in 2025, following an environmental study that indicates the installation of solar panels will not significantly affect the area's biodiversity. Once completed, the solar farm will be the largest of its kind in Singapore and will significantly contribute to the nation's push for more renewable energy. The farm is projected to generate 141 megawatt-peak (MWp) of clean energy, or 112.5 MWp when converted to alternating current (AC), the type of voltage used by both the electricity grid and most electrical devices in Singapore. This project will account for roughly seven percent of Singapore's 2030 goal of reaching two gigawatt-peak (GWp) of solar capacity, as outlined in the environmental report. Construction is slated to begin in 2025, with the solar farm expected to be operational by 2027 or 2028.
- PUB called a tender to conduct engineering studies for the deployment of two smaller floating solar PV systems at Bedok and Lower Seletar Reservoirs. Following up from the successful studies, PUB awarded a contract to local engineering firm to build the system. 1.5 MWp floating solar PV systems are deployed on the reservoir surfaces adjacent to Bedok Pumping Station and the Lower Seletar Pumping Station, taking up 2% of Bedok Reservoir's and 0.5% of Lower Seletar Reservoir's surface areas. These two floating solar PV systems can collectively generate enough energy to power about 800 four-room HDB flats and reduce PUB's carbon emissions by around 1.5 Kilotonnes annually.

Figure 10: 1.5 MWp floating solar PV system at Lower Seletar Reservoir

- ERI@N has implemented an offshore floating solar system to meet the energy demands of aquaculture farms. This innovative approach of using floating solar panels to power open-ocean aquaculture farms in Singapore is both groundbreaking and promising. Aquaculture, particularly in offshore environments, requires a large amount of energy for several key operations, such as: water aeration to ensure oxygen levels for fish, automated feeding systems, data collection and monitoring for farm management and water purification to maintain a healthy environment. Traditionally, these processes rely on diesel or other non-renewable energy sources, which are costly and environmentally harmful. The installation of the floating solar system serves to replace or supplement these energy needs, offering a cleaner, more sustainable power solution.

Figure 11: ERI@N's Offshore Floating Solar towards Aquaculture Centers

Renewable Energy Integration Demonstrator-Singapore (REIDS)

The Renewable Energy Integration Demonstrator – Singapore (REIDS) serves as a platform for Research, Development, and Demonstration (RD&D), focusing on the creation, testing, and demonstration of sustainable and cost-effective energy solutions tailored for Southeast Asia. REIDS plays a pivotal role in advancing sustainable, multi-activity off-grid communities by fostering extensive research and development across various energy domains. It supports both corporate and public sector stakeholders in Singapore, enhancing their position in the rapidly expanding renewable energy and microgrid markets. One of REIDS' key assets is the Low Voltage Microgrid Cluster (LVMGC) testbed located on Semakau Landfill, which acts as a real-world laboratory for industries, researchers, and government bodies to experiment with next-generation distribution grid solutions and address the engineering, economic, environmental, and societal challenges posed by energy transitions in off-grid and urban areas. With an emphasis on flexible reconfiguration, the REIDS platform offers grid-of-grids test scenarios, such as dynamic system optimization, smart grid network management, energy trading, and cybersecurity. These elements are essential for exploring early-stage RD&D opportunities within the energy sector.

Figure 12: Renewable Energy Integration Demonstrator – Singapore

REIDS Offshore, also known as the Tropical Marine Energy Centre (TMEC), is a project aimed at advancing offshore renewable energy integration and demonstration. Led by ERI@N and financially backed by ClassNK, a Japanese classification society, this initiative seeks to create the world's first large-scale marine renewable energy testing facility tailored to tropical conditions. A feasibility study was conducted to assess ocean energy potential around the southern islands of Singapore, identified by the Maritime and Port Authority of Singapore (MPA). Using resource mapping techniques, the study evaluated suitable test sites, followed by environmental impact assessments (EIA) to examine the effects of ocean energy systems on marine life and surrounding ecosystems. The findings will contribute to Singapore's marine energy guidelines and standards, in collaboration with Enterprise Singapore, and support the creation of marine energy resource mapping standards for new regions, including Southeast Asia, tropical islands, and remote coastal areas. Ultimately, the project aims to develop technologies and methods for providing sustainable energy to remote island regions

Singapore Energy Imports

As part of its efforts to decarbonize its economy, Singapore is focusing on reducing its carbon footprint while meeting its energy needs. By 2035, the country aims to import about 30% of its energy, potentially including renewable sources such as solar power, hydrogen, and regional clean energy imports from neighbouring countries. This shift aligns with Singapore's ambitious targets for reducing greenhouse gas emissions and transitioning to cleaner energy alternatives.

According to the Ministry of Trade and Industry (MTI), Singapore plans to import 6 GW of low-carbon electricity by 2035, which would represent approximately one-third of

the nation's energy supply. The electricity is expected to come primarily from Indonesia, Cambodia, and Vietnam. This initiative is crucial for decarbonizing the power sector and helps Singapore work toward its net-zero emissions goal by 2050. Importing electricity will also diversify the country's energy sources, reduce carbon emissions, and enhance energy security. MTI has already granted conditional approvals for several electricity import projects, making notable progress toward this goal.

The Energy Market Authority (EMA) has granted Conditional Approval to Keppel Energy Pte. Ltd. to import 1 GW of electricity from Cambodia to Singapore. This marks EMA's first Conditional Approval for electricity imports and is a significant step toward the goal of importing up to 4 GW of low-carbon electricity by 2035. The approval indicates that the project has been preliminarily evaluated as technically and commercially feasible, allowing Keppel Energy to proceed with obtaining the necessary regulatory approvals and licenses. This development builds on the Energy Cooperation Memorandum of Understanding (MOU) between Cambodia and Singapore, further reinforcing both nations' commitment to supporting the clean energy transition and regional decarbonization, including increased collaboration on cross-border electricity trading.

As part of the plan, the imported electricity will be generated from renewable energy, supported by battery energy storage systems (BESS) or pumped storage hydropower (PSH), and delivered to Singapore via subsea cables spanning over 1,000 km.

In addition, Singapore currently imports up to 100 MW of renewable energy from Laos through the Lao PDR-Thailand-Malaysia-Singapore Power Integration Project (LTMS-PIP). Another pilot being worked on by EMA is the 100 MW Malaysia trial, with YTL PowerSeraya appointed as the importer. This trial will run over a two-year period, with electricity supplied via the existing interconnector between Singapore and Malaysia.

5 private entities are also given Conditional Approvals by EMA to import 2 GW of electricity from Indonesia

- Pacific Medco Solar Pte Ltd (formed by PacificLight Renewables Pte. Ltd., Medco Power Global Pte. Ltd. and Gallant Venture Ltd.) for an import capacity of 0.6 GW
- Adaro Solar International Pte. Ltd. (formed by PT Adaro Clean Energy Indonesia) for an import capacity of 0.4 GW
- EDP Renewables APAC for an import capacity of 0.4 GW
- Vanda RE Pte. Ltd. (formed by Gurin Energy Pte. Ltd. and Gentari International Renewables Pte. Ltd.) for an import capacity of 0.3 GW
- Keppel Energy Pte. Ltd. for an import capacity of 0.3 GW

Electric Harbour Craft Charging Infrastructure

The Maritime and Port Authority of Singapore (MPA) has launched its first electric harbour craft (e-HC) charging pilot at Marina South Pier. The project, awarded to Pyxis Energy, Pyxis Maritime, and SP Mobility, includes a 150 kW fast charger to support e-HC operations and gather data for future charging infrastructure. MPA is working with Enterprise Singapore and industry partners to develop technical standards for e-HC charging and battery swapping. Additional pilots include Seatrium O&G's mobile charger and Yinson Electric's high-power DC charger. From 2030, all new harbour craft in Singapore must be electric, biofuel-capable, or compatible with net-zero fuels. MPA has shortlisted 11 e-HC vessel designs to lower costs and accelerate industry adoption. Financial incentives, such as the Enterprise Financing Scheme-Green (EFS-Green) and Energy Efficiency Grant, will support companies in transitioning. These initiatives aim to decarbonize Singapore's maritime sector and encourage wider adoption of e-HC technology. Public-private collaboration is key to advancing vessel and battery designs, financing, and charging infrastructure. MPA's efforts position Singapore as a leader in sustainable maritime innovation.

Figure 13: Singapore Launches Pilot for Electric Harbour Craft Charging Infrastructure

Other Research Activity's

Bio-fouling Coating Evaluations in Tropical Waters

A study in the coastal waters of Sentosa, Singapore, evaluated various anti-fouling coatings for their performance in tropical marine conditions. Test panels, simulating tidal turbines, were coated with different anti-fouling formulations and deployed for 365 days to observe natural bio-fouling development. Periodic assessments quantified fouling coverage, species composition, and adhesion strength. The results offered insights into coating efficacy, aiming to optimize surface protection and support efficient, low-impact cleaning technologies for marine renewables and offshore structures.

Figure 14: Bio-fouling coating Towards Tidal Turbine Needs

Surficial drone for Marine Resource

The surficial drone was designed to monitor and map various aspects of marine environments. Tested in Sentosa waters, it captures detailed seabed topography and monitors water quality, measuring parameters like temperature, pH, and dissolved oxygen. The drone also tracks coral health, aiding in coral assessment. This versatile technology is essential for marine research, conservation, and environmental monitoring, providing valuable insights into the health of underwater ecosystems.

NATIONAL EVENTS

Singapore International Energy Week (SIEW)

The Singapore International Energy Week (SIEW) is an annual platform for energy professionals, policymakers, and commentators to share best practices and solutions within the global energy space. The 17th Singapore International Energy Week (SIEW) is Asia's leading platform for the discussion of key energy issues that impact the region. Themed " A Connected and Sustainable Energy World", SIEW 2024 was organised by the Energy Market Authority of Singapore and took place from 21 to 25 October 2024 at the Sands Expo and Convention Centre, Marina Bay Sands, Singapore.

Asia Conference on Renewable Energy and Environmental Engineering (AREEE)

The 2025 6th Asia Conference on Renewable Energy and Environmental Engineering (AREEE 2025) was held in Singapore during March 22- 24, 2025. The aim of the conference was to provide a premier platform for environmental engineers and researchers to present their works and to share experiences and ideas in renewable energy and environmental engineering with experts and scholars from around the world. The conference program featured keynote and plenary sessions, oral and poster presentations. Distinguished speakers were invited to deliver keynote speeches and invited talks on emerging technologies in renewable energy and environmental engineering.

Offshore Energy Week (OSEA)

OSEA 2024 welcomed 15,000+ attendees over 3 days, from 19 – 21 November 2024 at the Marina Bay Sands Expo and Convention Centre, Singapore. OSEA showcased the latest technologies and solutions across 7 group pavilions. Supported by a high level steering committee, top offshore energy leaders also gathered and networked over 60+ content forums and 10+ networking sessions. OSEA has served as a key business platform and biennial meeting place for industry professionals in offshore Industry.

CleanEnviro Summit Singapore (CESG)

The sixth biennial CleanEnviro Summit Singapore (CESG) organised by Singapore's National Environment Agency in conjunction with Singapore International Water Week 2024 was held from 19 to 21 June 2024 and was themed 'Action for a Sustainable and Clean Environment'. It was a global platform where thought leaders, industry captains and policymakers convened to explore solutions for a sustainable and clean environment. This is a global platform for thought leaders, industry captains and policy makers to convene, connect, as well as consider solutions for enabling a sustainable and clean environment. Over 30,000 attendees from more than 95 countries and regions gathered over the three-day period of CESG 2024 and SIWW 2024. The event featured the Sustainability Summit, Sustainability and Clean Environment Convention, Youth Environment Leaders Immersion Programme, Environment Expo, and Site Visits to NEA facilities. These experiences offered participants valuable insights in enabling a sustainable and clean environment.

SPAIN

REPORT PREPARED BY:
Yago Torre-Enciso, Biscay Marine Energy Platform

OVERVIEW

The year 2024 was positive for the development of ocean energies in Spain, for several reasons: there is a wide range of research projects that progressed across low and high TRLs. Initiatives that drive networking and moved testing areas closer to certification as laboratories under the IEC TS 62600 standard were particularly noteworthy. Also, several full-scale prototypes either reached or are ready to reach the full-scale test phase in 2025.

From a legislative point of view, 2024 was also a successful year in Spain. New regulations were adopted that are set to facilitate the deployment of ocean energy facilities.

SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy

In September 2024 the Spanish Government approved the Royal Decree regulating the production of electricity from renewable sources located at sea RD 962/2024, the regulatory framework of reference to develop this type of facilities in a participatory and flexible way, so as to maximize their positive externalities, such as the generation of employment and industry, while minimizing environmental impacts.

This new regulation establishes that offshore renewable energy installations beyond a certain power capacity - including ocean energy - will only be built through a competitive bidding mechanism in the High Potential Areas (ZAPER), identified for this purpose in the Maritime Spatial Planning (POEM in its acronym in Spanish). The competitive concurrence procedure simultaneously would grant - within one administrative act - the Economic Regime of Renewable Energy, the reservation of access capacity in a specific node of the transport network and priority in the granting of the concession for the occupation of the Maritime Terrestrial Public Domain.

The new framework facilitates the processing and establishes a special regulation for those installations under the consideration of 'innovative offshore renewable installations', by exempting them from participating in the competitive concurrence procedures as long as the installed power does not exceed 20 MW - on ocean energy - or those located in State Ports of General Interest. The innovative nature of the installations will be accredited by means of reports from the Ministry of Science, Innovation and Universities and the Institute for Energy Diversification and Saving (IDAE), M.P., in charge of determining that the activity is considered to be as research and development or technological innovation. Exempt from this report are those installations requesting authorization for a term of less than five years or, in the case of offshore wind, which only have one wind turbine.

As a general framework, the "Roadmap for the Development of Offshore Wind and Marine Energies" remains in force, outlining Spain's objectives for the development of offshore wind and marine energies. The roadmap sets targets for installed offshore wind power capacity of 1 to 3 GW by 2030 and aims to position Spain as a European hub for technological development and environmental innovation in the marine energy sector.

The National Integrated Energy and Climate Plan (PNIEC) 2021-2030 sets specific installed capacity targets for various renewable energy sources in Spain, although it does not set a specific figure for wave or marine energy because these technologies are still in an emerging phase and require further development. Reference is made, however, to marine renewables in terms of their long-term potential.

In 2023, Spain approved the Marine Spatial Planning (MSP) framework through the Royal Decree 150/2023, establishing the Spatial Planning Plans for Maritime Areas (POEM) across five marine demarcations: North Atlantic, South Atlantic, Strait and Alboran, Levantine-Balearic, and Canary Islands. These plans aim to harmonize human activities in marine areas, such as fishing, maritime transport, environmental conservation, and the development of marine renewable energies.

Aligned with the EU Directive 2014/89, Spain's MSP framework ensures sustainable and balanced coexistence of marine uses, providing a regulatory and planning foundation for innovative projects like MAR+ and other renewable energy initiatives. The Ministry for the Ecological Transition and Demographic Challenge oversees this implementation, promoting the integration of marine renewable energy projects within the sustainable management of maritime space.

Market incentives

There are no specific market incentives for ocean energy in Spain but for renewable energy installations in general.

Royal Decree 413/2014 established that the support for new renewable facilities is granted through competitive public tender processes. Through these auction processes, bidders propose the initial value for the investment that they will be willing to accept, and the MW auctioned are allocated to the most competitive offers (the lower ones).

Royal Decree 960/2020, of November 3, which regulates the economic regime of renewable energies for electricity production facilities and Order TED / 1161/2020, of December 4, which regulates the first auction mechanism for the granting of the economic regime of renewable energies and establishes the indicative calendar for the period 2020-2025, will allow to start the tender calendar for the next five years.

The above mentioned Order TED/1161/2020 stablishes a tender of 20 MW every two years focused on "Other Technologies", where ocean energy is included, reaching 60 MW for 2025.

Additionally, tax incentives are being implemented in some regions as deductions for investment in R&D, which benefit companies developing research projects and technological prototypes related to marine energies.

Public funding programmes

The Call for the RENMARINAS DEMOS Programme in Spain is an initiative of the Ministry for Ecological Transition and the Demographic Challenge (MITERD), managed through the Institute for Diversification and Energy Saving (IDAE), which aims to grant investment aid in pilot projects and testing platforms and port infrastructure for marine renewables, within the framework of the Recovery, Transformation and Resilience Plan. Following the closure of the evaluation of the proposals submitted, the Call was resolved in October 2023, by granting aid to 21 actions in new investments in testing and demonstration platforms for marine renewable technologies in Spain: offshore wind energy, wave energy, floating photovoltaic or hybrids of these renewable technologies. It has allocated grants amounting to €147 million, which will mobilise investments of around €384 million. Of these, 4 projects in the field of wave energy, with a cumulative power of 1.7 MW and a joint support of €4.5 million; and one project of a hybrid prototype of wind and wave energy, with 5 MW of total power and aid of €7.5 million. These projects are expected to be completed by 2026.

In September 2024, MITERD launched the public consultation on the regulatory bases for aid for the physical adaptation of national port infrastructure, suitable for facilitating the assembly, manufacturing and maintenance of offshore renewable energy projects, not only for national projects, but also as a complementary part of the supply chain for international markets. This initiative aims to adapt Spanish ports for the deployment of offshore wind and marine energy in Spain and marks a significant step towards the consolidation of Spain as one of the leading countries in renewable energy.

The Basque Energy Agency (EVE) launched a new call of its "Demonstration and validation of emerging marine renewable energy technologies" programme in 2024. As previous calls, the programme has a total budget of 2.5 M€ for 3-year maximum duration projects.

RESEARCH & DEVELOPMENT

EUROPEWAVE

Horizon 2020 project **EUROPEWAVE** was launched in January 2021 and has the objective to bridge the gap to commercialisation of wave energy technology using pre-commercial procurement. The project brings together over €22.5m of national, regional and EU funding to provide the boost to Europe's wave energy innovation community necessary to transition to commercial viability. WES (Wave Energy Scotland) is the coordinator of the project and acts as lead procurer in the 'Buyers Group' formed by WES (Scotland) and EVE – Basque Energy Agency (Basque Country). The consortium is completed by Ocean Energy Europe, the sector's representative body, who will enable the widest possible engagement with those influential stakeholders able to maximise the environmental, economic and social benefits of wave energy technology for Europe. Main Activities of the EuropeWave Project in 2024 include:

- Progress on engineering activities towards open-sea testing activities for 3 developers:
  - Mocean Energy
  - IDOM Consulting, Engineering, Architecture
  - CETO Wave Energy Ireland
- Communication and Dissemination Efforts:
  - Organization of a side event at OEE 2024 to engage stakeholders and promote project outcomes

TURBOWAVE

The Basque Energy Agency (EVE) launched the **TurboWave** project in late 2022. This Pre-Commercial Procurement initiative aims to accelerate the development of cost-efficient, safe and reliable air turbine technologies that match the needs of the wave energy sector in general and the specific technical requirements of the Mutriku Wave Power Plant. The TurboWave project is expected to progress through 3 phases: "Concept development", "Design refinement and laboratory testing", and "Manufacture and on-site testing of prototypes at Mutriku wave power plant". The project has made significant progress during 2024:

- Successful completion of five Phase I projects
- Evaluation and Award of Phase II contracts to four developers:
  - Advanced Simulation Technologies – New Wave Technologies (Consortium)
  - Arrecife Energy Systems
  - IDOM Consulting, Engineering, Architecture
  - Kymaner – IDMEC (Consortium)
- Successful completion of manufacture, assembly and dry-lab testing of Phase II scale-model prototypes.

OWC solution been tested at a 1:85 scale at the facilities of Mondragon Unibertsitatea. © Arrecife Energy Systems

Clean Energy Transition Partnerhsip (Cetp)

EVE and the Economic Development, Sustainability and Environment Department of the Basque Country are partners of the CETP project. The aim of the project is to accelerate clean energy transition through annual calls published thanks to the collaboration and coordination between national/regional funding organisations. The 2023 Joint call funded several project in cross-cutting topics such as moorings, materials or electrical power transmission lines for MRE, as well as a project exploring solar energy in a hybrid solar thermal OTEC power generation arrangement in an open cycle for the production of green hydrogen and desalinated water. The 2024 call for pre-proposals was published on 19 September 2024 and closed on 22 November. Full proposal submission is expected to open in January 2025 and will close in April 2025.

MARES

CIEMAT is leading the MARES project (https://cordis.europa.eu/project/id/101172746), funded by Horizon Europe Programme, which started in 2024. The project is aligned with one of main R&D lines in marine energy in CIEMAT: the design, development and testing of Power Take-Offs (PTO). Over 4 years, and together with partners CYCLOMED, SUPRASYS, ANTEC, TEAMWORK, WEDGE, ASG, EFESTO, UNIBO and CERN, a complete and func-

tional prototype of a superconducting linear electric generator designed to act as a PTO in wave energy harnessing applications will be developed. A superconducting generator would allow, on the one hand, to increase the force density and, on the other hand, to increase the ability to implement reactive controls given the substantial reduction of losses. Both improvements would have a direct and positive impact on the goal of reducing the LCOE.

VALID

The VALID project, funded under the H2020 programme, successfully finalised in 2024. The first-of-a-kind implementation of a novel hybrid testing methodology was demonstrated on three critical components, results documented and recommendations for the ocean energy sector produced in several public deliverables. In Spain, TECNALIA, IDOM and BiMEP worked together in the analysis of the electric generator failure.

More information: https://www.validhtp.eu/

SEETIP Ocean

The SEETIP project, funded under the HE programme, supports the activities of both the European Technology and Innovation Platform for Ocean Energy (ETIP Ocean) and the SET Plan Ocean Energy Implementation Working Group (OE-IWG). In 2024, TECNALIA led the update of the Strategic Research and Innovation Agenda for Ocean Energy 2025-2030 in close collaboration with Ocean Energy Europe, the University of Edinburgh, and a wide representation of the sector. In addition to that, 6 webinars and workshops have been organised to enable knowledge sharing among sector stakeholders.

More information: https://www.etipocean.eu/

MAXBlade

The MAXBlade project, funded under the HE programme, aims to deliver essential blade and rotor innovations to improve performance, reduce cost, increase reliability, survivability, recyclability and financeability of tidal stream technologies. In 2024, an extensive experimental campaign started at TECNALIA's DANTE and HARSHLAB marine laboratories to test different blade coatings samples from Orbital Marine Power, their antifouling properties and dynamic frictional resistance under realistic conditions.

More information: https://maxblade.tech/

ONDEP

The ONDEP project, funded under the HE programme, aims to facilitate widespread commercialisation and large-scale deployment of wave energy production in Europe and beyond. This involves setting up a 2 MW farm with 4 WaveRoller devices of 500 kW and establishing a complete end-to-end European supply chain with a concrete roadmap for deployment. The project kicked off in October 2024 and technical work started with the detailed design of the wave energy farm. TECNALIA leads the specification and design of a structural digital twin of the farm to manage the functionality of critical components and increase its operational performance.

JRL-ORE

The Joint Research Laboratory on Offshore Renewable Energy was created in 2017. Based on the Basque Country, the JRL-ORE is a diverse scientific community composed of around 60 researchers from TECNALIA, BCAM and the University of Basque Country. The JRL-ORE is committed to the training of the future professionals for offshore renewables, being linked to the Master in Renewable Energy in the Marine Environment coordinated by the University of the Basque Country (REM+ Master https://www.master-remplus.eu/). In 2024, among other projects, the JRL-ORE has coordinated RUL-ET (Remaining Useful Life of Mooring Systems and Umbilicals for Offshore Renewables), a project funded by the Basque Government. The main objective of the project is to develop new approaches based on Artificial Intelligence and the creation of datasets for estimating the Remaining Useful Life of mooring systems and dynamic electrical evacuation cables for floating marine energy devices.

More information: https://jrl-ore.com/

SAFEWAVE

The project SafeWAVE - Streamlining the Assessment of Environmental Effects of Wave Energy co-funded by the European Climate, Infrastructure and Environment Executive Agency (CINEA) started on October 2021 and was extended until December 2024. During 2024 some environmental monitoring activities continued, and several documents on public education and engagement strategy, consenting, and marine spatial planning were produced as project deliverables. The project builds on the results of the WESE project representing the second effort of the EU in the objective of overcoming the non-tech-

nological barriers that could hinder the development of ocean wave energy projects in EU.

More information: https://www.safewave-project.eu/

MAR+

This project led by BiMEP and IHCantabria, aims to establish the world's first accredited cluster of laboratories for marine renewable energy testing. This initiative focuses on developing certified methodologies for wave energy and floating wind technologies, integrating advanced tools such as the digital twin for the Mutriku OWC plant. In 2024, MAR+ has significantly advanced the development of testing methodologies for wave energy converters and floating wind platforms. The project integrates numerical and experimental techniques, including the creation of a digital twin for the Mutriku OWC plant, which will undergo validation in 2025. These efforts are aligned with international standards (e.g., IEC TS 62600) and contribute to Spain's role as a leader in marine renewable energy innovation.

SHY Project

Wavepiston leads this project (Seawater Hydraulic PTO using dynamic passive controller for wave energy converters), which aims to develop a composite linear pump and controller valve that use seawater as a working fluid and a dynamic passive controller to maximize energy capture. This control method enhances power capture without requiring additional reactive energy. The technology will be tested on the Wavepiston wave energy converter, but it is designed to be applicable to other hydraulic PTO-based systems. A numerical model will be created to develop a cost-optimized control strategy.

WECHULL+

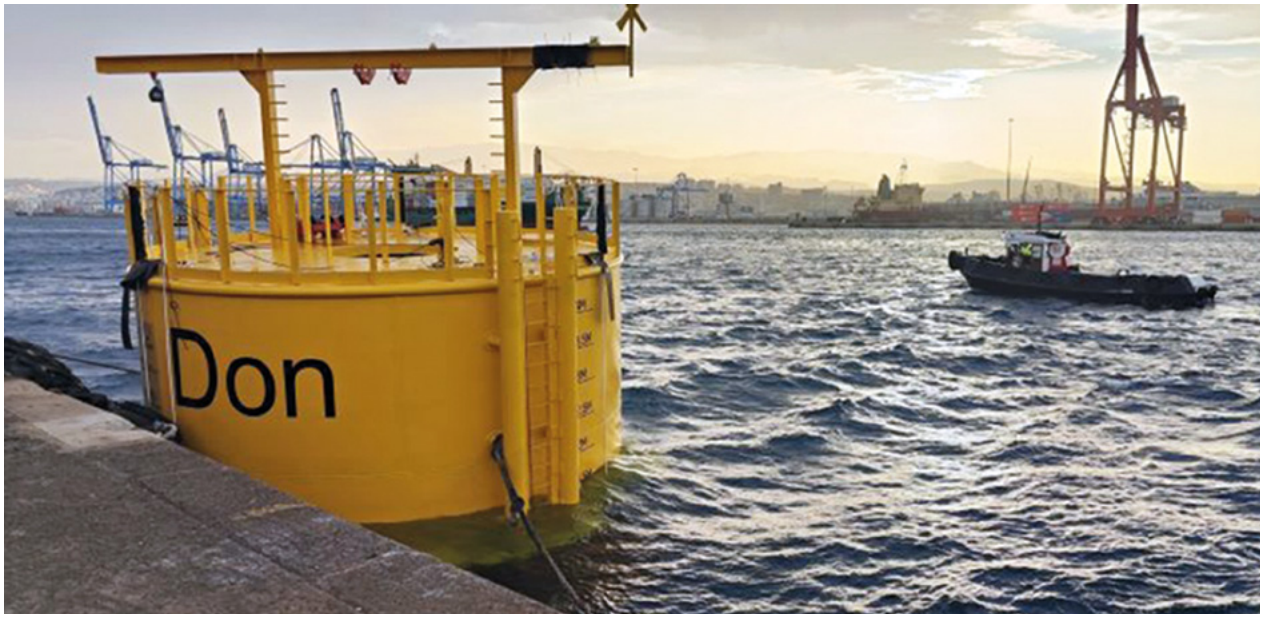
This project, funded with €3 million through the CET Partnership program, aims to transform the use of concrete in offshore renewable energy. Building on the success of WECHULL, this initiative, launched in 2023, focuses on developing a sustainable and circular concrete material for floating substructures in the renewable energy sector. Led by RISE Research Institutes of Sweden, it involves eight research institutions and industry partners across Europe. The project seeks to reduce concrete's carbon footprint by replacing over 70% of traditional cement with alternative materials. In 2025, scaled prototypes (1:5 WEC floater and 1:3 ballast system for floating PV) will be tested in real ocean environments, including PLOCAN in the Canary Islands.

TECHNOLOGY DEMONSTRATION

Existing open sea test sites

PLOCAN

A 23 km^2 offshore test site for marine technologies of multiple natures, with access to a unique ecosystem, to accelerate knowledge, sustainability and responsible



1:5 OTEC Prototype to be installed at PLOCAN under PLOTEC project

Plocan Testing Infrastructure

use of the marine environment in line with the Sustainable Development Goals (SDGs). It enables and contributes to the acceleration in the development of technologies and knowledge in the marine environment, with observation systems and open ocean, in real conditions. It is equipped with an electrical and communications infrastructure, consisting of two medium-voltage submarine cables (with one connection each) of 5 MW each, which allow the connection of technologies that use natural resources to generate electricity. These cables allow the energy generated to be delivered to the island's electricity transmission grid.

Harshlab 0.5 PLOCAN

Harshlab 0.5 is a laboratory for the evaluation of materials in real sea conditions. This infrastructure is suitable for testing corrosion phenomena, biofouling, material degradation, coatings performance, etc. Located in the Port of Taliarte (Telde, Gran Canaria), it consists of two structures or panels capable of housing standardised probes, but also able to test electrical cables, moorings, ropes, or any marine renewable element that needs to be tested in real marine conditions. Harshlab 0.5 offers the possibility to test marine materials in three different zones: immersed, intertidal and splash zone. Thanks to its design, the installation can be easily accessed 24/7 from the dock, totally independent of the weather conditions and without the need of auxiliary resources, which aims continuous monitoring of the experiments.

HARSHLAB

HarshLab testing laboratory was installed in BiMEP in June 2022. During 2024 HarshLab hosted several testing campaigns including not only on new coating systems that are more resistant to corrosion and fouling (eg. NEMMO, NEWSKIN projects), but also with tests that go beyond the field of materials. Thus, during this time it has been possible to carry out unique tests, such as those of two turbines at the scale of a wave energy generator (Arrecife Systems), different systems of sensorised gauges (Inalia, Lumiker), or an echo sounder for measuring biomass under floating

HarshLab installed at BiMEP

structures (Fundación Azti, at SAFEWAVE project), among others. In addition to customer trials, this full year at Bimep has been a real test of its survival for the HarshLab, which has successfully withstood the heavy swells that hit the Bay of Biscay during the winter.

More info at: https://harshlab.eu/

Biscay Marine Energy Platform - BiMEP

BiMEP is an open sea full scale grid connected test centre managing two sites: one located off the coast of Armintza, in the province of Bizkaia, and the other one onshore at the port of Mutriku, in the province of Gipuzkoa. Operating since June 2015, BiMEP offers technology developers an offshore area with suitable wave and wind resources, thereby enabling the demonstration and validation of the technical and economic viability of different concepts of energy converters, equipment and materials prior to commercial development.

Mutriku Wave Power Plant

The infrastructure is being improved to host the TURBOWAVE third phase, while it is used as test site and as a proper power plant. Commissioned in July 2011. The energy production during 2024 was 210 MWh.

Projects in the water

WAVEPISTON

The Danish company Wavepiston has reached a key milestone by installing its first full-scale energy collector at the PLOCAN test site in the Canary Islands. The system, consisting of wave collectors connected between two seabed-anchored buoys, converts wave movement into pressurized water, which can be used for energy generation or desalination. PLOCAN provides optimal conditions for testing, allowing Wavepiston to collect real-world data and validate its system's efficiency.

Projects planned for deployment

EUROPEWAVE

In the summer of 2025, two prototypes are expected to be installed in BiMEP due to the progress of the EUROPEWAVE project: CETO (CARNEGIE); and MARMOKA (IDOM).

SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

ELBE Eurocluster

The European cluster alliance ELBE (European Leaders of Blue Energy), led by the Basque Energy Cluster, was selected in 2022 by the European Commission as the "Eurocluster" initiative for offshore renewable energy. This Eurocluster is part of the European Commission's Industrial Strategy, structured around 16 priority industrial ecosystems, one of which is the "Renewable Energy Industrial ecosystem", which is the focus of this initiative.

The ELBE Eurocluster alliance gathers seven European leading clusters: Pôle Mer Méditerranée (France), Offshore Vast (Sweden), Energy Cluster Denmark (Denmark), GCE Node (Norway), Blue Cluster (Belgium), Pomeranian Offshore Platform (Poland) and BEC, as the coordinator of the alliance. Over 3 years, the clusters in the alliance are carrying out joint activities to support European SMEs in the sector around networking, innovation, adopting new technologies, training, and internationalisation.

REMAR

The REMAR international network, *Opportunities for Integration in Ibero-American Electric Grids of Marine Energies*, has concluded its formal activities in 2024 with the publication of a comprehensive final report titled *Marine Energy in Ibero-American Countries: Policies, Capacities, Resources, and Grid Integration*. This initiative, promoted and funded by the Ibero-American Programme of Science and Technology for Development (CYTED) and coordinated by CIEMAT in Spain, brings together insights from 13 member countries of the REMAR Network. The report provides an in-depth analysis of existing information on marine renewable energy across these nations. It exam-

ines key aspects such as marine energy policies, available resources, industrial capacity, experimental facilities, and the readiness of electric grids for integrating new renewable energy sources. The document also presents conclusions and actionable recommendations to facilitate the adoption and development of marine energy in the countries studied.

The document is available at:
https://www.cyted.org/REMAR.

Innovation Platform Sustainable Sea and Ocean Solutions (ISSS)

Several European Research Centres (+Atlantic CoLab, AZTI, ENEA, Fraunhofer, IFREMER, RISE, SINTEF, TECNALIA, TNO and VTT) started the joint Innovation Platform Sustainable Sea and Ocean Solutions (ISSS). Its vision is a climate-neutral continent through a completely green-blue transformed economy and society in 2050 and the mission is the responsible utilization of our oceans, to harness their potential and create additional value and future-proof jobs in the European marine and maritime sectors. ISSS aims at developing and mastering innovative technologies for a sustainable blue economy to boost the European Green Deal and facilitate an internationally competitive European maritime industry. TECNALIA participates in two focus areas of ISSS: Ocean Energy and Maritime Test Sites.

Several European Research Centres started the joint Innovation Platform Sustainable Sea and Ocean Solutions (ISSS). Its vision is a climate-neutral continent through a completely green-blue transformed economy and society in 2050 and the mission is the responsible utilization of our oceans, to harness their potential and create additional value and future-proof jobs in the European marine and maritime sectors.

RELEVANT NATIONAL EVENTS

Relevant events in 2024

The city of Portugalete hosted OREgaua, the European Researchers' night in the field of Offshore Renewable Energy (27th September). This big event was attended by more than 2,000 citizens who could learn about the science behind ORE. This event is part of ORE4citizens MSCA project (https://oregaua.org/) led by TECNALIA with the partners of the JRL-ORE, whose principal objective is to bring science closer to citizens and promote STEM vocations among students, all related to offshore renewable energy.

Relevant events planned for 2025

World Maritime Week (WMW) is a maritime gathering for key stakeholders in the global maritime industry. Held biennially, this event is designed to foster international partnerships, exchange knowledge, and collaboratively address emerging challenges in the maritime sector. Spanning two days of engaging sessions (March 19 and 20, 2025) and one additional day dedicated to technical visits (March 21, 2025), the event provides attendees with a comprehensive exploration of the maritime ecosystem through three distinct dimensions:

- **Innovation:** *Exhibition Area, where companies have the chance to showcase their services and products.*
- **Knowledge:** *A wide conference program representing 4 key sectors:*
  - SINAVAL: Focused on shipbuilding.
  - EUROFISHING: Dedicated to the fishing industry.
  - FUTUREPORT: Exploring the port industry.
  - MARINE ENERGY WEEK: Highlighting renewable marine energies.
- **Networking:** Opportunities to Build Strategic Connections: Hosted Buyers Program, 2nd edition of World Maritime Week Awards, Coffee Breaks, Cocktails with Speakers and Buyers, Technical Visits and Employment Forum.

SWEDEN

REPORT PREPARED BY:
Marit Marsh Strömberg, Robert Fischer and Jonas Pettersson,
Swedish Energy Agency

OVERVIEW

Throughout 2024, Swedish ocean energy developers have made noticeable progress in advancing their technologies, achieving key milestones, and conducting extensive testing and research across various projects. For example, Minesto achieved a key milestone by installing, commissioning, and operating the Dragon 12, the first grid connected megawatt tidal kite, in Vestmannasund, Faroe Islands. NoviOcean completed a one-year test of its WEC prototype in the Stockholm archipelago, Sweden, with the prototype surviving both stormy weather and the cold winter. OE Systems tested a 1:25 scale model of their wave energy converter, WaveMove, in the ocean and concluded that the system works under real-world conditions.

In addition, CorPower Ocean, which demonstrated storm survivability during a three-month period in late 2023 with their first commercial-scale wave energy converter (WEC), C4, in Aguçadoura, Portugal, has carried out an onshore campaign of upgrades and maintenance of the C4 device, with re-deployment scheduled for early 2025. Also, Ocean Harvesting Technologies and Waves4Power have made various R&D progress throughout the year.

In total, over 20 R&D projects were running, covering topics such as testing and methodology development, control strategies, array optimizations, mooring and anchoring systems, cable solutions, material improvements, environmental effects, resource assessment and development of new ocean energy devices.

SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy

The overall objective of the Swedish energy policy is to create the conditions for efficient and sustainable energy use and a cost-effective Swedish energy supply with low negative impact on health, environment, and climate and to facilitate the transition to an ecologically sustainable society. The policy is based on the legislation established within the EU and the objective builds on the same three pillars of EU´s energy cooperation which aims to reconcile security of supply, competitiveness and environmental sustainability. The Swedish energy and climate goals include the following targets:

- By 2045 at the latest, Sweden must have net zero emissions, of which at least 85% of the reduction in emissions must take place in Sweden.
- In 2040, electricity production must be 100% fossil-free.

Ocean energy is one of many areas included in Sweden's national maritime strategy, which identifies areas where action is needed to promote a sustainable development in the Swedish maritime sector. This strategy was enacted in 2015 by the Ministry of Enterprises, Energy and Communications. In February 2022, the Government adopted three marine spatial plans for its territorial waters and Exclusive Economic Zone. Marine spatial planning will form the basis for governmental agency and municipal decisions regarding the most appropriate usage of a marine area. To date, no specific area has been designated for ocean energy usage.

Market incentives

The current long-term Swedish energy policy relies on economic policy instruments, which are technology neutral, and include a carbon tax, international emissions trading and a renewable electricity certificate system. However, renewable electricity production developments commissioned beyond the end of 2021 are not eligible to receive electricity certificates. There are no instruments in place to specifically incentivise ocean energy deployment.

Public funding programmes

Swedish governmental agencies support academic and private sector R&D at various stages of technology maturity. Funding providers include:

- Swedish Energy Agency (SEA, www.energimyndigheten.se), which is responsible for facilitating a sustainable energy system in Sweden. To this end the agency funds relevant research, business and technology development and technology demonstration.
- Swedish Research Council (VR, www.vr.se), which is tasked with funding fundamental research and research infrastructure for a wide range of topics.
- Swedish Innovation Agency (VINNOVA www.vinnova.se), which supports business and technology development through funding.

In addition, regional authorities may also grant funding. Ocean energy projects can apply for funding within existing programmes such as, for example, Future Electricity Power Systems[1], Pilot and Demonstration Projects[2], Verification of Innovation with Customer[3] and Develop a Business Idea[4]. The Swedish Energy Agency is also involved in the Clean Energy Transition Partnership[5] (CETPartnership), which is a collaboration between national/regional funding organisations in European Members States and Associated Countries that aims to accelerate the energy transition.

RESEARCH & DEVELOPMENT

Swedish companies, universities and institutes have been involved with several research and development projects during 2024, see examples below:

Control of wave energy converters based on wave measurements, for optimal energy absorption (WAVEMEASURE)

The project has developed a simulation methodology that advances the precision of numerical wave energy converter models in power production simulations. The methodology is based on fully coupled hydro-mechanical time-domain simulations, including advance model of the PTO system as an integrated servo model. It was found that the steepness of the waves can be used to control the power output of the power plant, and that speed control of the generator seems to be preferable when controlling the wave power plant. In a cluster, or a park of several wave energy converter (WEC) buoys, the WECs were found to influence each other, sometimes positively and sometimes negatively, depending on the wave conditions. The distances between WECs in a hexagon pattern matter, and some asymmetry can be beneficial. The project was carried out by Waves4Power, Lund University and Chalmers University of Technology.

Electricity generators from weak ocean/sea waves

This project develops a wave energy converter that harvests and stores the triboelectricity at seawater/plastic interface. The project is carried out by the Royal Institute of Technology (KTH).

Harvesting of Blue energy using Swedish natural and artificial resources

The objective of this project is to evaluate the feasibility of harnessing salinity gradient power (SGP) in Sweden to produce blue energy using reverse electrodialysis (RED) technology. The project aims to assess the environmental impact of RED technology, identify technical bottlenecks, and develop solutions to overcome current challenges. In 2024, the study identified 32 potential estuaries for salinity gradient energy exploitation and analysed their water sources. Four estuaries were chosen for RED experiments. Seawater and river water were simulated using NaCl and multi-salt solutions to replicate natural conditions. The study assessed how operating conditions such as

1 https://www.energimyndigheten.se/forskning-och-innovation/forskning/elsystem/framtidens-elsystem/
2 https://www.energimyndigheten.se/forskning-och-innovation/affarsideer-test-och-internationalisering/pilot-och-demonstrationsprojekt/
3 https://www.energimyndigheten.se/forskning-och-innovation/affarsideer-test-och-internationalisering/verifiering-med-kund/
4 https://www.energimyndigheten.se/forskning-och-innovation/affarsideer-test-och-internationalisering/utveckla-en-affarside/
5 https://cetpartnership.eu/

seasonal temperature, salinity, and water flow rate affect RED performance and conducted a life cycle assessment (LCA) to compare its environmental footprint with other renewable energy sources. Additionally, improvements were made to the RED stack, including new spacers and membranes to enhance efficiency and performance. Project partners are Umeå University and Lund University.

Figure 1: Selected estuaries on Swedish map (red markers).
© Umeå University and Lund University

InfinityWEC Generation 6

Ocean Harvesting Technologies AB develops the 500 kW InfinityWEC Wave Energy Converter based on a power take-off with ball screw actuators and hydrostatic pre-tension system. During 2024, the ball screw actuation system has been further developed and improved in collaboration with ball screw manufacturer NSK to handle side loads and bending moments and the control force has been increased to improve motion control. Linear moment-based model predictive control (LM-MPC) has been implemented and evaluated in collaboration with Sigma Energy & Marine and Politecnico Di Torino. Simulations have verified compliance with ball screw requirements, and annual energy production and lifetime of the ball screws have been analysed for five reference locations and compared with non-predictive reactive control with promising results.

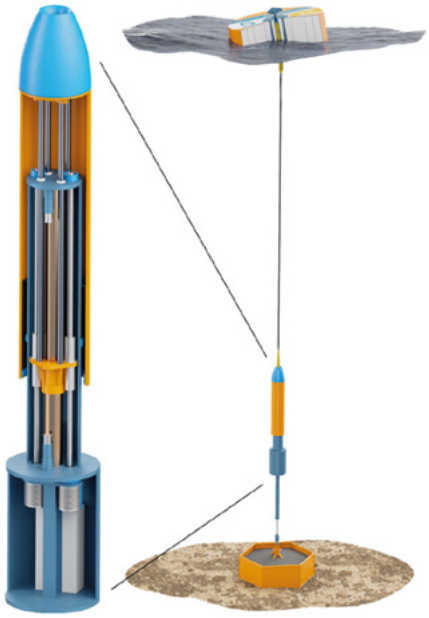


Figure 2: Visualization of an InfinityWEC unit deployed in the sea, including zooming in on the InfinityWEC Power Take-Off.
© Ocean Harvesting Technologies

Instant Force & Model Predictive Control for Ocean Energy Power take-off with High Fidelity (INFINITY)

In this project, hardware and control algorithms for a PTO are designed and optimized as a single system. The ambition is to develop a next-generation PTO with a model-predictive control algorithm, where an accurate mathematical model of the entire system is integrated into the control system. By considering both energy efficiency and effects on wear and service life, it is possible to optimize the system's Levelized Cost of Energy (LCOE), rather than just maximizing the amount of energy produced. As a test case, the project uses the point absorber InfinityWEC, developed by Ocean Harvesting Technologies AB. A 1:3 scale InfinityWEC power take-off will be built and thereafter tested in a Hardware-In-the-Loop (HIL) test-rig with the new control algorithm running on a real-time control system. Project partners are RISE Research Institute of Sweden, Ocean Harvesting Technologies, NILU klimat och miljöinstitutet AB, VGA, Julia F Chozas, Maynooth University, Politecnico di Torino and Technical University of Denmark (DTU).

Marine current power: Extracting power from slow water currents

Uppsala university is developing and testing a marine current converter, designed for low water speeds. It uses a vertical axis direct driven turbine connected to a permanent magnet generator. In 2024, a PhD student defended a thesis on the topic. Additionally, two journal papers and one conference paper were presented in South Korea.

Next Generation Marine Materials for Resilient Offshore Renewable Energy Devices (MORE)

The overarching goal of MORE is to introduce a new testing methodology to better evaluate and select materials used in offshore renewable energy (ORE) systems, ensuring greater resilience and lower costs. This involves both laboratory-scale testing and real-world validation for critical components of wave energy converters (WECs). In 2024, critical subcomponents for wave energy devices were selected, and detailed working conditions and load cases were documented to support material testing. Knowledge from the offshore oil and gas sector was used to develop test protocols for ORE systems. Additionally, two advanced small-scale multi-degradation test rigs (tribometers) were developed to evaluate material performance under various conditions. Project partners are RISE Research Institutes of Sweden, SINTEF, NTNU, GCE Node, WavePiston, Servi AS, CorPower Ocean, VGA SRL and Seal Engineering.

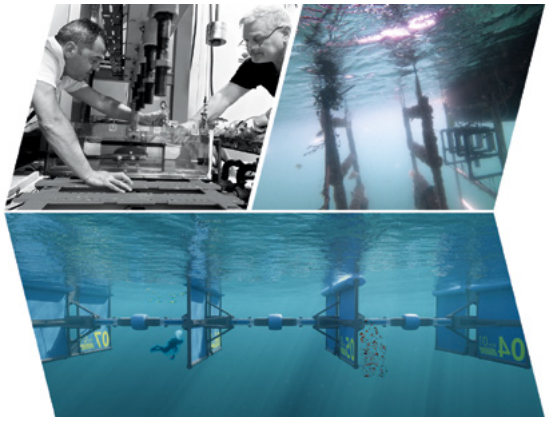


Figure 3: MORE project. © RISE

Product verification of WaveMove in scale 1:25

OE systems develops a wave energy converter called WaveMove, which is a terminator wave energy solution that works in water depths from 30m - 200m. The purpose of the project is to test WaveMove 1MW on a scale of 1:25 in a wave tank and in the sea to assess its stability, efficiency, and durability under realistic operating conditions. In 2024, results from wave tank testing were analysed and the results showed that the marine models were accurate to the wave tank testing performance and WaveMoves's power matrix could be confirmed. Additionally, the same scale model (1:25 of a 1MW system) was tested in the ocean and got the same results showing that the system also works in real conditions.

SEASNAKE+ Industrial upscale of surface protection system & fibre optic-based condition monitoring for the SEASNAKE MVC (Medium Voltage Cables)

The project aims to improve the cost-efficiency, reliability, and sustainability of medium-voltage dynamic cables used in floating offshore wind farms, ocean energy devices, and aquaculture. This will be achieved by developing and scaling up an antifouling surface protection system for dynamic cables, implementing an advanced fibre-optic shape sensing system for real-time condition monitoring and predictive maintenance and conducting nearshore and offshore demonstration tests in Italy and Sweden to validate the technology in real marine conditions. In 2024 a prototype fibre-optic shape sensing system has been developed. This system enables continuous monitoring of cable deformation and fatigue, feeding data into a digital twin model to predict failure modes and extend the cables' service life. Additionally, the scaling-up of the antifouling coating process is underway. Project partners are RISE Research Institutes of Sweden, I-Tech, Chalmers University of Technology, NKT Cables, D-ICE, Université Gustave Eiffel, Wave Venture, Geico, Par-ky Greensailor, Aeffe srl Keelcrab, CNR-IAS and Universidad de Alcala.

Smart mooring for safe and efficient ocean energy production (SmartMooring)

The project develops sensor-equipped mooring components for marine energy systems. The in-situ sensors will enable data-driven design optimizations, predictive maintenance, and in-operation optimization of energy yield. The technologies developed are applicable to offshore wind, solar, wave and tidal energy. Project partners are Calsens, CorPower Ocean, Minesto, RISE Research Institutes of Sweden, University Gustave Eiffel, and the Technical University of Valencia.

Sustainable Concrete Material Leading to Improved Substructures for Offshore Renewable Energy Technologies (WECHULL+)

The main objective of the WECHULL+ project is to develop and test new floating structures of high-performance concrete in the offshore renewable energy sector, reducing cost and CO2 footprint, as well as improving circularity and reliability. One user case is in wave energy and one in floating solar. WECHULL+ is based on the results and proof-of-concept from a previous project (WECHULL), where a new, highly flowable high-performance concrete formulation was developed for Ocean Harvesting's patented thin-walled honeycomb buoy. Project partners are RISE Research Institute of Sweden, Delft University of Technology, Carnegie Clean Energy, Ocean Harvesting Technologies, Gdansk University of Technology, SolarDuck, PLOCAN and Pekabex.

Figure 4: Visualization of an InfinityWEC buoy. © Ocean Harvesting Technologies

Wave energy AI-based Control Enhancement (WACE)

The main objective of the project is to achieve performance improvement of a wave energy converter (WEC) by utilising artificial intelligence to enhance an existing control strategy. The performance of the developed algorithm is proven via hardware-in-the-loop (HIL) testing providing a realistic real-time environment while using the existing operating strategy as a baseline. During 2024, a kick-off has been held. Project partners are CorPower Ocean and NTNU.

TECHNOLOGY DEMONSTRATION

Existing open sea test sites

Lysekil wave energy research test site – Lysekil, Sweden

The Lysekil wave energy research test site in Sweden is operational. It has 11 wave energy converters of a total of 260 kW installed. The working permission for the Lysekil research test site has been extended with 10 more years from 2024.

Testbed for Marine Materials - Fiskebäckskil, Sweden

The testbed for materials in marine environment was inaugurated in 2021 and offers development, testing and verification of antifouling systems, corrosion protection and environmental assessment. The testbed for materials in marine environment is located at the Kristineberg Marine Research and Innovation Center in Fiskebäckskil (Skaftö), Sweden. The facility gathers expertise, laboratory resources and field infrastructure.

Figure 5: Kristineberg Marine Research and Innovation Center in Fiskebäckskil, Sweden. © RISE

Projects in the water

Minesto - Vestmannasund, Faroe Islands

Early February 2024 Minesto reaches an historic milestone: the utility-scale tidal powerplant Dragon 12 – rated at 1.2 MW – is commissioned and delivers its first electricity to the national grid in the Faroe Islands. This first campaign resulted in a four-month period of testing and electricity production, generating valuable results and data to underline commercial readiness of Dragon Class technology at commercial scale.

Notably, real test and operational data from the commercial scale D12 is now available to customers and is used to show autonomous functionality, product performance, and service interval analysis.

In addition, for the first time an array of tidal kites was in operation – the 1.2 MW D12 and one 100 kW D4, adding valuable production data for array build-out.

CorPower - Aguçadoura, Portugal

In August 2023, CorPower Ocean successfully installed its first commercial scale WEC, C4, in Aguçadoura, Portugal. The CorPower C4 device was launched from the port of Viana do Castelo, before being towed to the project site located 4 km offshore. Following installation the commissioning period was started. Survivability was demonstrated in Autumn 2023 when the device endured storms Babet, Aline, Ciarán and Domingos. The first offshore access to the device was verified for O&M purposes, and the first retrieval and tow back has taken place.

During 2024 an onshore campaign of upgrades and maintenance of the C4 device has been carried out and re-deployment is scheduled in early 2025 to complete the power performance assessment and obtain prototype certification from DNV.

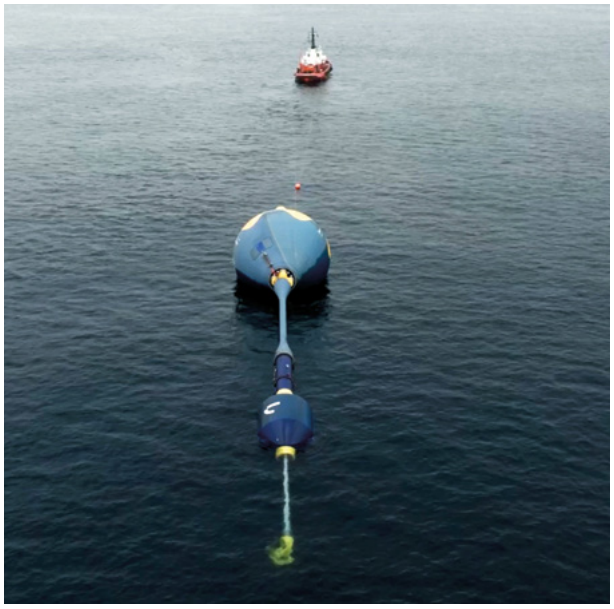


Figure 6 and 7: C4 WEC in Aguçadoura, Portugal. © Corpower Ocean

NoviOcean – Stockholm archipelago, Sweden

In the summer of 2023, NoviOcean deployed its second iteration of its WEC prototype at Svanholmen in the Stockholm archipelago. The primary objective of this deployment was to conduct extensive long-term trial while also utilizing the test site as a platform for showcasing the technology to invited guests. The test was running for one full year. The prototype survived the cold winter, enduring challenges such as ice formation and stormy weather. The freezing of the float within moving ice sheets caused two of the four mooring anchors to shift some meters.

Figure 8: NoviOcean's WEC prototype deployed in the Stockholm archipelago. © NoviOcean

Projects planned for deployment

Minesto - Hestfjord, Faroe Islands

Minesto is preparing for the next step, which is a 10 MW array of utility scale kites in Hestfjord, a nearby strait to Vestmanna in the Faroe Islands. Preparations include all aspects of such an undertaking, ranging from environmental monitoring activities to detailing out the systems which will be installed. This 10 MW array is the first step in Minesto's 200 MW buildout plan for the Faroe Islands.

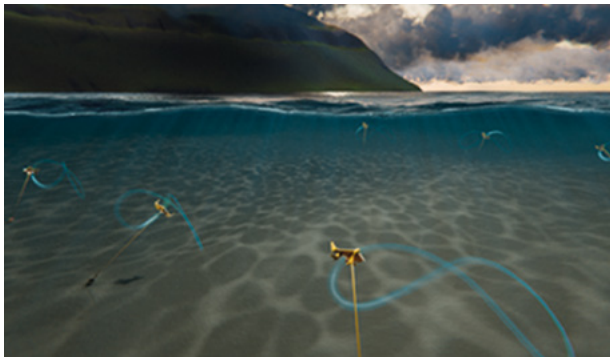


Figure 9: Dragon 12, 10 MW array, rendering. © Minesto

CorPower - Aguçadoura, Portugal

In parallel to the development and demonstration of the C4 WEC, work is ongoing on the C5 array design, manufacturing and deployment. This will see 3 production-ready full-scale WECs designed, built, and deployed at the Aguçadoura test site, forming the first grid-connected production-scale wave array. Deployment for the C5 array is scheduled to begin in 2026.

NoviOcean

In 2021, NoviOcean received 2.1 MEUR funding from the CINEA-LIFE Programme of the European Union. The LIFE NOVIOCEAN project focuses on detailed design, manufacturing, deployment, and offshore testing of their first pre-commercial pilot unit. NoviOcean is currently developing a full-scale 1 MW pilot, with deployment targeted for 2026. Location has not yet been determined.

Ocean Harvesting Technologies (OHT) – off west coast of Sweden

Sea trials of InfinityWEC at scale 1:3 is planned to start in 2027 and deployment to take place off the Swedish west coast.

OE Systems – Lysekil, Sweden

The manufacturing of a 10m wide surface collector has been finished during 2024. This first large-scale offshore pilot will be installed and tested during Q1/Q2 in 2025 outside Lysekil in Sweden. All necessary approvals for the installation have been obtained from the authorities.

SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

Corpower and SwitcH2 in new partnership

CorPower has unveiled a new partnership with SwitcH2 to deliver an industrial scale floating green ammonia production facility partially powered by wave energy.

ELBE Alliance

Since 2018, the Swedish companies active in renewable offshore energy participate via RISE Research Institutes in European cluster alliance ELBE. Current project ELBE EUROCLUSTER runs in the period 2022-2025 and supports more than 900 companies from Spain, Sweden, Norway, Denmark, France, Belgium, Poland, and UK to collaborate and strengthen European supply chain in renewable offshore energy. Support is provided via grants to SMEs to develop and test their technology, make innovations in their product and market strategy, and reach new markets outside Europe. In 2024, Swedish companies have been successful in receiving support to test their technologies and in obtaining grants to reach new markets and establish collaboration with business partners in USA, UK, Australia, Brazil, and Japan.

Offshore Accelerator for System Integration and Storage (OASIS)

OASIS, which is Interreg/EU financed, is a holistic programme to accelerate the development and uptake of system integration and storage SMEs in the offshore renewable energy (ORE) sector. By developing tools and consolidating expertise across borders, the project will provide training, market research and a strong network, all specifically targeted at the ORE sector. The project had a kick-off in September 2024. Consortium partners are Dutch Marine Energy Centre (DMEC), Uppsala University (Sweden), German Aerospace Center (DLR), Blue Cluster (Belgium), Flux 50 (Belgium), BOVA ENVIRO+ (Belgium), ÅKP (Norway), Energy Cluster Denmark, BUILDERS School of Civil Engineering (France) and OPEN-C Foundation (France).

RELEVANT NATIONAL EVENTS

Webinar on Offshore Tribology for Ocean Renewable Energy Production

This webinar on October 16, 2024 was organized by the MORE-Project and it featured presentations from experts at GCE NODE, RISE, CorPower Ocean, and WavePiston. Topics covered included the challenges of offshore tribology and corrosion, the importance of realistic qualification testing, and innovative solutions for wave energy converters. Participants came from both academia and industry.

In 2025, the tenth **International Conference on Ships and Offshore Structures (ICSOS)** will be held at the Campus Johanneberg at Chalmers University of Technology, Sweden (https://www.icsos.info/).

UNITED KINGDOM

REPORT PREPARED BY:
Kristofer Grattan, Donald R. Noble and Henry Jeffrey,
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OVERVIEW

As we near the midpoint of this critical decade for climate action, the UK can look back and recognise a sizeable shift in the national effort to achieve a Net Zero energy system, and specifically, observe the increase in momentum now gathering behind the ocean energy sector. With the UK's new Labour Government committed to delivering their Clean Power 2030 Plan, which promises that the UK will generate at least 95% of its electricity from clean sources by 2030, there is now a serious ambition for the UK to rapidly transition towards a low carbon energy system. Therefore, with this opportunity in mind, it is more important now than ever to fully understand the role that a commercial UK ocean energy sector can play in helping to achieve this future decarbonised energy system. With an increasing number of ocean energy projects being deployed in British seas, the results of decades worth of innovation funding and sector development are beginning to be realised. Alongside this, there is a growing understanding of the additional socio-economic benefits that the sector can bring to the UK, including high-value jobs in coastal communities; regional and national boosts to GVA; and a stake in strengthening our own energy security. Reflecting this, the role of the funding and innovation programmes that will be required to underpin the sector's continued development are enjoying increasing prominence within the national policymaking landscape.

Over the course of 2024, the UK has provided continued support to the ocean energy sector by setting a third consecutive ringfence for tidal stream within its flagship Contracts for Difference (CfD) market support mechanism. To date, contracts have been awarded for over 120 MW of tidal stream projects, the largest such allocation in the world. Coupled with the sustained support offered to wave energy technology developers via Wave Energy Scotland's world-leading innovation programme, the ocean energy sector has the potential to play a substantial role in the national energy mix over the coming decades.

However, despite the increase in momentum that is helping to drive the advancement of the UK's ocean energy sector, there remains a need for increased awareness of the potential challenges. A growing ocean energy sector will require a step-change in the capabilities and capacities of our domestic supply chains, the development of which is vital to ensure that the GVA and jobs associated with the deployment of these devices is retained within the UK. Additionally, there is still a requirement for the sector to demonstrate sustained innovation as it chases the cost-reductions required for wave and tidal stream devices to compete with more established renewable energy technologies. Finally, the sector must continue to emphasise the wider socioeconomic benefits that a commercial ocean energy sector can bring to the UK economy, to help justify its place in the future energy mix.

These challenges are far from insurmountable and should be met with the use of coordinated policy programmes, clear government ambitions and sustained innovation funding. With the largest pipeline of tidal stream projects in the world now on the immediate horizon, coupled with the progress made by the wave energy sector, the UK is well-positioned to establish itself as the nation leading the advancement of the ocean energy sector.

An expanded version of this chapter, with an increased number of entries, has been used in the publication of the 2024 UK Ocean Energy Annual Review, and is available here.

Throughout 2024, the UK wave energy sector continued to lead on the international stage as multiple technology developers and research institutions strove to develop the next generation of wave energy converters.

Tidal Stream Highlights

For the UK tidal stream sector, 2024 has proven to be another successful year, with a number of developers announcing exciting milestones:

- The UK tidal stream sector continued to enjoy success through the UK Government's Contracts for Difference (CfD) scheme, which saw its ringfence fund for tidal stream increased from £10m to £15m, with a further six contracts granted across the UK at a strike price of £2012172/MWh.
- Orbital Marine Power has announced the selection of the Global Energy Group as their preferred supplier to lead the manufacture and assembly of turbines for their awarded AR4 and AR5 CfD projects.
- Inyanga Marine Energy Group opened a new office in Wales to support the development of their innovative HydroWing tidal stream energy project. In addition to this, Inyanga and Verdant Morlais Ltd have signed a Memorandum of Understanding to deliver a 4.9 MW tidal stream energy project at Morlais in Wales.
- The Marine Energy Council were instrumental in the reassembly of the Marine Energy All-Party Parliamentary Group (APPG). This Group will offer a potential route through which the sector can present its ask for an expanded ringfence for the tidal stream sector and the creation of a ringfence for the wave energy sector in the next CfD auction.
- A recently published report by Scottish Enterprise has estimated that a commercial domestic tidal stream sector has the potential to generate over £4.5bn in economic benefit to the Scottish economy by 2050.

Wave Energy Highlights

Throughout 2024, the UK wave energy sector continued to lead on the international stage as multiple technology developers and research institutions strove to develop the next generation of wave energy converters:

- In the second round of their Direct Generation Concept Design Competition, Wave Energy Scotland (WES) has awarded a total of £400,000 to be shared between two projects, led by 4c Engineering and TTI Marine Renewables.
- Phase 3 of WES' collaborative EuropeWave program is supporting three projects to deploy large-scale wave energy converters in 2025-26: CETO Wave Energy Ireland and IDOM will deploy devices in the Basque Country's BiMEP test site and Mocean Energy will use Scotland's European Marine Energy Centre site.
- Mocean Energy recently launched a crowdfunding campaign on Crowdcube, Europe's largest private market investment platform. The campaign aims to finance the next phase of the company's ambitious growth plans as it looks to mature its pioneering technology.
- A recently published report commissioned by Wave Energy Scotland has estimated that a commercial domestic wave energy sector has the potential to generate over £4.2bn in economic benefit to the Scottish economy by 2050.

SUPPORTING POLICIES FOR OCEAN ENERGY

National energy strategy

The design and implementation of energy policy within the UK is a complex mix of reserved, devolved and shared competencies, where responsibility is broadly shared between the UK Government and the devolved governments in Scotland, Wales and Northern Ireland, each of which has differing degrees of autonomy in policy decision-making. Although the successful delivery of a future clean energy system is a shared ambition by both national and devolved governments, there is some divergence in the different Net Zero timelines which each nation has adopted. For example, the Scottish Government are aiming to deliver Net Zero by 2045, as opposed to 2050 in the rest of the United Kingdom.

The research, development and implementation of energy policy at a UK Government level is primarily the responsibility of the Department for Energy Security and Net Zero (DESNZ). This new government department, formed

in 2023, has taken on the energy policy responsibilities of the former Department for Business, Energy and Industrial Strategy (BEIS).

Within the UK, energy policy is largely transferred (devolved) to the Northern Ireland Executive. It is broadly reserved to UK Government in respect of Scotland and Wales, limiting the ability of Scottish and Welsh Governments to make decisions and policy independently of UK Government. However, the ability to enact policy which is designed to tackle climate change, through policy levers such as the promotion of renewable energy; energy efficiency; electricity generation; and transmission development is devolved to some extent. This provides each of the devolved governments with at least some powers to determine their overall domestic energy mixes.

United Kingdom

2024 marked the beginning of a new chapter in the UK's ongoing journey towards its legally mandated 2050 Net Zero targets. On 4th July, the UK electorate voted the Labour party into power with a landslide majority and with it arrived a new set of ambitions for the UK's Net Zero energy transition. The new UK Government ran on an ambitious manifesto, promising big changes to the UK's climate and energy policies, many of which will have a knock-on effect for the ocean energy sector. A number of these are listed below:

- The most ground-breaking of Labour's energy commitments in their manifesto was the promise to establish Great British Energy (GBE), a publicly owned clean energy company. As a fundamental part of the government's plan to make the UK a clean energy superpower by 2030, GBE will drive clean energy deployment by investing in and owning energy projects, leading projects through their development stages, supporting local and community energy generation, and facilitating the growth of supply chains across the UK.
- The incoming Labour government also arranged to acquire the Energy System Operator, which is now a new publicly owned organisation, the National Energy System Operator (NESO). The NESO will support the UK's energy security, help to keep bills down in the long term and accelerate the government's clean power mission.
- In the recently published Clean Power 2030 Action Plan, the Labour government committed to signalling key projects for clean power and speeding up planning and consenting processes across Britain. This is of significant importance for the ocean energy sector who are reliant on national grid upgrades and the development of ports and harbours to support the sector.

These commitments come at a moment when the UK, which itself is experiencing the challenges and dangers of a rapidly warming climate, has an increasingly important role as a world leader in the effort to mitigate the worst extremes of the climate emergency. While the Net Zero energy transition will provide the obvious benefit of lowering carbon emissions, it also proves the opportunity for jobs, socio-economic growth and the development of new sustainable industries, all housed within the UK. However, these benefits are also being chased by competing nations across the globe and the UK currently faces growing competition from the USA, China and the EU, all of whom have committed to large-scale, well-resourced policy programmes to promote the accelerated uptake of renewables into their national energy mixes. With just under 5 years remaining for the UK to meets the ambitions set out in the recent Clean power 2030 Action Plan, the argument for faster progress and continued leadership with regards to sustainable policies is clear. The role of wind and solar as the foundation of the UK's established Net Zero energy system is now well-established, with long-term deployment targets set and policy support to deliver in place. However, ensuring that the UK can achieve a sustainable, diverse and resilient energy mix, that harnesses all our national resources, will be necessary to ensure that a Net Zero energy system is delivered in a cost-effective manner. To this end, there is now a growing understanding of the role that the UK's abundant wave and tidal stream resources could play in helping to underpin and strengthen the national energy mix. This growing consensus is also reflected in the prevalence of ocean energy aims and objectives within high-level policy guidance reports published by the UK government over the previous year:

- In December 2024, the UK Government announced its plans for a new era of clean electricity, delivering on its manifesto commitment for clean power by 2030 with the Clean Power 2030 Action Plan. This Plan, designed to make Britain a clean energy superpower, proposes the most ambitious reforms to the energy system in generations. While the tidal stream sector is identified as having a limited role to play in the 2030 energy mix, achieving volume deployment of these technologies is identified as having potential long-term value to the UK's decarbonisation targets.

Aerial shot of O2 turbine off the Orkney coast. © Orbital Marine Power

• In October 2024, the UK Government launched its latest industrial strategy, Invest 2035, outlining that growth of critical sectors is the number one mission of the government over the next ten years. Within this strategy, advanced manufacturing and clean energy industries are identified as two of the 8 growth-driving sectors. This is welcome news for the ocean energy sector and the domestic supply chains that are looking to scale-up in line with the expected growth of the sector.

Scotland

Scotland continues to hold the most ambitious climate targets within the UK, with the Scottish Government committed to achieving net zero emissions of all greenhouse gases by 2045. In December 2020, the Scottish Government updated its Climate Change Plan, reflecting the increased ambition of the targets set by the Climate Change (Scotland) Act 2019. In April 2024, following feedback from the Climate Change Committee that it no longer believed Scotland's flagship target of reducing greenhouse gas emissions by 75% by 2030 was achievable, the Scottish Government announced the replacement of its annual targets with a system of multi-year carbon budgets. This change in policy underlines the challenges faced by the Scottish Government and emphasises the need for a proactive approach to energy policy and the rapid rollout of a diverse renewable energy system. The 2045 net zero target for Scotland remains in place.

Scotland's geographical location on the western edge of Europe and its unique geography of seaways and firths, exposes it to a combination of intense winds, Atlantic waves and turbulent tidal currents. As such, the country is well situated to harness its ocean energy potential, should the required infrastructure and financial support be provided. In early 2023, the Scottish Government published a draft Scottish Energy and Just Transition Plan which presents a vision for Scotland's decarbonised energy system and the collective actions needed to deliver this and contains a headline ambition for more than 20GW of additional low-cost renewable energy generation capacity to be installed by 2030. This draft report also states that new developments of wave and tidal stream devices have

the potential to quadruple the existing installed capacity to around 40 MW in Scottish waters by 2027, which could make a valuable contribution in addressing Scotland's total energy demand. This initial draft has also been accompanied by a comprehensive public consultation process, inviting communities, workers, citizens and businesses to provide feedback and shape Scotland's energy transition. This has resulted in just over 250 responses on two questions seeking views on the need for setting a marine energy ambition and identifying priority actions to build on the achievements of the sector in Scotland to date. However, as of the end of 2024, this draft Plan is still yet to be published. Scotland has also benefited from the formation of the Offshore Wind Directorate, a Scottish Government department responsible for the development of policy work related to offshore renewables, marine energy and sectoral marine planning. The Offshore Wind Directorate supports the growth of the offshore wind and marine energy sectors and the development of Scotland's supply chain by growing its manufacturing base and attracting inward investment, demonstrating the potential role for marine energy in Scotland's low carbon energy system and managing the environmental impacts of, and risks to, Scotland's journey to net zero through offshore renewables.

Over recent years, Scotland's ocean energy sector continues to make substantial progress as wave and tidal stream developers progress on the journey towards commercial-scale deployment. The 2024 CfD AR6 was a great success for the Scottish tidal stream sector, with five new contracts shared amongst three developers, who are now set to deploy in Scottish waters, securing around 18 MW of the total 28 MW of tidal stream capacity across the UK. Combined with the successful auctions from AR4 and AR5, there is now nearly 84 MW of tidal stream energy set for deployment in Scotland by the end of 2029. This represents a significant proportion of the global allocated capacity for tidal stream and highlights Scotland's position as a pioneer in the development and deployment of tidal stream energy, and the role that the technology could play in Scotland's future net zero energy system. The Scottish Government, together with the industry itself, continues to engage with the UK Government to ensure that maximum support, sufficient budget and more long-term certainty is provided to Scottish marine energy projects in CfD AR7, due to take place in 2025, and in future rounds. Finally, not all of Scotland's tidal stream success was linked to the CfD scheme, with Scottish developers Nova Innovation and Orbital Marine Power each securing €20m worth of Horizon Europe funding for tidal stream arrays off the coast of Orkney, rated at 4 MW and 9.6 MW respectively.

Through Wave Energy Scotland (WES), which receives majority of its funding through the Scottish Government, the Scottish wave energy sector has continued to benefit from sustained support and guidance to advance research, development and deployment of wave energy in Scotland. After the successful demonstrations of the AWS Waveswing and Mocean Energy Blue-X devices in Scottish waters, WES has continued to support its emerging technologies through innovation projects and the creation of commercialisation pathways. Scotland continues to play a leading role in international collaboration efforts by delivering the EuropeWave device development programme in partnership with the European Commission, Ente Vasco de la Energía (EVE) and Ocean Energy Europe.

Wales

2024 has proven to be an important year for the Welsh ocean energy sector, where, for the first time, the future development and deployment of both wave and tidal stream energy devices can be seen as potentially playing an important role in meeting long-term energy commitments. Following on from its 2019 climate emergency declaration and subsequent commitment to reach Net Zero by 2050, the Welsh Government has also committed to ensuring that 100% of the country's annual electricity consumption is powered by renewable sources. Coupling this ambitious commitment with the Welsh Governments stated desire to support innovation in new renewable energy technologies places ocean energy at the forefront of the energy transition in Wales.

Welsh waters, with some of the highest tidal ranges in the world and a highly energetic Atlantic-facing coastline, are a prime location for the deployment of wave and tidal stream devices, and as such are drawing interest from a range of developers and test-site hosts. This has resulted in multiple milestones, from the ongoing success of Wales' first tidal stream energy test site, Morlais, to the award of a 10 MW contract to the Ynni'r Lleuad 2 scheme from HydroWing via AR6 in the CfD scheme. Combined with the successful auctions from AR4 and AR5, there is now 38 MW of tidal stream energy set for deployment in Wales by the end of 2029. In addition, the Welsh Government published an independent review of the Marine Licencing Process, providing an important opportunity to improve and streamline the consenting process and

support the accelerated development of ocean energy in Wales. The Welsh government has consistently stated its commitment to providing strong policy support for the ocean energy sector, with an aim of capturing at least 10% of the potential tidal stream and wave energy off the Welsh coastline by 2025. This has led to an increasing number of technology developers choosing to site their testing and deployment in Welsh waters, such as Tidal energy developer HydroWing, who moved headquarters to Anglesey in early 2024.

The responsibility for coordinating the research and development of the ocean sector in Wales lies largely with Marine Energy Wales (MEW), the industry-led stakeholder group representing the wave, tidal and floating offshore wind industries. The MEW 2024 State of the Sector report highlights how Wales' marine renewable energy sector delivered an impressive £29.9 million to the Welsh economy during the 2023/24 financial year, bringing total cumulative spending and investment from the sector in Wales to roughly £292.9 million. Of this total, tidal stream has been by far the biggest contributor to date, injecting £116.1 million into the Welsh economy. Much of this has been fuelled by the infrastructure buildout at Morlais and the activity of tidal kite developer Minesto. Supply chain spend has accounted for £63.6 million to date. Projects developed thus far have utilised an impressive amount of local content, some as high as 80%, underscoring the importance of developing a robust local supply chain to maximise economic benefits in Wales. The MEW report also estimates that the ocean energy sector provides employment to approximately 430 full time employees across areas such as technology development, supply chain and academia.

Management of UK Seabed

The seabed that surrounds the UK lies largely under the ownership of the British Crown. Where this applies, this seabed portfolio is maintained and managed for the benefit of the nation by The Crown Estate and, in Scotland, by Crown Estate Scotland.

The Crown Estate

The Crown Estate has a diverse £16bn portfolio that includes urban centres and development opportunities; one of the largest rural holdings in the country; Regent Street and St James's in London's West End; and Windsor Great Park. The Crown Estate also manage the seabed and much of the coastline around England, Wales and Northern Ireland, playing a major role in the UK's world leading offshore wind sector.

The Crown Estate are a unique business established by an Act of Parliament, tasked with growing the value of the portfolio for the nation and returning all of its net profit to HM Treasury for the benefit of public spending. This has totalled £4bn over the last ten years. Through its activities and investments, The Crown Estate creates environmental, social and financial value both for now and into the long term.

https://www.thecrownestate.co.uk/

Crown Estate Scotland

Within Scotland, Crown Estate Scotland manages property – including buildings, land, coastline and seabed – on behalf of the Scottish people. The Scottish Crown Estate Act 2019 provides a national framework covering a range of matters relating to management of the Scottish Crown Estate. This requires Crown Estate Scotland to manage the assets in a way that is likely to contribute to the promotion of economic development, regeneration, social and environmental wellbeing. Crown Estate Scotland is a public corporation that holds the rights to lease the seabed out to 12 nm for cables, pipelines and aquaculture and the rights to offshore renewable energy and gas storage out to 200 nm. Net revenue generated by Crown Estate Scotland is returned to the Scottish Government and capital is reinvested in the Scottish Crown Estate, with a £113.2 million returned in the 2023/24 financial year to aid in public spending. In the wave and tidal energy space, Crown Estate Scotland continue to offer ad-hoc leasing whereby applicants can apply for seabed rights to develop projects up to 30 MW in capacity.

https://www.crownestatescotland.com/

Market incentives

Contracts For Difference

The Contracts for Difference (CfD) scheme is the UK government's flagship program for supporting low-carbon electricity generation. Based on top-up payments between a wholesale market reference price and a strike price, CfDs offer long-term price stabilisation and are awarded via competitive auctions. The CfD scheme incentivises investment in renewable energy by providing developers of renewable energy projects, normally projects with high upfront costs and long lifetimes, protection from volatile wholesale prices. To date, there have

been six allocation rounds (AR) which have seen a range of renewable energy technologies bid for contracts, with competitive auctions being the current method by which these contracts are awarded. In AR4, AR5, and AR6, tidal stream has benefitted from a dedicated minimum budget in the auction, where support is ringfenced for tidal stream in the CfD auction round before the competition opens up to other renewable technologies. For AR6 this resulted in four developers across five sites securing six contracts to deliver 28 MW of tidal stream capacity at a rate of £172/MWh:

- Nova Innovation were successful in securing three contracts amounting to 6 MW of tidal stream capacity, 4 MW under the SEASTAR project and 2 MW under the OCEANSTAR project. Both of these projects will be deployed at EMECs Fall of Warness test site.
- SAE Renewables have successfully secured an additional 9 MW contract to be deployed at their MeyGen project, bringing the total under development to 59 MW.
- Magallanes Renovables were successful in winning a 3 MW extension to its existing scheme at EMEC.
- Inyanga Marine Energy Group have been awarded a further 10 MW contract to support their project at the Morlais Demonstration Zone in Anglesey, Wales.

Building on the 94 MW of tidal stream capacity that was awarded in AR4 and AR5, there is now a total pipeline for 122 MW of tidal stream projects in the UK, all of which are expected to be commissioned by 2029. While wave energy projects have not yet been successful at CfD auctions, developers are increasingly confident that the technology is approaching the levels of technological maturity required to bid for multi- MW contracts.

For the first time, the CfD will also run a Clean Industry Bonus (CIB), a competitive allocation process extra revenue support which runs before the main CfD auction. The CIB is designed to encourage applicants to invest in more sustainable supply chains across their project's development and deployment. The CIB application window is currently scheduled to open in February 2025, however at present the allocation is only available to offshore wind developers.

Public funding programmes

UK Research and Innovation

Launched in April 2018, UK Research and Innovation (UKRI) is a non-departmental public body sponsored by the Department for Science, Innovation and Technology. UKRI is the national funding agency investing in science and research in the UK. Operating across the whole of the UK with a combined budget of more than £6 billion, UKRI brings together the seven Research Councils, Innovate UK and Research England.

https://www.ukri.org/

Engineering And Physical Sciences Research Council

The Engineering and Physical Sciences Research Council (EPSRC) is the main funding body for engineering and physical sciences research in the UK. The EPSRC aims to create knowledge and fund innovation with the capability to benefit both society and the economy by supporting research through the provision of fellowships, studentships, research and training grants, competitive funding, and prizes. The EPSRC funds and co-invests with industry, at both national and international levels, helping to deliver advanced research facilities and resources for engineering and physical sciences, including wave test facilities and tidal tank testing. EPSRC also provides technology push policy support mechanisms, such as the Industrial CDT in Offshore Renewable Energy (IDCORE), a programme designed to provide sector-specific training to bring forward the next cohort of highly skilled engineers, which was renewed and will now run until 2032. In addition, IDCORE also provide a number of fellowships, managed activity, standard grants and programme grants and is also responsible for funding the ORE Supergen Impact Hub.

https://www.ukri.org/councils/epsrc/

Innovate UK

Part of UKRI, Innovate UK inspires, involves, and invests in businesses developing life-changing innovations to create a better future. Providing sectors with expertise, fa-

Testing at the COAST Laboratory at the University of Plymouth.
© Supergen ORE Hub

cilities and funding, Innovate UK helps test, demonstrate and evolve ideas, driving UK productivity and economic growth. Innovate UK's network and communities of innovators realise the potential of ideas and accelerate business growth.

www.ukri.org/councils/innovate-uk/

Wave Energy Scotland

Since 2014, Wave Energy Scotland (WES) has been using Scottish Government funding, alongside a competitive stage gate process, to tackle the key technical challenges of wave energy generation, pushing innovative solutions from concept towards commercialisation. Separate funding streams have supported the development of novel wave energy devices, power take-off systems, control systems, quick connection systems and materials. Alongside this, WES is supporting further development of wave devices through the EuropeWave programme, in partnership with the European Commission, Ente Vasco de la Energía (EVE) and Ocean Energy Europe.

During 2024, WES has focused on continued innovation support and promoting commercialisation pathways for the emerging technologies, including opportunities for co-location with the growing floating wind sector and grouping wave devices into multi-megawatt clusters. Building on a 2023 study which showed significant cost of energy reduction for wind and wave projects, WES is working to demonstrate the benefits and feasibility of multi-use marine spaces, aiming to maximise the energy generation and economic benefit from available sea areas while helping balance the energy system.

In support of more radical cost-reduction opportunities, WES continued the Direct Generation competition, funding enabling R&D and concept design projects using flexible wave energy devices based on electrostatic power conversion technologies. WES continues to collaborate widely, playing a leading role in the guidance and delivery of the innovation activity required to take wave energy towards commercial readiness and contribution to net zero.

https://www.waveenergyscotland.co.uk/

Testing of multi wave absorber platform at FloWave.
© Wave Energy Scotland

Scottish Enterprise

Scottish Enterprise (SE) is Scotland's national economic development agency and a non-departmental public body of the Scottish Government. It supports businesses to transform the Scottish economy, by focusing on new market opportunities through targeted investment, innovation and internationalisation. SE has a focus on economic transformation with a goal to create a more productive, resilient and competitive economy for Scotland. This will be accomplished through three interlinked missions: to create an internationally competitive renewable energy industry in Scotland; to scale the impact of Scotland's innovation strengths in future high growth industries; and to drive capital investment to deliver a step change in Scotland's productivity.

Marine energy is an important part of the effort to create an internationally competitive renewable energy industry, and as such, SE commissioned a report on the economic benefit of tidal stream energy to Scotland by 2050. The report looks at the potential GVA and jobs that 4.3 GW of tidal stream energy deployed in Scotland could bring to the Scottish economy, as well as the economic benefits from UK and international deployments. The report is due to be published in early 2025.

SE, as part of a group of Scottish public sector organisations including Highlands and Islands Enterprise, Crown Estate Scotland and Wave Energy Scotland, sponsored the Ocean Energy Europe conference for its return to Scotland in 2024. The event, held in Aviemore, showcased the Scottish opportunities in marine renewables and European developments in this sector.

In 2024, Scottish Enterprise, on behalf of all the Scottish Economic Development agencies led on delivery of the European Clean Energy Transition (CET) Partnership a Horizon Europe partnership that provides funding for trans-national collaborative R,D&I projects. The Scottish budget for the Joint Call 2024, which closed for pre-proposals in November 2024, is €5 million. The call includes opportunities for ocean energy under the call module "advanced renewable energy technologies for power production". Results of the call will be published in July 2025.

https://www.scottish-enterprise.com/

R&D INSTITUTIONS AND TECHNOLOGY DEMONSTRATION

Key R&D institutions

Supergen Offshore Renewable Energy (ORE) Hub

The Supergen ORE Hub was established in July 2018 with £5 million of funding from EPSRC. It was subsequently awarded a further £4 million in June 2019, and secured a further £7.5 million from EPSRC in July 2023 for the second phase of its program. The Supergen ORE Hub provides research leadership to connect stakeholders, inspire innovation and maximise societal value in offshore renewable energy. The Supergen ORE Hub is led by the University of Plymouth, with co-directors from the Universities of Aberdeen, Edinburgh, Exeter, Hull, Manchester, Oxford, Southampton, Strathclyde, and Warwick.

Some key updates as announced by the organisation in 2023/24 are as follows:

- The Supergen ORE Hub Seventh Annual Assembly took place between 23 – 24 April 2024 at the University of Plymouth, bringing together over 250 delegates from across the marine energy communities.
- The Supergen ORE Hub has awarded £600,000 to 6 research projects at UK institutions through its Flexible Funding scheme in 2024. The Flexible Funds are designed to support research into ORE technologies, including novel mooring and anchoring systems, advanced environmental classification and floating tidal energy and marine energy structure analysis.
- The Supergen ORE Hub has awarded an additional £62,000 to 15 ECR projects at UK institutions through its Early Career Researcher fund in 2024. These recent awards bring the total investment into ECRs between 2018 and 2024 to £228,000 across 55 projects.
- In 2024, the Supergen ORE Hub also published its new report in response to the UK Offshore Wind Industrial Growth Plan titled "ORE Outlook 2040 UK Offshore Renewable Energy in 2040: Building a Sustainable and Competitive ORE Sector on a Pathway to Net Zero by 2050". The report summarises the current and future contribution of ORE to the 2050 Net Zero target, using 2040 as a key milestone on this journey.

Throughout 2023/4 the Supergen ORE Hub has engaged with the UK offshore renewable energy community through 29 events and responded to a UK Government consultation on the introduction of the Contract for Difference (CfD) Sustainable Industry Reward Scheme within the CfD scheme. In addition, Supergen ORE held the first in a series of policy roundtable workshops with key UK and devolved administration Government bodies and funding and statutory stakeholders to develop and inform ORE policy programmes. The Supergen ORE Hub has also directly produced, or contributed via its core research and Flexible Fund awards, to 69 new publications across the marine energy sector.

https://www.supergen-ore.net/

Offshore Renewable Energy Catapult

The Offshore Renewable Energy (ORE) Catapult is the UK's flagship technology and innovation research centre for offshore energy, and a key actor in helping to deliver the UK's Net Zero targets. ORE Catapult is accelerating the creation and growth of UK companies in the ORE sector by providing access to its unique research and development capabilities along with, and providing access to, demonstration and testing facilities.

In 2024 ORE Catapult launched the Marine Energy Partnership (MEP), a collaborative joint industry programme to address sector-wide challenges aimed at reducing costs, accelerate development and create opportunities for local supply chains. Key project themes for the MEP are investment and insurance, technology innovation; cost reduction monitoring; project de-risking; supply chain support to volume manufacturing; and finance. The first of these activities is underway looking at a more appropriate insurance business model based on the Ocean Energy Accelerator.

On behalf of Crown Estate Scotland, ORE Catapult delivered an in-depth report on how to finesse the present leasing arrangement for projects between 3 and 30 MW. This analysis was based on a comprehensive survey of wave and tidal technology developers, project developers and key stakeholders. Supporting EMEC, ORE Catapult also co-authored a report commissioned by Crown Estate Scotland looking at alternative off-takers for tidal stream energy. Finally, ORE Catapult also provided analysis and research support to technology developers preparing to deploy at the Morlais tidal site in Anglesey, Wales.

In 2025, ORE Catapult is planning to expand its support to wave energy with the issue of a wave energy cost reduction roadmap and increase their support to establishing the case for tidal range energy in Wales. ORE Catapult are also supporting The Crown Estate in the development of

tools to evaluate the suitability of sites around the UK for tidal stream energy development.

https://ore.catapult.org.uk/

Key demonstration projects

The UK was well represented throughout 2024 in collaborative European projects, which are primarily funded through Horizon 2020 and Horizon Europe:

EURO-TIDES

EURO-TIDES, funded by the EU and UKRI, aims to deliver a fully operational 9.6 MW tidal energy farm composed of four 2.4 MW Orbital Marine Power turbines. EURO-TIDES objectives are as follows: to de-risk tidal energy technology development; reduce the LCOE of Orbital Marine Power's technology; boost the availability of tidal stream energy production to over 95%; increase the bankability and insurability of the Orbital technology's; improve market confidence and supply chain capacity; and increase knowledge of environmental impacts. The project will deliver a step change in the wider commercialisation programme for the scale deployment of Orbital's leading technology. The project will also work to bring forward commercial scale tidal projects in French waters to augment Orbital's existing commercial project portfolio in the UK and overseas. The project is being coordinated by OEE and the consortium comprises Center for Wind Power Drives, EMEC, Énergie de la lune, ENGIE Laborelec, MaraSoft, Orbital, and University of Edinburgh.

https://www.euro-tides.eu/

EUROPEWAVE

Wave Energy Scotland (WES), Ente Vasco de la Energía (EVE) and Ocean Energy Europe (OEE) are currently delivering the EuropeWave wave device development programme, with co-funding from the European Commission. Phase 3 of EuropeWave (aligned with Stage 3 of the Evaluation and Guidance IEA-OES Framework) is supporting three projects to deploy large-scale wave energy converters in 2025-26: CETO Wave Energy Ireland and IDOM will deploy devices in the Basque Country's BiMEP test site and Mocean Energy will use Scotland's European Marine Energy Centre site. Alignment with the IEA-OES recommendations helps the funders guide rigorous engineering activities and the developers to demonstrate their technical qualities and future commercial prospects.

https://www.europewave.eu/

O2 device at sea. © Orbital Marine Power

FORWARD 2030

In 2024, the FORWARD-2030 project successfully passed its go/no-go milestone. FORWARD-2030 will see the installation of the next iteration of the company's turbine, the O2-X. This will feature a range of cost reduction innovations and will be coupled with a hydrogen production and new battery storage facility at EMEC, with battery installation scheduled for 2025. The project will also develop and assess the large-scale integration of tidal energy to the European energy system, and develop a smart energy management system and an operational forecasting tool. EMEC will host the demonstration, facilitate hydrogen production, deliver a comprehensive environmental monitoring programme, and develop a live environmental monitoring system and test programme. The University of Edinburgh will deliver techno-economic analysis of tidal energy, and the MaREI Centre at University College Cork will be responsible for addressing marine spatial planning issues for wide scale uptake of tidal energy.

https://forward2030.tech/

MAXBLADE

Awarded in 2022 and launched at the University of Edinburgh's FastBlade test facility in early 2023, MAXBLADE is a €10 million project funded by the EU and UKRI. The project aims to investigate the performance and full lifecycle of tidal turbine blades from fabrication to decommissioning, embedding a circular economy element in their design. The project is currently progressing through a range of blade testing activities which will culminate in the full-scale, accelerated life testing of an optimised blade in 2025. MAXBlade is led by TechnipFMC and includes Orbital Marine Power, Marasoft, TECNALIA, The University of Edinburgh, EMEC, Laborelec and European Composites Industry Association. It is supported by Edinburgh University's commercialisation service Edinburgh Innovations.

https://maxblade.tech/

MEGA WAVE PTO

The MEGA WAVE PTO project aims to provide an enabling technology to transform ocean waves into clean, reliable energy. Through this project, an innovative, scalable, reliable, and easily maintainable all-electric modular power take-off system for wave energy devices, ranging from kW to MW capacities, will be developed. Using CGEN's modular design, including components like the magnetic gear and generator, this modularity will create a robust system that is easier to manufacture, install, maintain, and recycle, compared to current alternatives. It also addresses the common challenges within the marine energy sector, making energy production more flexible, reliable and eco-friendly.

https://www.megawave-pto.eu/

SEASTAR

The Sustainable European Advanced Subsea Tidal Array (SEASTAR) project will deliver a 4 MW tidal farm of 16 tidal stream turbines – the largest number of turbines deployed in a single location globally. Building on the success of Nova's previous 6-turbine array in Shetland, SEASTAR will utilise Nova's well-proven turbines to deliver the large-scale 16-turbine array at the EMEC Fall of Warness tidal site in Orkney. Jointly funded by the EU Horizon Europe programme and the UKRI, the SEASTAR project will run from December 2023 to February 2029. In 2024, Nova Innovation was successful in securing a 4 MW CfD contract, via AR6, for the SEASTAR project, ensuring long-term price certainty for the project and delivering a positive step forward in enhancing the bankability and insurability of the SEASTAR tidal farm.

https://www.seastar-tidal.eu/

Nova Innovation M100-D tidal turbine 'Eunice'. © Nova Innovation)

SEETIP Ocean

The Horizon Europe funded SEETIP Ocean project is coordinated by Ocean Energy Europe, involving the University of Edinburgh, Wave Energy Scotland, and other European partners. It supports the activities of the European Technology & Innovation Platform for ocean energy (ETIP Ocean) and the SET Plan Ocean Energy Implementation Working Group (OceanSET). In October 2024, the updated Strategic Research and Innovation Agenda (SRIA) for Ocean Energy was launched. The SRIA identifies the main

Waverider buoy prior to deployment at EMEC. © EMEC

'Challenge Areas', each of which contains research and innovation priorities that the ocean energy sector should work on and what EU, national and regional R&I funding should focus upon during the period of 2025-2030 to deliver the greatest progress in the ocean energy sector.

https://www.etipocean.eu
https://www.oceanset.eu

TEST SITES AND TECHNOLOGY DEMONSTRATION

Existing open sea test and demonstration sites

European Marine Energy Centre

2024 was another year of progress for the European Marine Energy Centre (EMEC), the world's leading centre for the testing and demonstration of wave and tidal stream devices in the sea. As a plug-and-play facility EMEC helps reduce the cost, time and risk of testing technologies offshore. EMEC provides pre-consented grid-connected demonstration sites in harsh wave and tidal regimes as well as scale test sites in gentler conditions for testing smaller scale technologies, subsystems and components. EMEC is the world's only accredited test facility for ocean energy, accredited by the United Kingdom Accreditation Service, and is the first International Electrotechnical Commission Renewable Energy Testing Laboratory for ocean energy.

In 2024, EMEC welcomed £3 million of support from the UK Government to bolster its future growth plans, including the expansion of test facilities to support tidal stream arrays. In August, EMEC was pleased to welcome the UK Minister for Climate to witness the clean energy innovation taking place across the islands. This was closely followed by a fact-finding visit by officials from the Department of Net Zero and Energy Security. This provided EMEC with the opportunity to highlight the support that they can provide to the to the UK Government's clean power mission and the importance of R&D investment into emerging technologies.

EMEC is actively pursuing the expansion of both of its grid-connected test sites to accommodate demonstrations of multiple technologies with work in progress to expand the tidal site at the Fall of Warness to 50 MW and the wave energy test site at Billia Croo. EMEC continues to work closely with the UK's leading tidal stream developers: Orbital Marine Power is operating its O2 tidal turbine at EMEC's Fall of Warness tidal energy site, and working closely with EMEC and consortia on a number of European-funded innovation projects (MaxBlade, FORWARD-2030 and EURO-TIDES); and Nova Innovation

is gearing up to deploy a 4 MW, 16 turbine, tidal energy farm EMEC via the EU-funded SEASTAR project.

On the wave energy front, Irish developer OceanEnergy has signed a berth agreement to test its 1 MW OE35 floating wave energy converter at EMEC's Billia Croo wave energy site via the EU-funded WEDUSEA project. Meanwhile, Edinburgh-based developer, Mocean Energy is preparing to deploy a 250 kW wave machine at the EMEC Billia Croo wave test site in the near future as part of a £3 million EuropeWave project, and EMEC is working with AW Energy on the EU ONDEP project to deploy a 2 MW wave energy array in Portugal.

https://www.emec.org.uk/

Marine Energy Test Area

The Marine Energy Test Area (META), situated in the Milford Haven Waterway, is managed by Marine Energy Wales and offers pre-consented 'Open Water' and 'Quayside' test sites. Aiming to bridge the gap between tank testing and the Welsh Demonstration Zones, this series of eight non-grid-connected sites is suitable for a range of wave and tidal component, sub-assembly, part-scale and full-scale device tests. META is the only pre-consented, pre-commercial test facility of its kind in Wales. Funded through the Swansea Bay City Deal and a keystone partner of the Pembroke Dock Marine Project, META offers testing in real sea conditions for wave, tidal and floating offshore wind technology in the Milford Haven Waterway, alongside world class port, engineering and manufacturing facilities.

In March 2024, META successfully deployed and tested its first tidal turbine at their Warrior Way test site in Pembroke Dock. This collaborative endeavour, working with project leads Swansea University, allowed researchers to capture the real-time tidal flow during testing to fully understand the turbine's response and performance in relation to the flow. In addition to this, META also supported Dolphyn Hydrogen to test the performance of some of their components in a floating environment and PEBL Environmental Monitoring to test various marine biodiversity remote monitoring stations.

https://www.meta.wales/

Morlais

The Morlais project, encapsulates 35 km² of seabed around the promontory of Holy Island being developed by Menter Môn. It boasts powerful tidal current resources and relatively low wave regimes, representing a prime site for future exploitation of tidal energy, and has been leased for 45 years. Infrastructure works to enable the export of electricity generated from tidal stream devices was completed in 2023. The first phase of the project was successfully delivered in February 2024 with the handover of the substation to Menter Môn. Four developers have secured subsidy support under the Contracts for Difference (CfD) scheme in AR4, AR5 and AR6, namely Hydrowing, Magallanes Renovables, Môr Energy, and Verdant Isles.

https://morlaisenergy.com

Research and test facilities

In addition to these large-scale test sites, research institutions across the UK continue to maintain and operate several cutting-edge test facilities, providing invaluable support to early-stage technologies and simulations of real-sea conditions. These include but are not limited to:

- COAST Laboratory – Plymouth University
- Fastblade – University of Edinburgh
- Flowave – University of Edinburgh
- Kelvin Hydrodynamics Laboratory – University of Strathclyde

Arrays and demonstration projects in the water

Magallanes Renovables

Spanish developer Magallanes Renovables continue to test their ATIR turbine at the European Marine Energy Centre, Fall of Warness site. They are also working on the design of the next-generation ATIR 2.0 device, which is expected to be deployed at Morlais in 2027. Magallanes were again successful in the CfD AR6 in 2024, winning a 3 MW extension to the existing 1.5 MW at EMEC. They also have a CfD for 3 MW at Morlais, both from AR5.

https://magallanesrenovables.com

Mocean Energy

Throughout 2024, Mocean Energy has gained considerable traction with key clients as part of its commercialisation and internationalisation roadmap for its Blue Star technology (tens of kW), whilst furthering the development of its Blue Horizon technology (hundreds of kW). 2024 also saw Mocean's prototype WEC, Blue X, complete over 13 months of operational time offshore as part of the Renewables for Subsea Power project, with the collaborative project being hailed a success after demon-

strating reliable power and communications provision from a WEC to a subsea micro-grid off the east coast of Orkney. The technology came out of the waters in spring 2024, to allow in-depth inspection and analysis, and is now being prepared for its next deployment, envisaged to occur in 2025.

Mocean has successfully demonstrated the hybridised power solution of wave, solar and battery storage, enabling the provision of continuous, predictable renewable energy throughout the year. Mocean continues to advance its innovative technology portfolio, such as the novel Vernier Hybrid Machine (generator) technology, well suited to high-torque low-speed applications and bringing direct-drive electrical generators to the sector and potentially other markets. Mocean continues to strengthen its commercial and industrial links, and continues to build on its strategic goals towards commercialisation. This includes adding key appointments and several initiatives for investment to realise these goals, such as crowdfunding and strategic Series A, both of which are currently ongoing.

https://www.mocean.energy

MeyGen

The MeyGen project, established in 2010 and situated in the Pentland Firth, is the largest tidal stream project in the world. The site has consent awarded for 86 MW, and the option to develop up to 398 MW. The project is being delivered in phases with the 1st phase operational since 2018, with four 1.5 MW turbines. As of December 2024, phase 1 has delivered over 70 GWh of clean, predictable electricity to homes and businesses, with 10 GWh produced in 2024 alone. Phase 1 incorporated two different turbine technologies, Proteus Marine Renewables AR1500 and Andritz Hydro Hammerfest AH1000 MK1. Both turbine technologies are consistently delivering >95% availability.

Phase 1 of the MeyGen Project has faced and overcome a significant number of challenges, both commercial and technical. Having addressed a range of early breakdowns, the first of class machines selected for phase 1 are now proving their technical suitability to long term continual deployment. MeyGen will continue to monitor all the turbines and plan preventative maintenance activities based upon condition monitoring. During 2024, phase 1

Mocean Blue X off the coast of Orkney. © Mocean Energy

was successful in returning to operation all four 1.5 MW turbines, bringing it to full power, to deliver 6 MW of predictable electricity to the local grid.

The next phase of MeyGen will deliver an additional 59 MW of capacity utilising 3 MW turbines of up to 26 m rotor diameter. Securing the consents and funding required to deliver this world leading project has acted as a signpost for the wider industry. In maintaining its leading position within the tidal industry MeyGen is working to expand its current 86 MW capacity up to 200 MW+ in support of the UK government NET Zero targets and continued support under the CfD.

https://saerenewables.com/tidal-stream/meygen/

Nova Innovation

Nova Innovation continue to operate the Shetland Tidal Array, which has been generating for over eight years and accumulated 80,000 hours and counting of turbine operation. Nova is currently advancing the design for their next-generation tidal turbine under the UpTEMPO project. In 2023 a pan-European team led by Nova Innovation was awarded the SEASTAR project that will see 4 MW array Nova Innovation turbines deployed at the European Marine Energy Centre in Orkney. In October 2024, Nova won 6 MW of CfD in the UK Government's latest auction round to support the deployment of turbines at the EMEC Fall of Warness site.

2024 was also a ground-breaking year for Nova, seeing the launch of its floating solar joint venture - 'AquaGen365' - with RSK. This partnership brings together Nova's innovative approach and RSK's global expertise, unlocking the potential of floating solar technology to complement its tidal energy solutions.

https://novainnovation.com

Orbital Marine Power

Orbital continues to operate the O2 tidal turbine at the European Marine Energy Centre in Orkney as part of a long-term test and demonstration programme. The O2 project serves as a platform for quantifying component reliability, de-risking offshore operations ahead of tidal farm deployments and a testbed for trialling environmental monitoring hardware.

In April the O2 set a new generation record for the most amount of power from a single 6-hour tide at 8.63 MWh at EMEC's Fall of Warness site. Orbital is continuing to progress environmental surveys and consenting work for the Westray Tidal Array, Orkney ahead of finalising a consent application next year.

In March Orbital was confirmed as the technology partner for Orcas Power & Light Cooperative's proposed tidal pilot project off Blakely Island in Rosario Strait, Washington State, USA. The company is also finalising permitting for a pilot project at the Fundy Ocean Research Centre for Energy, Nova Scotia, Canada in conjunction with local development partner Euclaire.

https://www.orbitalmarine.com/

Projects planned for deployment

AWS Ocean Energy

AWS Ocean Energy has developed the Archimedes Waveswing wave energy converter – a modular, fully submergible, pressure differential absorber. The successful at-sea testing of a 16 kW Waveswing prototype at the EMEC Scapa Flow scale test site in Orkney, UK, has proven the key technology sub-systems necessary to give confidence that the concept will work at full scale. Since the demonstration campaign, AWS has continued to progress the feasibility of large-scale multi-absorber wave energy platforms, working towards exploitation of the Waveswing technology and addressing the fundamental challenges of scale and the practical offshore maintenance, which are essential to the delivery of affordable utility scale power. AWS is seeking partners to develop its pre-commercial prototype, whilst also pursuing other opportunities for deployment of smaller systems in bespoke applications.

https://awsocean.com/

HydroWing

Inyanga Marine Energy Group plan to deploy their HydroWing technology at Morlais in Wales. The 20 MW tidal array will incorporate the Tocardo T3 turbine, with each of the twenty HydroWing units to be powered by two T3 turbines. The turbines include a Passive Pitch Unit which was successfully tested at the Kelvin Hydrodynamics Laboratory at the University of Strathclyde in 2024.

The company has secured 20 MW of capacity for their project at Morlais through the CfD scheme in AR5 and AR6, to be commissioned in 2027/28. A demonstration project will take place at Morlais in 2025. HydroWing is also developing tidal energy projects in Indonesia and Canada.

https://hydrowing.tech

OceanEnergy

Irish wave energy developer, OceanEnergy, has signed up to demonstrate its 1 MW OE35 floating wave energy converter at EMEC. OceanEnergy intends to demonstrate the OE35 over a two-year period, expected to begin in 2025/26, at the EMEC Billia Croo wave energy test site. EMEC will support OceanEnergy with environmental monitoring and will further undertake technical inspection and performance assessment to confirm that the OE35 and moorings satisfies reliability, survivability and performance targets and adhere to IEC international standards. The demonstration is supported by the WEDUSEA project, co-funded by the EU Horizon Europe Programme and Innovate UK.

https://wedusea.eu/

Proteus Marine Renewables

Proteus Marine Renewables is a leading marine energy technology and offshore services provider. To date, Proteus turbines have generated more than 20 GWh to the grid from over 25 deployments in six countries. In December 2024, Proteus successfully redeployed the AR1500 bringing MeyGen phase 1 back up to its full power output of 6 MW. Earlier in the year, Proteus was selected by Ocean Renewable Power Company to join the American Tidal Energy Project, funded in part by US Department of Energy, which will deploy Proteus and ORPC technology into Alaska's Cook Inlet. Proteus' French subsidiary Normandie Hydroliennes is developing the 12 MW NH1 pilot array at Raz Blanchard, France. Proteus has also completed upgrades to its 1.1 MW AR1100 turbine, set for redeployment in Japan's Naru Straight in early 2025.

In November 2024, Proteus signed a Memorandum of Understanding with SKF and GE Vernova, setting out a framework to potentially supply tidal turbine generation systems to developers of large-scale tidal arrays. An initial focus includes delivering a minimum 59 MW to MeyGen in Scotland, the largest tidal stream facility in the world. Development of the latest generation Proteus AR series turbine system has also progressed significantly, with a rotor diameter of up to 26 m and an installed capacity of 3 MW.

https://proteusmr.com/

QED Naval

2024 has been a year of significant development for QED and its subsidiaries, with the Tocardo assets, established in the UK, centred around new workshops and facilities in Angelsey, North Wales. Good progress was made in the front-end-engineering and design work for the next-generation Subhub-ID. This included significant upgrades to their Tocardo T3 turbine to enhance commercial viability, with a larger rotor diameter to capture more energy. Through Môr Energy, QED has also been busy on a commercial front, driving the Morlais project towards a financial investment decision. They are therefore on track to deliver their first commercial project, with 4.5 MW at Morlais, as the first phase of a 30 MW project.

The QED Subhub tidal technology completed over 2 years of operational experience at Strangford Lough. In 2024, the platform was towed to southwest Wales where it was brought ashore to refit the new Tocardo T1 tidal turbines. The platform and turbines were then fully tested ashore before being deployed to the coast around Land's End. The platform is now situated in Langstone Harbour awaiting another MMO application which is nearing completion for longer term remote testing and environmental monitoring and impact assessment.

https://qednaval.co.uk/

RELEVANT NATIONAL EVENTS

Relevant events for the ocean energy sector that took place in the UK in 2024 include:

- **6th-8th February** – Scottish Marine Energy Research (ScotMER) symposium, online
- **13th-14th March** – Marine Energy Wales Annual Conference, Swansea
- **15th-19th April** – Environmental Interactions of Marine Renewables Congress, Orkney
- **24th April** – Supergen ORE Hub Annual Assembly, Plymouth
- **15th-16th May** – All-Energy, Glasgow
- **5th-6th November** – Ocean Energy Europe 2024, Aviemore

Relevant events planned for 2025

- **25th-28th February** – Scottish Marine Energy Research (ScotMER) symposium, Stirling/hybrid
- **7th-8th May** – Marine Energy Wales Annual Conference, Cardiff
- **15th April** – Supergen ORE Hub Annual Assembly, Manchester
- **14th-15th May** – All-Energy, Glasgow

An expanded version of this chapter, with an increased number of entries, has been used in the publication of the 2024 UK Ocean Energy Annual Review, and is available here.

UNITED STATES OF AMERICA

REPORT PREPARED BY:
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U.S. Department of Energy's Water Power Technologies Office

OVERVIEW

The United States made substantial commitments to advancing wave and tidal energy in 2024 through record investments in technology development and demonstration programs. These programs, in addition to many others throughout the nation, will focus on developing marine energy for a range of power requirements from at-sea applications to utility connections.

A wave energy funding opportunity, known as "Oceans of Opportunity," from the U.S. Department of Energy's (DOE's) Water Power Technologies Office (WPTO) will provide up to $112.5 million for wave energy development and testing over five years with the first stage of funding expected to be awarded in 2025. One of two major tidal energy projects that kicked off planning studies in 2024 will advance to the next phase with an additional $29 million to work toward a pilot demonstration in years to come. Additionally, progress in building the PacWave South test site and planned upgrades to the Pacific Northwest National Laboratory's (PNNL's) Sequim Bay test site will support future open water testing. In addition to wave and tidal energy, researchers and developers in the United States are advancing river current technologies and assessing the feasibility of ocean thermal energy conversion for tropical areas.

At least five wave, one tidal, and three river current energy projects conducted open water testing in the United States in 2024, collecting data and lessons learned to improve these technologies' performance and survivability in oceans and rivers. U.S. researchers and developers also continued working on methods, models, hardware, and outreach tools to advance marine energy.

SUPPORTING POLICIES FOR OCEAN ENERGY

National strategy

National Ocean Energy Policy

Members of the U.S. House of Representatives from districts along the U.S. West Coast introduced the Marine Energy Technology Acceleration Act in 2024 that could allow for up to $1 billion in funding to advance marine energy. The bill's future is uncertain, but if passed, it could substantially increase public funding disbursement by WPTO's Marine Energy Program. Additionally, other representatives from the U.S. West Coast introduced the Blue Ocean Energy Innovation Act in 2024, which aims to fund research and development (R&D) of renewable energy technologies and greenhouse gas capture and removal technologies located in aquatic environments.

The National Hydropower Association's Marine Energy Council (MEC), the U.S. trade group representing marine energy, released a position paper in July 2024 denoting updated priorities and recommendations to advance marine energy in the Unites States. The MEC engages in national- and state-level policy discussions and initially published a commercialization strategy in 2021.

On the state level, California made progress toward the aims of its marine energy bill (California Senate Bill 605) that passed in 2023. The California Energy Commission held a public workshop and sponsored a report to assess feasibility, costs, and benefits of using wave and tidal energy in the state. The report concluded that the state's promising wave and tidal energy resource potential and existing clean energy policies indicate a supportive envi-

ronment for research, development, testing, and eventual installation of marine energy technologies in an environmentally responsible manner. The report also identified a need for specialized workforce training programs and local manufacturing capabilities for advancing the marine energy sector.

Following the release of the Ocean Climate Action Plan in 2023, the White House issued a one-year progress report in 2024. The report mentions WPTO's marine energy public funding opportunities as contributing to one of the plan's major goals to create a carbon-neutral future.

Market incentives

The Inflation Reduction Act of 2022 (IRA) included clean energy production and investment tax credits applicable to marine and hydrokinetic technologies. Since passage of the law, the U.S. government has released final rules on several tax credits created or extended by the IRA.

For example, in December 2024, the government released final rules for the Investment Tax Credit, also known as the Section 48 Energy Credit, which supports capital investment in renewable energy projects beginning construction before 2025.

In 2025, the Investment Tax Credit—and the closely related Production Tax Credit—will be replaced by a technology-neutral approach with credits that will be available in full for projects beginning construction at least through 2033. In January 2025, the government released final rules for these Clean Electricity Production and Investment Tax Credits, also known as technology-neutral credits. These credits provide incentives for companies to invest in clean energy technologies and eliminate the need for recurring legislative tax credit extensions, providing clean energy project developers clarity and certainty to undertake major investments. The final rules clarify which zero-emissions clean electricity technologies qualify for the credits, including marine and hydrokinetic technologies.

The energy-related tax rules were developed by the U.S. Department of the Treasury and the Internal Revenue Service in consultation with the U.S. Department of Energy. WPTO maintains an updated webpage summarizing tax incentives for water power technologies.

Public funding programs

DOE is the primary distributor of national-level public funding for marine energy in the United States. Agencies such as the Department of Defense (DOD) and National Science Foundation (NSF) also fund and support marine energy research, development, and demonstration.

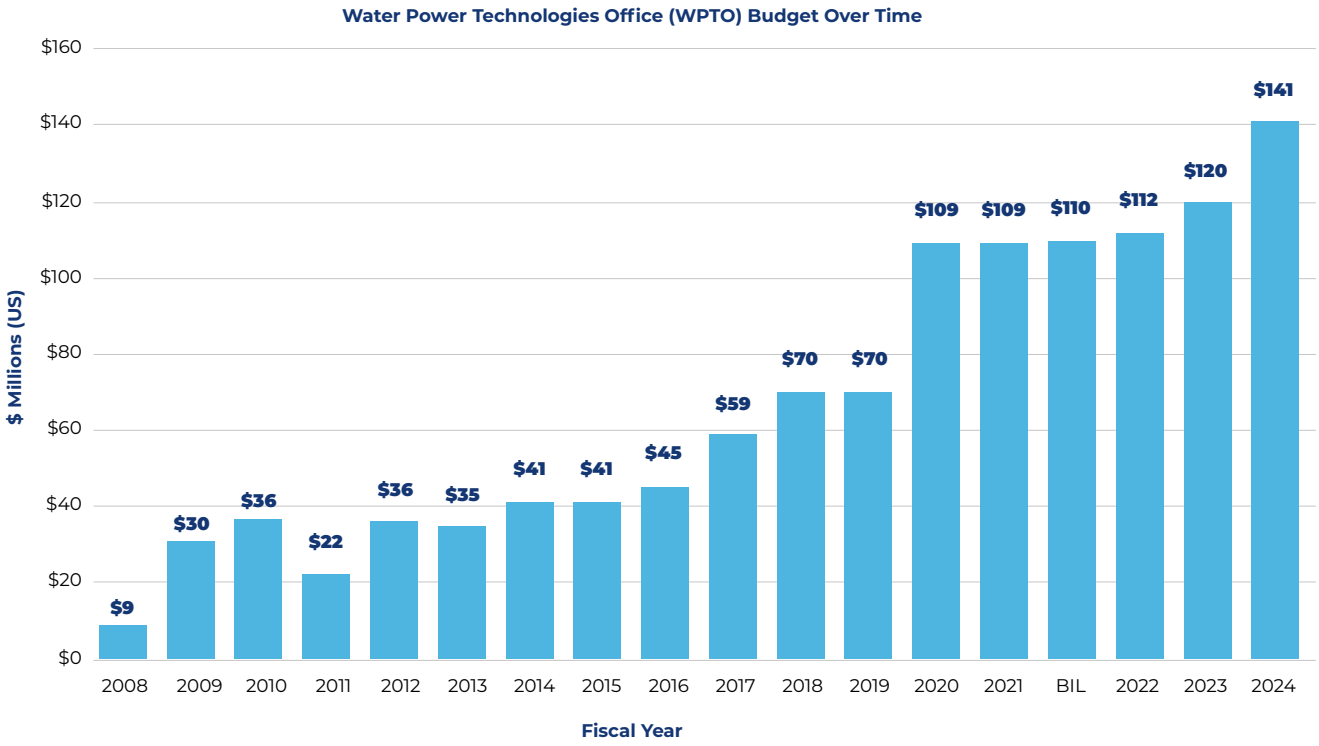
Within DOE, WPTO's Marine Energy Program is the United States' primary public funder of marine energy R&D and had a $141 million budget for Fiscal Year 2024 (October 2023 to September 2024), the largest since the program began. This budget included $21 million for facilities upgrades at PNNL's Marine and Coastal Research Laboratory. As of January 2025, Congress had not passed a final Fiscal Year 2025 budget, and government agencies were being funded by a temporary funding bill. In addition to annual appropriations, the Infrastructure Investment and Jobs Act enacted in 2021, known as the Bipartisan Infrastructure Law (BIL), provided $110.4 million to WPTO for marine energy activities and the office continued disbursing these funds in 2024.

In 2024, WPTO's marine energy funding and technical assistance programs included notable opportunities for businesses, developers, universities, and students.

For businesses and developers, in September 2024, WPTO opened the "Oceans of Opportunity" funding opportunity, which will provide up to $112.5 million for wave energy development and testing over five years, representing the largest U.S. investment in wave energy to date. The opportunity aims to advance commercial adoption of wave energy technologies by reducing financial risks for developers, identifying and maturing promising technologies, and facilitating open water testing that can provide data and lessons for the industry. Three topic areas focus on different sizes and uses of wave energy: distributed, community, and utility applications. Selections for the first stage of funding are expected to be announced in summer 2025.

In February 2024, WPTO announced two projects selected to receive a combined $6 million for tidal energy research, development, and demonstration projects and another project to receive $9.5 million for a community-led river current energy R&D project. In 2025, one of the tidal energy projects is expected to be selected to receive an additional $29 million to proceed to the next phases with the ultimate goal of testing and operation.

WPTO continued to support small businesses in 2024 through the Small Business Innovation Research (SBIR) program. Sixteen projects received a combined $11 million to either begin or continue work on various projects related to marine energy components and subsystems,



co-development with blue economy end users, emerging sensors and monitoring technologies, and more. WPTO also opened a funding opportunity for organizations to develop or augment incubator and accelerator programs that will help small businesses advance their water power technologies. Eight projects were selected in January 2025, receiving $100,000 each for their initial planning phase.

Additionally, 14 projects were selected to receive nearly $17 million to further support durable and environmentally responsible U.S. offshore wind energy and marine energy deployments. Among other efforts, these projects include research for technology advancements to improve the integrity of mooring systems for marine energy converters and offshore wind energy platforms. WPTO, DOE's Wind Energy Technologies Office (WETO), and the Department of the Interior's Bureau of Ocean Energy Management and Bureau of Safety and Environmental Enforcement jointly funded this opportunity.

To complement funding awards, WPTO sponsors the Testing Expertise and Access for Marine Energy Research (TEAMER) program, which is run by the nonprofit Pacific Ocean Energy Trust. Developers can apply to TEAMER for technical support provided by expert researchers and state-of-the-art facilities. Support can range from numerical modeling to tank testing to open water testing. TEAMER selected more than 50 projects in 2024 and increased project budget caps for technical support and testing. Both U.S. and non-U.S. developers are eligible to apply to TEAMER.

For universities, WPTO, working with WETO, announced the selection of 27 projects in a more than $18 million funding opportunity focused on marine energy and offshore wind R&D in the academic sector. Projects will focus on data and test platforms, co-development with aquaculture, undergraduate senior design or research, and many other novel concepts.

More than $41 million was also provided to the university-led National Marine Energy Centers for new and continuing R&D projects and testing infrastructure improvements over the next five years. Additionally, WPTO funded three marine energy projects through a seed funding initiative to support research at minority-serving colleges and universities.

WPTO also sponsors opportunities directly aimed at undergraduate and graduate students, helping to build the future marine energy workforce. One of these is the annual Marine Energy Collegiate Competition (MECC), where interdisciplinary teams of students design marine energy solutions for powering ocean economy activities. In 2024, the University of New Hampshire won first place in the fifth annual competition, and WPTO announced the

23 teams selected to compete in 2025. Another student opportunity is the Marine Energy Fellowship Program, which awarded five graduate students in 2024 the opportunity to work alongside a host institution on research that contributes to their dissertation. The program was expanded for the upcoming fellowship year in 2025, offering an additional post-graduate track for students who graduated within the last two years and switching to two application periods per year for greater flexibility in start dates.

DOE's national laboratories also receive public funding to perform marine energy R&D. In 2024, DOE national laboratories were awarded about $18 million from WPTO across 40 new or continuing marine energy R&D projects. Projects span topics such as molecular methods of environmental monitoring, tools to generate wave energy equations of motion, ocean thermal energy conversion and seawater air conditioning assessments, and modeling marine energy integration with activities like ocean observation and marine carbon dioxide removal. Through DOE's Office of Technology Transitions (OTT) funding opportunities and training programs, WPTO also sponsors national laboratory projects focused on customer discovery and technology readiness. In 2024, seven marine energy projects were selected through OTT programs, such as one focused on a piezoelectric technology technoeconomic assessment and another focused on hydrophone flow shields.

More broadly, WPTO-sponsored marine energy prizes are open to the public and solicit innovative concepts to solve specific challenges. In 2024, the Innovating Distributed Embedded Energy Prize selected 15 winning teams for Phase 2, each receiving $80,000. Competitors are developing distributed embedded energy converter prototypes with an emphasis on interdisciplinary collaboration. Phase 3 of this prize closes in early 2025. The Power at Sea Prize announced 20 winners in its first phase, each receiving $10,000. This prize seeks innovative marine energy solutions that could power ocean economy activities, with winning teams proposing diverse applications ranging from aquaculture to autonomous underwater vehicles to artificial reef integration. The next and last phase of the prize will close in summer 2025.

SUMMARY OF WPTO PUBLIC FUNDING OPPORTUNITIES OF 2024

Opportunity name	Brief description	Total funding available	Awards	Link for more information
Oceans of Opportunity	Wave energy open water testing	Up to $112.5 million	Expected summer 2025	Funding notice
U.S. Tidal Energy Advancement	Pilot tidal/current energy site; community-led tidal/current project	$44.5 million	Two pilot tidal site candidates selected, and one community-led current project selected; pilot tidal site Phase 2 selection expected summer 2025	Award notice
Small Business Innovation Research	Grants to small businesses (supports a range of topics)	$11 million	16 projects selected	Award notice
Water Power Innovation Network	Water power incubator or accelerator programs	$4.8 million	Eight candidate projects selected; up to four will be selected in 2026 to continue	Award notice
Installation Noise Reduction and Reliable Moorings for Offshore Wind and Marine Energy	Mooring durability	$16.9 million (joint opportunity with $2 million from WPTO)	Seven projects selected in the Moorings topic area	Award notice

Marine Energy University Foundational R&D	University-led R&D (supports a range of topics)	$18.2 million (joint opportunity with $17.4 million from WPTO)	27 projects selected	Award notice
National Marine Energy Centers	R&D, infrastructure, outreach, and more at four university-led centers	$41 million	More than 30 R&D projects at nine universities within the National Marine Energy Centers	Award notice
Seedlings for Universities	R&D seed funding for minority-serving institutions	$1.2 million (total for marine energy and hydropower)	Three marine energy projects selected	Award notice
Innovating Distributed Embedded Energy Prize	Distributed embedded energy converter technologies	$1.2 million for Phase II	15 teams selected in Phase II	Award notice
Power at Sea Prize	Marine energy for ocean economy applications	$200,000 for Phase I	20 teams selected in Phase I	Award notice
Testing and Expertise for Marine Energy Research Program	Technical support through expertise and testing facilities	About $7 million	51 projects selected in 2024	TEAMER news

Other DOE offices, including the Office of Clean Energy Demonstrations and Loan Programs Office, provide funding for post-R&D stage projects. Marine energy projects are typically eligible for these opportunities, though none have been funded yet. DOE's Advanced Research Projects Agency-Energy (ARPA-E) continues to fund marine energy R&D projects through its Submarine Hydrokinetic And Riverine Kilo-megawatt Systems (SHARKS) program.

Outside of DOE, NSF funded several university-led marine energy projects in 2024 as well as a business-led project through its own SBIR program. For example, a group of interdisciplinary researchers across multiple universities received $3.6 million to design wave energy solutions for community-identified needs at two coastal locations in the United States.

Some U.S. states, such as Alaska and Washington, also have their own public funding programs for energy projects inclusive of marine energy. For example, in 2024, wave energy developer Oscilla Power was selected for a grant through Washington's Department of Commerce, funded by the state's Climate Commitment Act. The funding will support Oscilla's continued development of its 1 MW Triton wave energy converter (WEC) drivetrain technology.

RESEARCH & DEVELOPMENT

A sample of U.S. marine energy research highlights in 2024 includes tidal energy grid integration studies, wave energy for powering ocean observation, methods for wildlife monitoring around marine energy devices, and approaches to protect technologies in harsh marine environments.

Researchers at the National Renewable Energy Laboratory (NREL) published a case study in 2024 that evaluated how tidal energy in Alaska's Cook Inlet, known for its speedy currents, could potentially integrate with the region's electric grid that serves about 75% of Alaska's population. Researchers modeled the grid and found that, under current transmission infrastructure, it could handle about 200 MW of the abundant tidal energy from Cook Inlet (>18,000 MW theoretical tidal resource). This tidal energy capacity could increase to 300 MW with transmis-

sion line upgrades, with the caveat that these estimates assume tidal energy generation will be commercially feasible by 2035.

Researchers are also investigating marine energy technologies that could serve much smaller power needs, such as sensors in ocean observation buoys. PNNL staff are evaluating a small pendulum wave energy generator through field trials for its potential to power ocean observation buoys in remote Arctic waters. They are also continuing to build and test triboelectric nanogenerators for similar applications and assessing the feasibility of using marine energy to power coastal and offshore aquaculture.

Researchers continued to optimize and test methods for measuring potential impacts of marine energy devices on surrounding ecosystems and wildlife. For example, a team from PNNL and Sandia National Laboratories (SNL), in collaboration with the National Oceanic and Atmospheric Administration, tested their helium-filled, tethered balloon system off the coast of California in January 2024. The balloon system has optical and multispectral sensors and a thermal camera and could be used for monitoring wildlife such as whales during marine energy testing. The balloon would be able to conduct lengthier monitoring efforts compared to a drone, which has a limited battery life.

In the field of materials and advanced manufacturing, teams from PNNL and NREL assessed the performance of 3D-printed tidal turbine blades and small tidal turbines, using materials that proved durable after months of exposure in seawater tanks. 3D-printing turbines and turbine components could potentially improve a turbine's longevity, as well as quicken the manufacturing process to provide customized parts for testing.

Also aimed at increasing a device's lifetime and reducing maintenance in marine conditions, PNNL's Superhydrophobic Lubricant Infused Coating (SLIC) performed well in several long-term field tests across the country—fouling from mussels, barnacles, and other organisms adhered less frequently to SLIC and were easier to remove than from a leading commercial coating. Field test results led to strong interest in technology transfer and commercialization, and the SLIC coating is now being made in pilot quantities by a company outside of the lab for the first time.

Researchers at Oak Ridge National Laboratory continued working on their new class of eco-friendly, high-lubricity ionic liquids (ILs) as lubricant additives, demonstrating significantly improved lubricating performance, biodegradation, and non-toxicity compared with commercial baselines in a proof-of-concept study. These ILs are being explored as a non-toxic and higher performance lubricant alternative for marine energy applications.

TECHNOLOGY DEMONSTRATION

Existing open water test sites

Construction continues at the grid-connected and pre-permitted wave energy test site known as PacWave South off the coast of Oregon. In 2024, subsea and terrestrial cables were installed, and construction of the Utility Connection and Monitoring Facility was completed. Wave energy device testing is expected to start in 2026. Farther up the coast, the PacWave North site in Oregon state waters is available for testing smaller wave energy prototypes with a relatively streamlined permitting process. The Wave Energy Test Site (WETS) in Hawaii also continues to offer a pre-permitted site for wave energy technology testing, and Jennette's Pier in North Carolina is a test site for smaller wave energy devices.

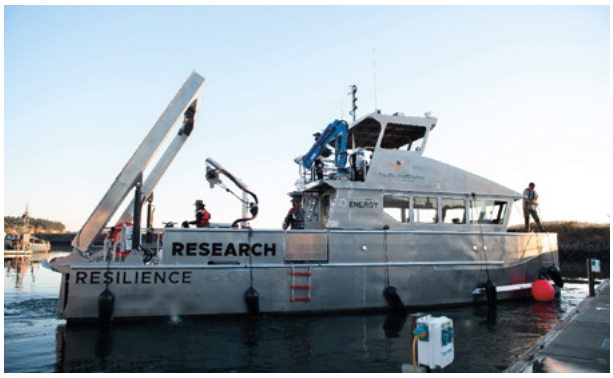
For tidal energy testing, the Bourne Tidal Test Site in Massachusetts' Cape Cod Canal received a pilot license from the Federal Energy Regulatory Commission (FERC) in 2024. The license allows pre-permitted testing of larger tidal devices and for devices to transmit power to the grid. In New Hampshire, the University of New Hampshire offers a tidal energy testing platform on the Piscataqua River, where small prototype turbines can be installed.

Upgrades to PNNL's Sequim Bay test site continued in 2024. PNNL's Marine and Coastal Research Laboratory

Teams work offshore to finish laying subsea cables for the PacWave South test site. © PacWave

in Sequim, Washington, is planning for facility and dock upgrades. The Sequim campus also unveiled its new hybrid research vessel, the RV Resilience, in 2024. This vessel will enable marine energy research and testing, as well as other coastal research. Construction continued on the Cabled Research Array for the Blue Economy and Energy (CRABEE), which will become part of the Sequim Bay test site. CRABEE is scheduled to be commissioned in 2025 and will allow concurrent testing of technologies like tidal turbines, ocean monitoring instruments, and more, sending power and data to shore through one connection cable. PNNL also supports a pre-permitted marine test site in Clallam Bay on the north coast of Washington state in the Strait of Juan de Fuca.

For riverine current technologies, the Tanana River Hydrokinetic Test Site in Alaska offers testing support and is a TEAMER open water facility.



PNNL's new research vessel, the RV Resilience, will be able to operate quietly on batteries for conducting noise-sensitive environmental research and monitoring. © Andrea Starr, PNNL

Projects in the Water

Several different types and sizes of WECs were demonstrated across the United States in 2024. Developer C-Power deployed a commercial-scale SeaRAY autonomous offshore power system (AOPS) at WETS in Hawaii, following a first-phase demonstration in 2023 and subsequent system upgrades. This second-phase demonstration generated, stored, and distributed power and provided bidirectional data communications between the seafloor and the data cloud. Separately, the University of Washington (UW) Applied Physics Lab (APL) deployed C-Power's TigerRAY wave power system, a smaller SeaRAY prototype configured for drifting operation, for a third time. C-Power's SeaRAY AOPS product line is intended for remote offshore operations.

Wave energy devices designed specifically for small-scale desalination were tested on the U.S. East and West coasts. In North Carolina at Jennette's Pier, NREL conducted several additional open water tests of its hydraulic and electric reverse osmosis (HERO) WEC, after a successful deployment in 2023. This small, modular system produced freshwater but encountered challenges with intense weather and snapped mooring lines. Based on lessons learned, the NREL team plans to improve the system's mooring lines along with other optimizations in a second prototype. While initially developed as a baseline or validation device for the Waves to Water Prize, NREL continues developing the device and offering its publicly available data for the marine energy industry.

Developer C-Power conducted a second-phase deployment of the SeaRAY AOPS at the Wave Energy Test Site in Hawaii (1. In-harbor operational testing; 2. Open water demonstration). © C-Power

NREL staff deployed the HERO WEC off the coast of North Carolina, where it successfully produced freshwater.
© John McCord, Coastal Studies Institute

In California, the developer Oneka tested its IceCube wave-powered desalination device for 30 days in collaboration with the Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC) at the Surface Warfare Center testing facility in Port Hueneme. The test enabled important data collection and informed opportunities for device improvement. Oneka previously won the grand prize in the Waves to Water Prize for its Snowflake buoy designed for emergency relief applications.

Additionally, Panthalassa tested its Ocean-2 wave energy generating buoy ("node") in the Strait of Juan de Fuca. Ocean-2 demonstrated end-to-end capabilities required for commercial deployment.

The developer Littoral Power Systems deployed a novel configuration of six Spotter buoys in 2024, which are part of a wave estimation system that could provide near real-time wave data back to a WEC's control system.

For tidal energy testing, UW APL completed a nearly six-month deployment (October 2023 to March 2024) of its cross-flow Tidal Turbine Lander at the Sequim Bay test site in collaboration with PNNL and supported by NAVFAC EXWC. The deployment included a specialized, UW-developed environmental monitoring sensor package to enable wildlife monitoring. Environmental monitoring was performed in collaboration with MarineSitu, Inc. and was supported by TEAMER. The Tidal Turbine Lander is small enough to deploy off a small vessel and could power instruments and sensors in more remote locations. The system is subsequently undergoing modifications.

According to DOD's Defense Advanced Research Projects Agency (DARPA), the developer PacMar Technologies also tested its full-scale energy harvesting system in 2024. This project is part of DARPA's Manta Ray program, which aims to advance the range and duration of uncrewed underwater vehicles, in part through undersea energy harvesting.

For riverine current technologies, ORPC's two Modular RivGen devices remained in Millinocket Stream in Maine in 2024 for continued testing. Another two ORPC RivGen devices remain in the Kvichak River at the Village of Igiugig in Alaska. In collaboration with the Igiugig Village Council, PNNL, and Aquacoustics, ORPC monitored salmon smolt migration around the RivGen devices in summer and measured sound produced by the devices.

The Oregon-based company BladeRunner Energy also continued field-testing its hydrokinetic turbine at the Tanana River Hydrokinetic Test Site in real-world, uncontrolled river conditions, in collaboration with the Univer-

sity of Alaska Fairbanks (UAF) and the Alaska Center for Energy and Power. The 2024 field-testing campaign was the fourth round of full-scale field testing at the Tanana site since the initiation of the ARPA-E SHARKS project led by UAF in partnership with BladeRunner Energy.

Projects planned for deployment

Developers C-Power and CalWave were awarded funding from WPTO in 2022 for testing the first wave energy technologies for deployment at PacWave South, which is expected to be ready for deployments in 2026. C-Power's next generation system, the Oregon-class SeaRAY AOPS, can support a range of surface and sub-surface assets, including operating equipment, metocean data gathering sensors, and uncrewed vehicles. The SeaRAY AOPS fabrication, integration, and initial in-water shakedown testing is planned for 2025 prior to deployment at PacWave South that is set to commence in 2026. The SeaRAY is planned to support three operating assets from partners during operations at PacWave.

Developers Oscilla and Dehlsen Associates were also awarded WPTO funding in 2022 to design WEC systems that, by the end of the project, could be ready for building and testing at PacWave South. Oscilla's 100 kW Triton-C WEC is also moored at WETS in Hawaii in preparation for deployment.

Ocean Motion Technologies is preparing to launch its updated wave-powered data buoy and autonomous underwater vehicle charging station in Puget Sound on the shores of Washington state in 2025. Its WEC system was informed by ocean observation stakeholders and aims to enable autonomous ocean monitoring and data collection by providing an integrated, small-scale power source. Additional long-duration commercial deployments of its WECs have also been planned with pilot customers.

Panthalassa is developing its next generation of wave energy buoys (nodes) for persistent deployment far from shore, with the first expected to come online in late 2025.

In 2026, NREL aims to complete and deploy the second version of its desalination-focused HERO WEC, following several potential optimizations to improve survivability, ease of installation, and operating efficiency.

In 2024, Eco Wave Power signed a co-investment agreement with Shell's Marine Renewable Program for the development of its first wave energy project in the United States, located at AltaSea's premises at the Port of Los Angeles. Eco Wave Power received the final nationwide permit from the U.S. Army Corps of Engineers and plans to complete installation of the onshore system in 2025, which will consist of wave energy floaters installed onto the piles of an existing concrete wharf.

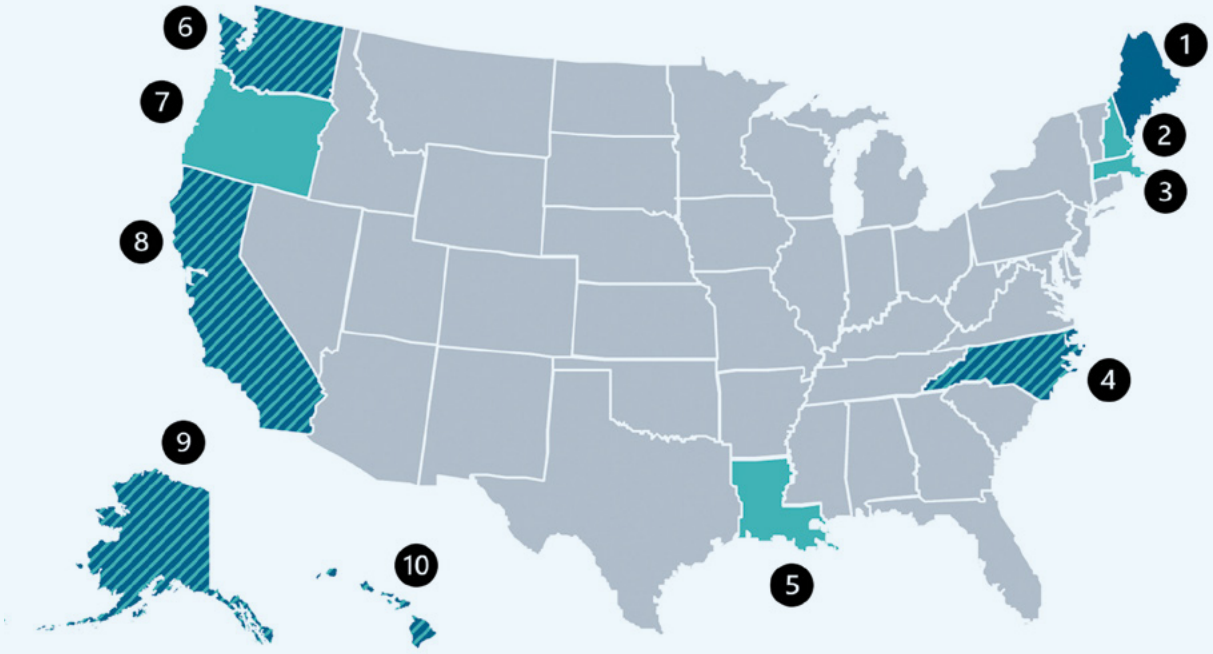
Future tidal energy testing in the United States will include the Open-Source Tidal Energy Converter at the University of New Hampshire's tidal energy testing platform on the Piscataqua River in 2025. The university and DOE national laboratories instrumented this axial-flow turbine to provide publicly available, high-resolution data to advance tidal energy development.

One of two Phase 1 projects funded through WPTO's tidal energy pilot demonstration opportunity is expected to be selected to continue to Phase 2 in 2025, advancing to a 1–2 MW tidal energy pilot test over the next few years. One of these projects, the American Tidal Energy Project, aims to harness tidal energy from Cook Inlet to power the Kenai Peninsula in Alaska and is led by developer ORPC. The other project is led by Orcas Power and Light Cooperative (OPALCO), a non-profit electric utility in the San Juan Islands of Washington, in partnership with the Scotland-based company Orbital Marine Power. This project aims to deploy a 1–2 MW Orbital O2 floating tidal energy device in Rosario Strait, building on OPALCO's efforts starting in 2018 to understand tidal energy's potential as a local power source for the San Juan Islands. In the first phase of these two projects, the teams are focused on site characterization, permitting planning, environmental risk analysis, technology assessments, and outreach.

Additionally, a community-led microgrid riverine hydrokinetics project launched in Galena, Alaska, in 2024. UAF was funded to develop the project in partnership with Sustainable Energy Galena Alaska. The team began with desktop analyses of the site and community engagement and education to prepare for the technology selection process. If the investigation shows promise, in 2025 the project aims to conduct site characterization, establish an environmental baseline, select the in-river turbine technology, and secure permits for future demonstration.

With additional funding secured from ARPA-E, BladeRunner Energy is working alongside the Native Village of Napaimute in Alaska toward the first pilot demonstration of its riverine system. This initial pilot deployment will integrate a 5 kW-rated system with an existing microgrid in this small seasonal community located along the shores of the Kuskokwim River. For 2025, the team is planning for a system deployment that will continuously operate from July through the fall.

Recent Open Water Tests and Planned Deployments



Key
Open water test completed in 2024
Planned open water test

1. Maine: ORPC deployed river current devices in the Millinocket Stream.

2. New Hampshire: University of New Hampshire will deploy a tidal turbine in the Piscataqua River.

3. Massachusetts: The Bourne Tidal Test Site will support tidal energy device testing.

4. North Carolina: NREL deployed its HERO WEC in Nags Head and plans to deploy a second version of the prototype in 2026. Woods Hole Oceanographic Institution, SNL, and NREL plan to deploy a wave energy converter in 2026.

5. Louisiana: ORPC plans to demonstrate Modular RivGen devices in the Lower Mississippi River at a Shell Technology facility.

6. Washington: UW APL's tidal turbine lander was deployed at PNNL's Sequim Bay site in 2024. Panthalassa tested a WEC in Puget Sound. Ocean Motion Technologies plans to deploy its wave-powered data buoy and autonomous underwater vehicle charging station in 2025.

7. Oregon: C-Power and CalWave will test their devices at PacWave South beginning in 2026.

8. California: Oneka tested its wave-powered desalination device at Port Hueneme in 2024. Eco Wave Power plans to install its wave energy system in Los Angeles in 2025.

9. Alaska: BladeRunner Energy demonstrated its hydrokinetic device at the Tanana River Test Site and is planning its first pilot demonstration in 2025 in the Kuskokwim River. ORPC's RivGen river current system is deployed in Igiugig. UAF plans to deploy a tidal turbine in Galena.

10. Hawaii: C-Power tested at WETS in 2024. Oscilla's Triton-C WEC is at WETS and plans to test.

SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

PNNL, in collaboration with other OES member countries, published the 2024 State of the Science Report: Environmental Effects of Marine Renewable Energy Development Around the World as an output of the OES-Environmental working group. More information on the report and other OES-Environmental accomplishments in 2024 can be found in the OES-Environmental section of this report under Key Task Achievements.

International entities are eligible to participate in some U.S. funding and technical assistance opportunities. For example, non-U.S. developers can apply to TEAMER for technical expertise and testing support, and non-U.S. institutions are eligible to participate in MECC (though must partner with a U.S. institution to be eligible for cash prizes). Some U.S. funding opportunities also allow international collaborators or subrecipients along with a U.S.-based primary recipient. Non-U.S. marine energy researchers and developers are also welcome to join the University Marine Energy Research Community (UMERC) member portal, which can facilitate communication, collaboration, and coordination among those in the marine energy sector.

RELEVANT NATIONAL EVENTS

Marine energy events in the United States in 2024:

- **March 13–15, 2024:** Water Power Week; Washington, District of Columbia
- **May 20–23, 2024:** Ocean Renewable Energy Conference and 2024 MECC Grand Finale; Portland, Oregon
- **August 7–9, 2024:** Marine Energy Technology Symposium and UMERC Summit; Duluth, Minnesota

Events planned in the United States in 2025:

- **March 31–April 2, 2025:** Water Power Week; Washington, District of Columbia
- **May 19–22, 2025:** Ocean Renewable Energy Conference and 2025 MECC Grand Finale; Portland, Oregon
- **August 12–14, 2025:** UMERC Summit; Corvallis, Oregon

05 APPENDICES

CorPower C4 device before being towed to the project site at Aguçadora, Portugal © Corpower Ocean

APPENDIX 1

MEMBERSHIP OF THE EXECUTIVE COMMITTEE

CABINET 2024

CHAIRMAN

Dr. Ir. Matthijs SOEDE
EC DG Research & Innovation
European Commission

VICE-CHAIR

Dr. Purnima Jalihal
National Institute of Ocean Technology (NIOT)
India

VICE-CHAIR

Mr. Tim Ramsey
US Department of Energy
USA

VICE-CHAIR

Prof. Christophe Gaudin
The University of Western Australia
Australia

SECRETARY

Dr. Ana Brito e Melo
WavEC Offshore Renewables
Portugal

DELEGATES

Country	Delegate	Alternate
Australia	**Professor Irene Penesis** University of Tasmania	**Professor Christophe Gaudin** The University of Western Australia
Belgium	**Dr. Ludovic Mouffe** Federal Public Service Economy	**Dr. Vicky Stratigaki** Ghent University
Canada	**Dr. Jinxing Huang** Natural Resources Canada	**Mrs. Elisa Obermann** Marine Renewables Canada
China	**Mr. Peng Wei** National Ocean Technology Center, SOA	**Mr. Wang Ji** National Ocean Technology Center
Denmark	**Mrs. Laerke Scov Hansen** Danish Energy Agency	**Dr. Kim Nielsen** Development v Kim Nielsen

European Commission	**Dr. Ir. Matthijs SOEDE** EC DG Research & Innovation	**Ms Evdokia Tapoglou** Joint Research Center
France	**Dr. Jean-François Filipot** France Energies Marines Since September 2024: **Dr. Christophe MAISONDIEU** IFREMER Centre Bretagne	**Mr. Nicolas Ruiz** France Energies Marines Since September 2024: **Mr. Benoît AUGIER** IFREMER Centre Bretagne
India	**Dr. G A Ramadass** National Institute of Ocean Technology Since December 2024: **Professor Balaji Ramakishnan** National Institute of Ocean Technology	**Dr. Purnima Jalihal** National Institute of Ocean Technology
Ireland	**Ms. Kerrie Sheehan** Sustainable Energy Authority of Ireland	**Dr. Emer Dennehy** Sustainable Energy Authority of Ireland
Italy	**Mr. Luca Benedetti** Gestore dei Servizi Energetici (GSE)	
Japan	**Dr. Yasuyuki Ikegami** Institute of Ocean Energy, Saga University	**Dr. Shuichi Nagata** Institute of Ocean Energy, Saga University
Korea	**Ms. Jae-ok Roh** Ministry of Oceans and Fisheries	**Dr. Jin-Hak Yi** Korea Institute of Ocean Science & Technology
Monaco	**HE Bernard Fautrier** Government of the Principality of Monaco	**Mr. Jérémie Carles** Fondation Prince Albert II de Monaco
Netherlands	**Mr. Sjoerd van Dijk** Netherlands Entreprise Agency	**Lisanne Brummelhuis** Ministry of Economic Affairs and Climate
New Zealand	**Mr. Martin Knoche** AWATEA	**Dr. Vladislav Sorokin** AWATEA
Portugal	**Prof. Luis Gato** Instituto Superior Técnico (IST)	**Prof. António Falcão** Instituto Superior Técnico (IST)
Singapore	**Prof. Subodh Mhaisalkar** Energy Research Institute	**Dr Srikanth Narasimalu** Energy Research Institute
Spain	**Mr. Yago Torre-Enciso** BIMEP - Biscay Marine Energy Platform	**Ms. Dorleta Marina** Simply Blue Energy Ltd
Sweden	**Ms. Marit Marsh Stromberg** Swedish Energy Agency	
UK	**Mr. Tim Warham** Department for Business, Energy and Industrial Strategy (BEIS)	**Mr. Henry Jeffrey** The University of Edinburgh
USA	**Mr. Tim Ramsey** U.S. Department of Energy	**Ms Judith Elaine Buck** US Department of Energy **Dr Michael Lawson** National Renewable Energy Laboratory (NREL)

APPENDIX 2

EXECUTIVE COMMITTEE MEETINGS

Meeting	Date	Local	Country
1	19 October 2001	Paris	France
2	21 - 22 March 2002	London	UK
3	31 October 2002	Brighton	UK
4	4 March 2003	Paris	France
5	15 - 16 September 2003	Cork	Ireland
6	26 - 27 February 2004	Lisbon	Portugal
7	4 - 5 November 2004	Copenhagen	Denmark
8	4 March 2005	Paris	France
9	16 - 17 November 2005	Brussels	Belgium
10	1 - 3 May 2006	Vancouver	Canada
11	14 - 15 November 2006	Lisbon	Portugal
12	20 - 21 March 2007	Mexico City	Mexico
13	16 - 17 October 2007	Messina	Italy
14	15 - 16 April 2008	New York city	USA
15	13 - 14 October 2008	Brest	France
16	30 - 31 March 2009	Bilbao	Spain
17	4 - 5 September 2009	Oslo	Norway
18	22 - 23 April 2010	Wellington	New Zealand
19	30 Sep - 1 Oct 2010	Dublin	Ireland
20	26 - 27 April 2011	Washington DC	USA
21	13 - 14 September 2011	Madeira	Portugal

22	17 - 18 May 2012	Daejeon	Korea
23	22 - 23 October 2012	Aalborg	Denmark
24	14 - 15 May 2013	Guangzhou	China
25	22 - 23 October 2013	Cape Town	South Africa
26	13 - 14 May 2014	Paris	France
27	10 - 11 November 2014	Halifax	Canada
28	12 - 13 May 2015	Kassel	Germany
29	11 - 12 November 2015	Cancun	Mexico
30	9 - 10 May 2016	Gothenburg	Sweden
31	20 - 21 October 2016	Singapore	Singapore
32	10 - 11 April 2017	Monaco	Monaco
33	14 - 15 November 2017	Chennai	India
34	14 - 15 June 2018	Cherbourg	France
35	29 - 30 November 2018	Las Palmas	Spain
36	26 - 27 March 2019	Riviera Maya	Mexico
37	2 - 3 October 2019	Dublin	Ireland
38	18 – 22 May 2020	Online meeting	
39	4 - 6 November 2020	Online meeting	
40	10 - 11 March 2021	Online meeting	
41	19 - 20 May 2021	Online meeting	
42	15 - 16 September 2021	Online meeting	
43	8 December 2021	Online meeting	
44	10 - 11 March 2022	Online meeting	
45	29 – 30 June 2022	Online meeting	
46	17 October 2022	San Sebastián	Spain
47	22-23 March 2023	Online meeting	
48	23-24 October 2023	The Hague	Netherlands
49	20-21 March 2024	Online meeting	
49B	18 June 2024	Online meeting	
50	15-16 September 2024	Melbourne	Australia

ABOUT THE INTERNATIONAL ENERGY AGENCY (IEA)

The IEA works with governments and industry to shape a secure and sustainable energy future for all.

The IEA is at the heart of global dialogue on energy, providing authoritative analysis, data, policy recommendations, and real-world solutions to help countries provide secure and sustainable energy for all.

The IEA was created in 1974 to help co-ordinate a collective response to major disruptions in the supply of oil. While oil security remains a key aspect of our work, the IEA has evolved and expanded significantly since its foundation.

Taking an all-fuels, all-technology approach, the IEA recommends policies that enhance the reliability, affordability and sustainability of energy. It examines the full spectrum issues including renewables, oil, gas and coal supply and demand, energy efficiency, clean energy technologies, electricity systems and markets, access to energy, demand-side management, and much more.

IEA Technology Collaboration Programmes

The Technology Collaboration Programme supports the work of independent, international groups of experts that enable governments and industries from around the world to lead programmes and projects on a wide range of energy technologies and related issues. The experts in these collaborations work to advance the research, development and commercialisation of energy technologies. The scope and strategy of each collaboration is in keeping with the IEA Shared Goals of energy security, environmental protection and economic growth, as well as engagement worldwide.

The breadth of the analytical expertise in the Technology Collaboration Programme is a unique asset to the global transition to a cleaner energy future.

These collaborations involve over 6 000 experts worldwide who represent nearly 300 public and private organisations located in 55 countries, including many from IEA Association countries such as China, India and Brazil.

About IEA-OES

Ocean Energy Systems (OES) is a Technology Collaboration Programme (TCP) within the International Energy Agency (IEA)

The **International Energy Agency (IEA)** works to ensure reliable, affordable and clean energy for its 29 Member Countries and beyond. Founded in 1974, the IEA was initially designed to help countries coordinate a collective response to major disruptions in the supply of oil such as the crisis of 1973/4. While this remains a key aspect of its work, the IEA has evolved and expanded. It is at the heart of global dialogue on energy, providing authoritative statistics and analysis.

The IEA examines the full spectrum of energy issues and advocates policies that will enhance the reliability, affordability and sustainability of energy in its 29 Member Countries and beyond. The four main areas of focus are:

- **energy security:** promoting diversity, efficiency and flexibility within all energy sectors;
- **economic development**: ensuring the stable supply of energy to IEA Member Countries and promoting free markets to foster economic growth and eliminate energy poverty;
- **environmental awareness:** enhancing international knowledge of options for tackling climate change;
- **engagement worldwide:** working closely with non-member countries, especially major producers and consumers, to find solutions to shared energy and environmental concerns.

Technology Collaboration Programmes (TCPs) are independent, international groups of experts that enable governments and industries from around the world to lead programmes and projects on a wide range of energy technologies and related issues. TCPs currently cover topics related to:

- efficient end-use (buildings, electricity, industry, transport);
- cleaner fossil fuels (greenhouse-gas mitigation, extraction, supply, transformation);
- renewable energy and hydrogen (technologies and policies for deployment);
- cross-cutting issues (modelling, technology transfer, project financing);
- fusion power (safety, physics, materials, technologies).

www.ocean-energy-systems.org