Technology Collaboration Programme
by IEA


# ANNUAL REPORT

AN OVERVIEW OF OCEAN ENERGY ACTIVITIES IN 2023

OES OCEAN ENERGY SYSTEMS

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CHAIR

## Dr. Ir. Matthijs SOEDE

EC, DG Research & Innovation

With a PhD in Chemical Engineering from Delft University of Technology, started his career at the Netherlands' Ministry of Economic Affairs focusing on international research cooperation. In 2008, he joined the European Commission's DG Research and Innovation, initially dealing with Industrial Technologies, then transitioning to Clean Energy, specifically offshore renewables. He is member of the IEA Renewable Energy Working Party, and since 2019, vice-chair of the IEA-OES. In 2021, he joined the MI Clean Hydrogen Mission as a co-lead and was appointed Mission Director.

VICE-CHAIR

## Dr. Purnima Jalihal

National Institute of Ocean Technology (NIOT)

Dr. Purnima Jalihal is a senior scientist who heads the Energy and Fresh Water group in the National Institute of Ocean Technology, India. She has led device developments for harnessing ocean energy from waves, marine currents and ocean thermal gradient (OTEC) and has played a major role in developing the ocean thermal desalination technology. She has a PhD in Civil Engineering from Duke University, USA. She was awarded the Vishwakarma Medal in 2006 by the Indian National Science Academy and the Uehara Prize for 2019 by the International OTEC community for Contribution to the development of OTEC. She is on many committees of Indian Government organizations, related to water and renewable energy and is the EU led Clean Energy Mission Innovation Champion for India, 2020.

VICE-CHAIR

## Mr. Tim Ramsey

USA Department of Energy

Tim Ramsey has been with the U.S. Department of Energy (DOE) since 2005 and currently serves as the Program Manager for the Water Power Technologies Office's Marine Energy Program. In this role, he leads the Program's efforts to conduct RDD&D specific to Marine Energy applications, supporting the development of new, cutting-edge technologies and the establishment of a strong and competitive Marine Energy industry in the United States. The Program provides substantial financial support to researchers at a wide range of different organizations to focus on solutions to high priority challenges broadly applicable across the industry. Prior to joining the DOE Federal Team, Tim worked for Navarro Research and Engineering, a multi-program support service contractor for the Department of Energy. Tim holds a Bachelor of Science in Chemical Engineering from Ohio University.

VICE-CHAIR

## Professor Christophe Gaudin

University of Western Australia

Christophe is a professor of offshore geotechnical engineering at the University of Western Australia (UWA), Perth with over 20 years' experience in research and consulting. Over the last 7 years, his focus has been on supporting and developing marine renewable energy using multidisciplinary approaches. He is the founding Director of Marine Energy Research Australia, a research centre that supports industry, scientists and government in developing innovative offshore renewable energy technologies and in defining the future energy landscape in Australia and worldwide. Christophe is currently the Director of the UWA Oceans Institute, a multidisciplinary research centre with over 250 members and world leading expertise in marine biology, ocean science and engineering, maritime archaeology, maritime laws and oceans socio-economics.

SECRETARY

## Dr. Ana Brito e Melo

WavEC

Ana is a Civil Engineer with a PhD in Mechanical Engineering, and more than 25 years' experience in the field of marine renewable energies, currently Chief Operating Officer at WavEC. She developed significant research expertise in the wave energy field during her 10-year tenure with the wave energy team at Instituto Superior Técnico, University of Lisbon. Ana joined WavEC in 2003 and has been responsible for securing and executing services for major energy companies, developers, governments and public bodies. In addition,since 2002, she has held the role of Executive Secretary of the IEA-OES.

Photo courtesy of Corpower

# CHAIRMAN'S MESSAGE

**Matthijs Soede**
European Commission
IEA-OES Chairman (2023-2024)

# Tripling renewables capacity by 2030? Yes, but ocean energy capacity even more!

At the end of 2023 more than 100 countries agreed to triple renewable energy capacity by 2030 at the COP 28 climate summit in Dubai. Renewable energy is key to meeting the 2015 Paris climate agreement to limit global warming. And while renewables are already expanding fast, this latest goal would require an even faster acceleration in the deployment of solar and wind power.

But what if ocean energy would contribute 'substantially' to this ambitious target? More than 1% of the total installed capacity? That would make an incredible achievement in my view and, of course, it would be great to see this happening. You might raise the question if it is really needed to develop and support ocean energy but in fact the answer is unequivocally yes. To reach the objectives of the 2015 Paris climate agreement, leveraging all renewable energy sources is imperative. Reaching the 1% with ocean energy means that merely tripling the current deployments is not sufficient. The target must be set much higher. Realising this goal requires a clear vision and coordinated collaborative action.

At the end of 2023, alongside COP2028, we presented an ambitious vision in our "Ocean Energy and Net Zero: An International Roadmap to Develop 300GW of Ocean Energy by 2050". This roadmap outlines a comprehensive strategy that will help to drive the global development of ocean energy.

Such a roadmap is not just 'great reading material'. It is a call for action to the whole ocean energy community from government to industry and private investors. Coordinated efforts and exchange of experiences would be important for accelerating the development of the ocean energy sector.

In this year's annual report you will find the latest developments. I am inviting you to have a look on what is happening across all our member countries and having all these developments in mind, let's use the coming months to discuss what we can do together to realize the ambitious call to roll-out ocean energy at a global level. How we can path the way from research and innovation to deployment and to build new collaborations.

2024 will be an interesting year which I hope will be filled with a lot of fruitful discussions. I am looking forward to the 10th International Conference on Ocean Energy which will take place on 17-19 September in Melbourne, Australia. Invitations have been sent out already and I am really looking forward seeing you there.

My gratitude to Ana Brito e Melo, who is the linking pin in the IEA OES technology collaborative programme and is taking care for the secretariat. Without her we wouldn't have this annual report so timely.

With kind regards,

**Dr. ir. Matthijs Soede**
Chair IEA TCP on Ocean Energy Systems


Photo courtesy of Sabella

# EXECUTIVE SUMMARY

**Ana Brito e Melo**
IEA-OES Executive Secretary

# 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).

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.

Work is funded by participants, and there is a close co-operation 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.

As of December 2023, 21 Member Countries and the European Commission are members of the IEA-OES, providing a broad international base of information, sharing experience and knowledge and further a diversified representation of interests: members are from governmental departments, utilities, universities and research organizations, energy agencies and industry associations. This is one of the benefits of joining OES: participants gain an international perspective on ocean energy issues, opportunities and present challenges.

The twenty-two 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. SIDS DOCK, representing 32 small islands and low-lying developing states across the globe, participates as an Observer.

Membership in OES offers participants a unique opportunity to gain valuable insights into ocean energy challenges, opportunities, and global perspectives. The collaboration facilitates access to advanced R&D teams, harmonizes testing measures and protocols for prototypes, reduces national costs through international collaboration, fosters crucial contacts between government, industry, and science, and encourages the exchange of information and networking.

This Annual Report serves as a testament to the IEA-OES collaborative efforts, highlighting key achievements and recent outcomes on a global scale. Additionally, it provides updates on ocean energy policy, research initiatives, and deployment progress across all member countries, underscoring the collective progress and impact of this international cooperation.

# Key achievements in 2023

## Launch of an International Vision for Ocean Energy

A significant milestone in 2023 was the publication of "Ocean Energy and Net Zero: An International Roadmap to Develop 300GW of Ocean Energy by 2050". Released in November 2023, this roadmap strategically addresses the challenges and opportunities within the tidal stream and wave energy sector. The publication outlines a comprehensive vision and international implementation strategy, emphasizing the importance of research and development synergy, coordinated leadership, and a clear implementation strategy. By forecasting a global installed capacity of 300GW by 2050, generating 680,000 jobs, contributing $340 billion in gross value added (GVA), and preventing over 500 million tonnes of carbon emissions, the roadmap envisions a hopeful and sustainable future for ocean energy. IEA-OES proactively shared this roadmap during COP28 to drive global development in ocean energy, highlighting its potential to play a pivotal role in the broader low-carbon energy mix and contribute significantly to socio-economic growth while combating climate change.

## Substantial Evolution of the Stage-Gate Metrics International Framework for Ocean Energy

Since 2017, the IEA-OES has been addressing the need for a more rigorous technical review approach in the ocean energy sector, under the collaborative task on Stage-Gate Metrics International Framework for Ocean Energy. Recognizing the significance of improved evaluation methods and metrics, the task focuses on enhancing the due diligence review and evaluation of ocean energy technologies. The achievements include the publication of four comprehensive reports since 2021, including a jointly published report with the International Electrotechnical Commission (IEC). The latest report, published in 2023, represents a substantial evolution of the framework, incorporating Environmental Acceptability as a pivotal consideration in technology development. This adaptability to user feedback and emerging industry needs showcases the responsiveness of the framework to ensure its continued relevance and effectiveness in guiding ocean energy technology development.

## Integration of ocean energy with desalination processes as a response to global freshwater challenges

IEA-OES has been collaborating on providing an understanding of the opportunities for ocean energy in alternative markets: ocean energy can contribute to decarbonise island energy generation and enhancing resilience while reducing release of

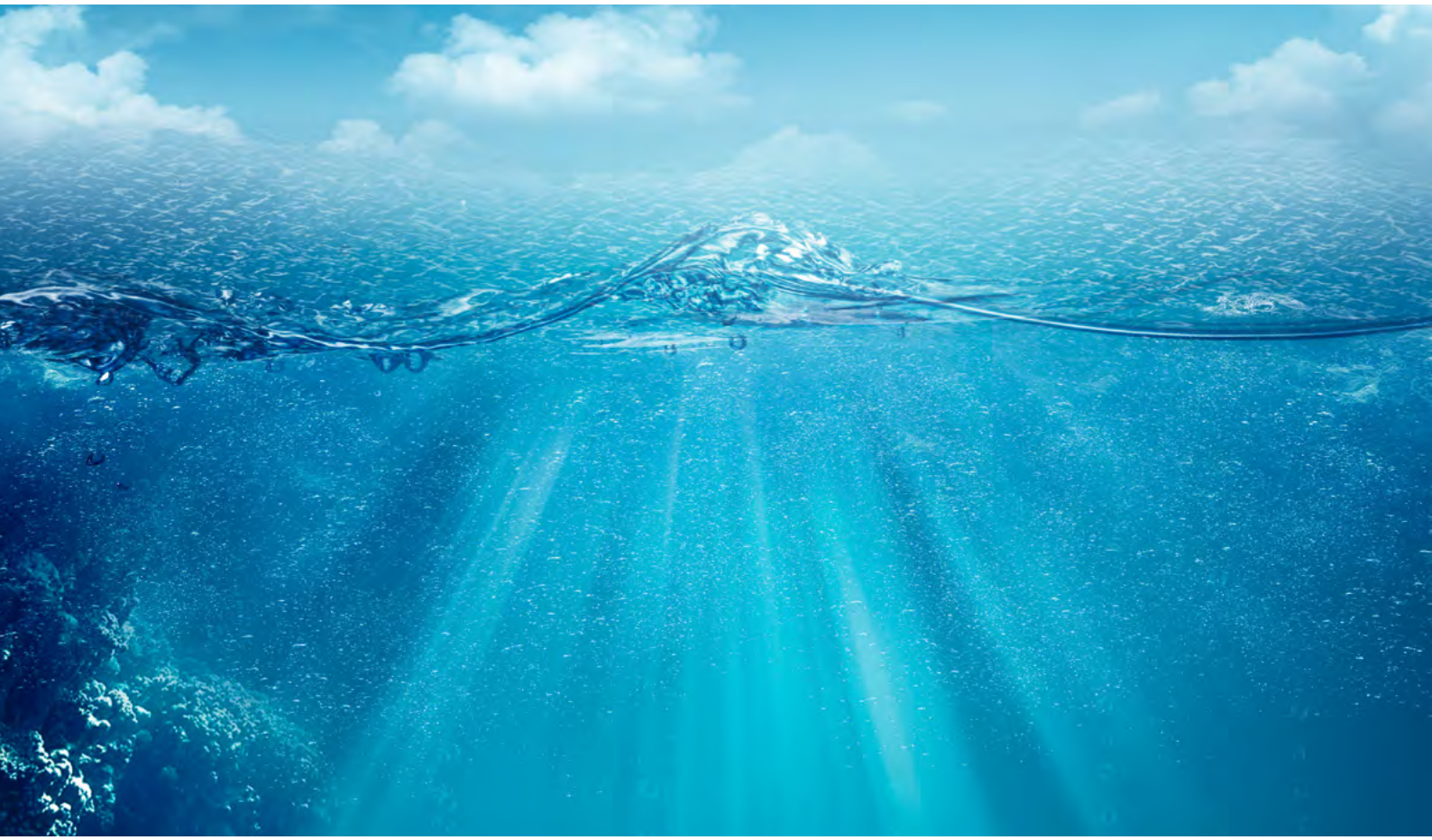
pollutants. Further, offshore industries (e.g. aquaculture, marine macroalgae), water supply (desalination), science (e.g. oceanographic research), and security activities offer a growing potential of direct use. In 2022 a report "Offshore Aquaculture: a Market for Ocean Renewable Energy" was published providing an understanding of the potential of ocean energy to co-locate with aquaculture along with the supply of energy to this sector. In 2023 our focus extended to the integration of ocean energy with desalination processes as a response to global freshwater challenges. This study, to be published in early 2024, will provide valuable insights into the diverse landscape of the desalination market.

## Ongoing outreach and engagement under the OES-Environmental Task

The OES-Environmental (OES-E) Task now has sixteen participating countries and is led by the US Department of Energy (DOE) and implemented by the Pacific Northwest National Laboratory. The publicly accessible knowledge management system, Tethys (https://tethys.pnnl.gov), has been updated and expanded to include papers, reports, and other information related to the environmental impact of marine renewable energy. Outreach and engagement with the marine renewable energy community has been ongoing through workshops, webinars, and conferences. In 2023, the initiative focused on streamlining the consenting and licensing process through the development of a risk retirement process, as well as evaluating existing information on the environmental impact of marine renewable energy in tropical, subtropical, and southern hemisphere waters and other underrepresented regions of OES member countries.

## Understanding the economics of Ocean Thermal Energy Conversion (OTEC)

A group of member countries – Japan, India, China, France, Singapore and The Netherlands – have collaborated on exploring the potential of Ocean Thermal Energy Conversion (OTEC) globally and evaluating the current



state and plans for its implementation. A White Paper on OTEC was published in 2021 with recommendations for the widespread adoption of OTEC. In 2023 a study on the Economics of OTEC was undertaken to address significant challenges faced by the OTEC sector. Currently, very few nations have ventured into OTEC, and despite the existence of a few pilot-scale demonstration plants, the lack of reliable cost data poses a barrier to understanding the economic feasibility of full-scale OTEC plants. Moreover, due to the novelty of OTEC technology, there is limited awareness and a scarcity of expertise in the field. The outcomes of this study will be published in 2024.

## Collaborative efforts on numerical modelling tasks on wave and tidal energy

Progress has been made in two OES tasks dedicated to modeling, verification, and validation of ocean energy technologies. The wave energy task, led by Ramboll in Denmark, and the tidal energy task, led by the Energy Research Institute at Nanyang Technological University in Singapore, have collaborated with experts from universities, research institutions, and companies. The teams have actively engaged in comparing results obtained from various numerical codes to enhance understanding and accuracy in their respective focus areas.

## 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 Collaboration:** 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 Support:** IEA-OES consistently supports young researchers through INORE, sponsoring activities like the European and North America Symposia.
- **IEC-TC 114 Liaison:** Actively contributing to international standards for wave and tidal energy technologies through collaboration with IEC-TC 114.
- **WECANET Partnership:** Engaging with WECANET, a collaborative platform for wave energy stakeholders, to facilitate dialogue and cooperation.
- **SEETIP Ocean[1] Collaboration:** Collaborating on data collection with SEETIP Ocean to enhance cooperation within and outside the European ocean energy sector.
- **Ocean Energy Europe (OEE):** Collaborating on data sharing to ensure a unified and clear message for the ocean energy sector.

IEA-OES also maintains a strong link with the International Conference on Ocean Energy (ICOE), further enhancing its role in the global ocean energy community through this key industry event.

## 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's objectives revolve around global collaboration, impactful leadership, information exchange, and stakeholder engagement in the field of ocean energy. IEA-OES aims to amplify its influence by developing key messages and advocating for ocean energy benefits. Additionally, it serves as a hub for information exchange, promoting awareness through discussions, webinars, and global events. OES enhances cooperation with stakeholders and international organizations, contributing to the advancement of ocean energy on a global scale.

1 EU-funded SEETIP Ocean project coordinate actions at European level to bring individuals and organisations together, exchange and create knowledge on ocean energy.

# Country highlights in 2023

## Policy Landscape

Globally, policies are being developed to foster the growth of the ocean energy sector. These policies range from creating comprehensive support programs and regulatory frameworks to streamline licensing processes, setting deployment targets, and providing financial backing for research and development.

There is also a growing emphasis on the establishment and support of marine energy test sites. These sites serve as hubs for innovation, allowing for the testing of emerging technologies in controlled environments. This initiative is complemented by the integration of maritime spatial planning efforts, which allocate specific zones for the development of marine energy projects. This strategic planning balances the dual objectives of promoting ocean energy development and preserving marine ecosystems, ensuring a sustainable approach to harnessing the ocean's power.

Moreover, international collaboration and knowledge sharing have become key elements of the global strategy to advance ocean energy.

By embracing a variety of approaches, these policies aim to foster innovation, reduce technological and financial risks, and ultimately enhance the competitiveness of ocean energy technologies. This diversity in policy approaches reflects a global recognition of the potential of ocean energy to contribute to a sustainable energy future.

However, it's essential to be aware of the challenges the sector faces due to economic fluctuations, supply chain uncertainties, and commitments to net zero goals. These issues collectively pose significant risks to the industry. Furthermore, despite recognition of the non-financial advantages a thriving commercial wave and tidal stream sector can bring to nations, such as regional economic growth and energy cost savings, there's still a pressing need for ongoing innovation within the sector. This is crucial for achieving cost reductions similar to those seen in other energy sectors.

Further complexities and delays in obtaining permits can significantly hinder project timelines, and in some cases, may even lead to the cessation of these projects. This challenge emphasizes the need for streamlined regulatory frameworks to support the efficient and timely development of ocean energy initiatives. Such improvements are crucial to ensure that the potential of this renewable energy sector is not undermined by procedural hurdles.

Table 1 highlights recent impactful initiatives in member countries that contribute to ocean energy development and 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**<br>Under development by the Australian Government, through the Department of Climate Change, Energy, the Environment, and Water (DCCEEW), targeting completion by the end of 2024. It aims to outline a collective vision for Australia's oceans up to 2040, focusing on sustainable economic growth. |
| **Belgium** | **"Blue Accelerator" test platform**<br>Maritime innovation and development platform for offshore blue economy research and industry projects. |
| **Canada** | **Offshore Renewable Energy Regulations (ORER)**<br>A new legislation with continuous pre-engagement efforts aiming to establish comprehensive requirements for safety, security, and environmental protection in the offshore renewable energy sector.<br>**New Regulatory Roadmap**<br>To tackle regulatory and operational challenges and explore innovative approaches for a sustainable blue economy.<br>**Bill C-49, proposed changes to energy regulation**<br>Seeks to establish a new regulatory regime for offshore renewable energy projects with a focus on wind, wave, and tidal energy off the coasts of Nova Scotia and Newfoundland and Labrador.<br>**Tidal Task Force on Sustainable Tidal Energy Development in the Bay of Fundy**<br>Aims to reduce turnaround time for regulatory decisions for tidal energy projects. |
| **China** | **Plan for Green and Low-carbon Advanced Technology Demonstration Projects**<br>Issued in August 2023 to support the implementation of demonstration projects including marine clean energy such as wave energy, tidal current energy and OTEC.<br>**Green electricity certificates**<br>Issued in July 2023 a Notice on the full coverage of renewable energy green electricity certificates, to promote renewable energy electricity consumption. |
| **Denmark** | **National Strategy for wave energy development**<br>In place since 2013 with continuous support of EUDP (Energy Technology Development and Demonstration Program) and Energinet DK. |
| **European Commission** | **"Delivering on the EU offshore renewable energy ambitions"**<br>New communication, proposing to increase Europe's offshore wind capacity to at least 111 GW by 2030 and adjusting the timeline for ocean energy 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. |

### Continuous support to ocean energy through EU funding programmes

The Horizon Europe programme has launched new calls in 2023. The Innovation Fund support programme has been launched in 2020 and published new calls in 2022 with deadlines in 2024.

## France

### Open-C Foundation Creation

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

### Flowatt Project

Benefited from a €75 million public investment and a feed-in tariff to secure the business model of the farm, illustrating the government's commitment to ocean energy.

## Ireland

### Designated Maritime Area Plan (DMAP)

Has been established as a first draft in 2023 in the framework of the National Marine Planning Framework (NMPF) to set out Ireland's future development for offshore renewable energy.

## India

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

This Committee of Bureau of Indian Standards (BIS) has been created in 2023 to formulate standards for the development of ocean energy in India.

## Italy

### Blue Italian Growth National Technology Cluster (BIG)

Is making strides toward creating an open structure that brings together stakeholders from various sectors of the Blue Economy, including Marine Renewables. It has formulated Sectoral Action Plans to guide its efforts.

### Sea Plan for 2023-2025

Approved in 2023, recognizing the significant role of the sea in renewable energy production, such as offshore wind and wave energy, as part of its energy strategy.

## Korea

### Carbon Dioxide Reduction Goal

Set by the government aiming for a 2.3 million tCO2 reduction by 2050 from the ocean energy sector, backed by various R&D projects.

### 2030 Ocean Energy Development Plan

A strategic plan outlining steps for expanding R&D, developing large-scale ocean energy farms, entering the global market, and reviewing the ocean energy certification system.

### Renewable Energy Portfolio Standard (RPS):

Established in 2012, it mandates utility companies with a capacity greater than 500 MW to source a portion of their electricity from renewable energy. The tradable Renewable Energy Certificate (REC) system supplements this policy, with tidal and wave energy having distinct REC values.

## Monaco

### National Green Fund

Dedicated to financing actions for the reduction of GHG emissions, energy efficiency and development of renewable energies.

**Portugal**

### Technological Free Zones (ZLT)

The government announced a ZLT for marine renewable energies projects located Offshore northern Portugal and published its legal framework in 2023. ZLTs are physical spaces for the testing and demonstration of new technologies and innovations, in a real environment, under special legislation and permanent monitoring by regulatory entities.

**Singapore**

### Renewable Energy Integration Demonstrator - Singapore (REIDS)

A Singapore-based Research, Development, Demonstration and Deployment platform 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**

### Swedish Maritime Strategy

Policy document for socially, environmentally and economically sustainable development in the Swedish maritime sectors. Ocean energy is one of the areas.

**Spain**

### Maritime Spatial Planning Plan

Approved on February 28, 2023, encompasses the spatial planning for Spain's five marine demarcations. The plan advocates utilizing existing test sites like BiMEP and PLOCAN for prototype testing, and it sets aside various maritime zones for the priority use of research and development projects.

### Basque Energy Agency (EVE) new call

Launched in 2023 for "Demonstration and validation of emerging marine renewable energy technologies" programme in 2023 with a total budget of 2,5 M€ for 3-year maximum duration projects.

**UK**

### UK's flagship Contracts for Difference (CfD)

Has significantly supported tidal energy projects, in its latest allocation round, in 2023.

### Scottish Government's Draft Energy Strategy

Released in 2023, it outlines the vast potential of tidal stream technology and recommends continued support for Wave Energy Scotland (WES) programme

### Wave Energy Scotland (WES) programme

Continues to drive wave energy R&D activity in the UK. Through WES programme, wave energy technologies have been successfully deployed and tested in real sea conditions in EMEC.

### Marine Energy Wales (MEW) 2023 State of the Sector Report

It highlights how the development of significant infrastructure projects has helped the ocean energy sector to produce record contributions to the Welsh economy during the past two years.

**USA**

### Water Power Technologies Office's Marine Energy Program

In fiscal year 2023 (October 2022-September 2023) the U.S. federal government provided $120 million, a record amount, to WPTO's Marine Energy Program.

### Marine Energy Law enacted by California

Release in 2023, it will require state agencies and stakeholders to assess the feasibility and potential impacts of wave and tidal energy and to identify suitable locations in state and federal waters.

**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 | | ● | | ● | | | | ● | ● | |

The achievements of the ocean energy sector in 2023, marked by significant technological deployments, signal a promising direction towards realizing the full potential of ocean energy.

## Highlighting Project Progress in 2023

Over 2023, the ocean energy sector continued to witness advancements with ocean energy devices, showcasing the sector's evolution beyond experimental phases into more mature stages of technology deployment and operational demonstration. Throughout the year, the global ocean energy community, comprising dynamic teams of developers, researchers, and innovators from various member countries, engaged in the rigorous testing and deployment of their technologies in the open ocean.

Highlights from the year included the launch of projects across the globe, each contributing uniquely to the sector's growth. These projects ranged from tidal and wave energy converters reaching new benchmarks in power generation and operational reliability, to the establishment of multi-technology platforms that integrate ocean energy systems with other renewable sources and storage solutions. The diversity of these initiatives reflected the sector's comprehensive approach to addressing the challenges of marine energy production and its integration into the broader energy system.

Moreover, the advancements in 2023 were not limited to technology alone but extended to the development of supportive infrastructures, such as enhanced test sites and collaborative research facilities. These infrastructures provided critical platforms for the testing, validation, and refinement of ocean energy technologies under real conditions, facilitating a deeper understanding of their performance and environmental interactions.

The achievements of the ocean energy sector in 2023, marked by significant technological deployments, signal a promising direction towards realizing the full potential of ocean energy.


## CHINA

- The **Wanshan 1 MW** wave energy project advanced with the completion of "Zhoushan" and "Changshan" devices, each with 500 kW, setting the stage for demonstration.
- The **"Penghu"** platform developed by GIEC showcased the successful integration of wave energy and aquaculture.
- The **LHD Tidal Current Project** reached over 6 years of operation, with the "Endeavour" turbine generating over 2.9 million kWh in 20 months.
- The **Zhoushan** tidal project achieved a technical upgrade for grid-connected operations, led by China Three Gorges Corporation.

## KOREA

- **KRISO** has been developing 30 kW wave energy converters applicable to breakwaters in remote islands, with an OWC pilot plant built at the Mook-ri port in Chuja Island, located between Jeju Island and the mainland.
- The development and installation of vertical-axis tidal current energy converters in conjunction with a 500 kWh ESS was completed in June 2023 and is currently operating at the **Uldolmok Tidal Power Pilot Plant.** This system has an output of 100 kW at a rated flow speed of 3.6 m/s.

## INDIA

- Following the successful development and demonstration of a **wave-powered navigational buoy** by the National Institute of Ocean Technology (NIOT), Kamarajar Port Ltd. in Chennai has provided funding to NIOT for the development of a new buoy system.

## SINGAPORE

- **REIDS** and its partners are testing and demonstrating the integration of solar, wind, tidal, diesel, storage as well as waste-to-energy and power-to-gas technologies & end-use technologies and solutions suitable for deployment in Southeast Asia.
- Preliminary engineering design and feasibility studies have been conducted for larger scale floating solar PV systems.
- Jurong Island is now planned to serve as a "Living" test-bed for floating renewables.

## AUSTRALIA

- **AZURA Ocean Technology** is advancing its commercialization program by adapting its core wave energy generation technology into modular floating systems (up to 200 kW) and fixed infrastructure systems (up to 25 kW).
- **Marine Renewable Energy Solutions (MaRen.Energy)**, formed from the restructuring of MAKO Tidal Turbines and Altum Green Energy, focuses on deploying small modular horizontal axis tidal turbines in arrays for coastal communities, rivers, and canals.
- **Carnegie Clean Energy** in 2023, secured contracts for deploying a CETO prototype in the Basque Country by 2025. It also made significant advancements in its MoorPower technology, targeting the offshore aquaculture sector.
- **WaveX**, revitalizing ROC Technologies' Wave Powered Generator (WPG) IP since January 2023, in partnership with the University of Western Australia (UWA), successfully deployed a 1:40 scale model in the Swan River. Plans are set for a larger prototype deployment in open water in 2024.
- **Wave Swell Energy (WSE)** operated its UniWave200 unit in Tasmania until its decommissioning in late 2022, and since then has been recycling or repurposing all components. WSE is developing a future project pipeline, especially in the US and Pacific Islands.

## NEW ZEALAND

- **Ruka Marine Turbine** project is progressing to deploy in 2024 a "proof of concept" surface floating turbine in Tai Tokerau, New Zealand.


## THE UNITED STATES

- **Triton Systems** tested a wave energy prototype near Cape Cod, Massachusetts, designed for oceanographic uses, surviving a hurricane's eight-foot waves. Also in Cape Cod, **Littoral Power** tested a tidal energy device at the Bourne Tidal Test Site.
- **BladeRunner Energy** showcased their hydrokinetic device at the Tanana River Test Sitsh, in Alaska.
- The **Ocean Renewable Power Company (ORPC)** tested in Maine a Modular RivGen hydrokinetic device and a tidal energy converter, TidGen, with plans for further deployment. ORPC also has plans for testing in the Lower Mississippi River.
- **Oscilla Power** deployed a wave energy prototype in Maine and prepared for the launch of another wave energy device off Hawaii.
- **C-Power** completed in-harbor tests of their SeaRAY system, with further testing planned for 2024.
- Other planned developments: CalWave, Oscilla, and Dehlsen Associates are preparing for deployments at PacWave, following selection by WPTO in 2022. Ocean Energy's OE35 buoy and Eco Wave Power's technology are set for deployment in Hawaii and Los Angeles, respectively. Oneka Technologies plans to showcase a wave-powered desalination buoy off California.

## CANADA

- **Ocean Renewable Power Company (ORPC)** has been conducting a demonstration project for its RivGen Power System at the Canadian Hydrokinetic Turbine Test Centre in Manitoba, which was installed in 2022. It is also supporting Igiugig, Alaska, by providing local baseload power.
- **Big Moon Power** is preparing its "Falcon" tidal energy barge for deployment.
- **DP Energy** is advancing the 9 MW Uisce Tapa tidal project in Nova Scotia, planning to use 6 turbines.
- **Jupiter Hydro** is testing a 1 MW prototype in the Bay of Fundy, with plans for a 2 MW demonstration.
- **New Energy Corporation** aims to deploy an 800 kW project in the Bay of Fundy and develop two more tidal projects in Canada with 25 kW turbines, also expanding its presence to Southeast Asia with 5 turbines delivered to Singapore.
- **Nova Innovation** is moving forward with a 1.5 MW tidal project in Nova Scotia, with the first phase set for 2024 deployment.
- **Eauclaire Tidal** has partnered with Orbital Marine Power for deploying a 2.4 MW tidal turbine at FORCE.
- **Yourbrook** received funding for a tidal power project in British Columbia.
- **Oneka Technologies** is scaling up its wave-powered desalination technology, with significant funding and partnerships for deployments in Chile and California, emphasizing utility-scale solutions and emergency freshwater supply.

# EUROPE

## UNITED KINGDOM

- **Magallanes Renovables** has completed the engineering phase for its advanced ATIR 2.0 and secured tariffs for two significant projects: a 3 MW expansion in Wales and a 1.5 MW project in Scotland through the UK's CfD auctions.
- The **MeyGen** project in the Pentland Firth, operational since 2018 with four 1.5 MW turbines, has produced over 60 GWh of electricity by December 2023. Its next phase aims to add 50 MW of capacity by 2028.
- **Nova Innovation** installed two additional turbines in 2023, increasing capacity to 0.6 MW. The original three turbines, deployed in 2016/17, were decommissioned in 2023, marking a full lifecycle demonstration. Nova is now developing a new-generation tidal turbine.
- **Orbital Marine Power** secured a 30 MW project in Westray Firth, Orkney, and received 7.2 MW in CfD allocations for two projects to be deployed near the existing O2 tidal turbine. Orbital is also the technology partner for a project in Nova Scotia, Canada.
- **Mocean's** BlueX wave energy prototype operated for 10 months and showcased solar panel integration. Mocean received £3.2 million for developing its 250 kW Blue Horizon WEC.
- **AWS Ocean Energy** tested a 16 kW Waveswing wave energy converter and is seeking partners for a 2 MW prototype.
- **OceanEnergy** is set to demonstrate its 1 MW OE35 floating wave energy converter at EMEC.
- With 94 MW of tidal projects in the UK pipeline, commissioned by 2028, there's a significant growth in the sector, spurred by CfD allocations in AR4 and AR5.

## IRELAND

- The **Saoirse project**, a pre-commercial wave energy initiative off Ireland's west coast, plans to deploy a 5MW CorPower Ocean WEC array, named CorPack, contingent on obtaining the necessary approvals and grid connection. Simply Blue Energy and ESB Wind Development have entered into a 50:50 joint venture to develop this pioneering wave farm.

## SPAIN

- Since its commissioning in July 2011, **Mutriku Wave Power Plant** reached a significant milestone by generating 3 GWh of energy by 2023, with 266 MWh produced within the year alone.
- **WavePiston** is advancing its technology at the PLOCAN test site. The installation of collectors began at the end of the year, aiming for completion in early 2024. Once fully installed, the collectors will supply water for electricity generation and desalination.
- Selected for Phase 3 of the EuropeWave Programme, **Carnegie Clean Energy**, through its wholly owned subsidiary CETO Wave Energy Ireland, is set to deploy a scaled CETO device at the BiMEP test site.
- **IDOM** has been awarded development rights in Phase 3 of the EuropeWave project. The deployment of the MARMOK-A-5 at the BiMEP test site is scheduled for 2025.
- **Arrecife Energy Systems** throughout 2023 conducted extensive studies, both in the lab and in open sea conditions as part of the EuropeWave program, to further investigate their Trimaran system's capabilities.
- From March to November, **Rotary Wave** tested its low power full scale WEC (20 kW) in La Marina de Valencia producing 30,000 kWh.


## PORTUGAL

- **Corpower Ocean** successfully installed their first device in the Atlantic coast and it was in the waters from September to November 2023. This is the first prototype of a wave energy farm of 1.2 MW under development.

## FRANCE

- Two prototypes were tested at the Saint Anne du Portzic site: the **Legendre DIKWE** designed to be integrated into port infrastructure and the **Seaturn** concept, showcasing innovative approaches to wave energy conversion.
- The FloWatt project incorporating 7 x 2.5 MW tidal turbines of **Hydroquest technology** – 17.5 MW is planned to be installed in the Alderney Race, aiming to become operational in 2026.

## 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 thalossothermal loops connected to seawater heat pumps have been put into service and the buildings are being connected.

## ITALY

- The Mediterranean University of Reggio Calabria has been advancing their wave energy converter **REWEC3**, an OWC integrated into a vertical breakwater. REWEC3 is already operational in Civitavecchia port and is planned for inclusion in other sites.
- Polytechnic of Turin has been developing and testing **ISWEC**, a wave energy converter utilizing gyroscopic technology for energy generation in seas with mild climates like the Mediterranean. A revamped 250 kW unit was installed off Pantelleria in early 2023.
- **Gemstar** tidal kite developed by SeaPower s.c.r.l. has evolved since 2005 and aims for significant energy production, notably in the Strait of Messina, with a next goal to install a 300 kW prototype.

## NETHERLANDS

- **Tocardo** has completed their array testing and development programme of the Tocardo T-2 turbine, informing their next-gen T-3 series, which will be used in a 10 MW tidal energy project in Wales by HydroWing.
- **Water2Energy** demonstrated a grid-connected tidal turbine in Vlissingen, with aims to scale up and install more devices in water channels.
- **SeaQurrent** is progressing towards a 2024 demonstration of the TidalKite system in Ameland.
- **REDstack** continues to generate Blue Energy from the difference in salinity between river water and sea water at the Afsluitdijk since 2014, exploring applications in natural and industrial settings.
- **WECO** initiated a demonstration campaign at North Sea Farmers' OTS, leading to a long deployment period of their wave energy scale device, starting in 2024 to collect performance data.
- **Slow Mill** is preparing for the deployment of their Slowmill-40 for validation tests, with a full-scale wave energy converter planned to power households on Texel.
- **Dutch Wave Power** is aiming to deploy a wave energy demonstrator for extensive testing at the Offshore Test Site near The Hague by late 2024 or early 2025.
- **Symphony Wave Power** is advancing with dry tests of its innovative wave energy conversion technology and preparing for water testing in Scotland by 2025.

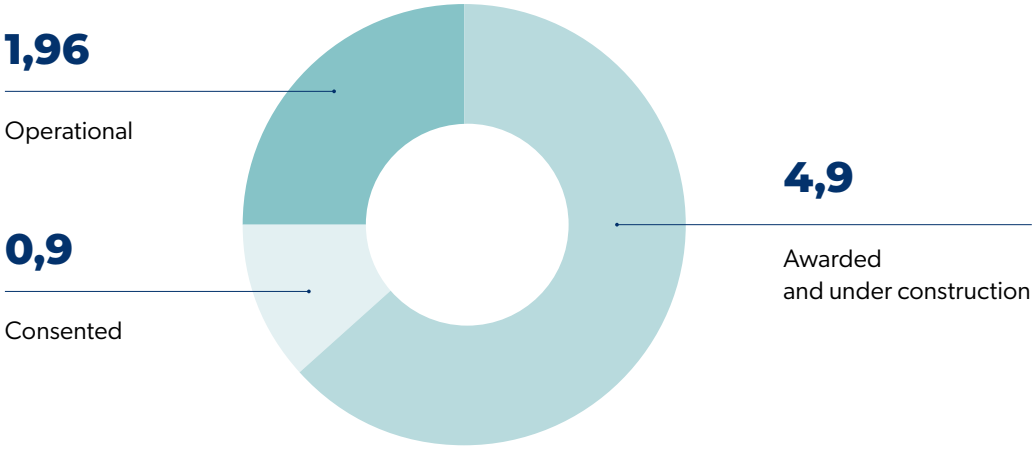
## DENMARK

- **Wavepiston** completed the installation of a full-scale prototype at the PLOCAN test site in Gran Canaria for power production and desalination, with commissioning planned for Q1-2024.
- **Exowave** is planning to deploy a 100 kW wave energy converter off the Danish west coast in the North Sea, with onshore testing in the first half of 2024 and offshore demonstration in the second half.
- **Floating Power Plant** announced the deployment of a semi-submersible platform off Gran Canaria in 2026, integrating wind, wave, and hydrogen systems for sustainable energy production.
- **Crestwing** received support from the Energy Technology Development and Demonstration Programme (EUDP) funds for upgrading the PTO system of the "Tordenskiold" prototype, with further offshore testing planned.
- **Weptos** is progressing towards the design of their 1 MW wave energy converter.

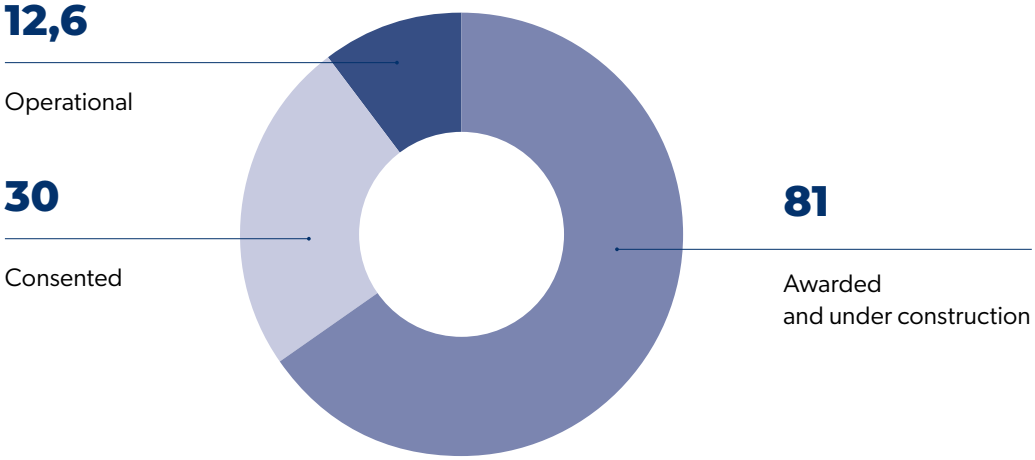
## SWEDEN

- **CorPower Ocean** successfully installed its first commercial-scale wave energy device, C4, in Aguçadora, Portugal, demonstrating strong durability against storms. It's set for redeployment in 2024 for performance assessment, with plans to launch 3 full-scale WECs by 2025 in Aguçadoura.
- **Minesto's** Dragon 4 tidal energy projects in the Faroe Islands continue to produce electricity, with preparations complete for the larger Dragon 12 system's installation.
- **Novige's** NoviOcean wave energy converter showed promising results at Coast Laboratory in the UK, aiming for a pilot deployment in Spain by 2025/2026.
- **Ocean Harvesting Technologies** is preparing for InfinityWEC's sea trials off Sweden's west coast.
- **OE Systems** is working on deploying their WaveMove prototype at 1:5 scale in 2024.

# 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** | Haishan Tidal Power Plant | Haishan Tidal Power | 250 kW |
| **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 |
| **China** | OTEC Floating OTEC device | Guangzhou Marine Geological Survey | 20 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 | - |

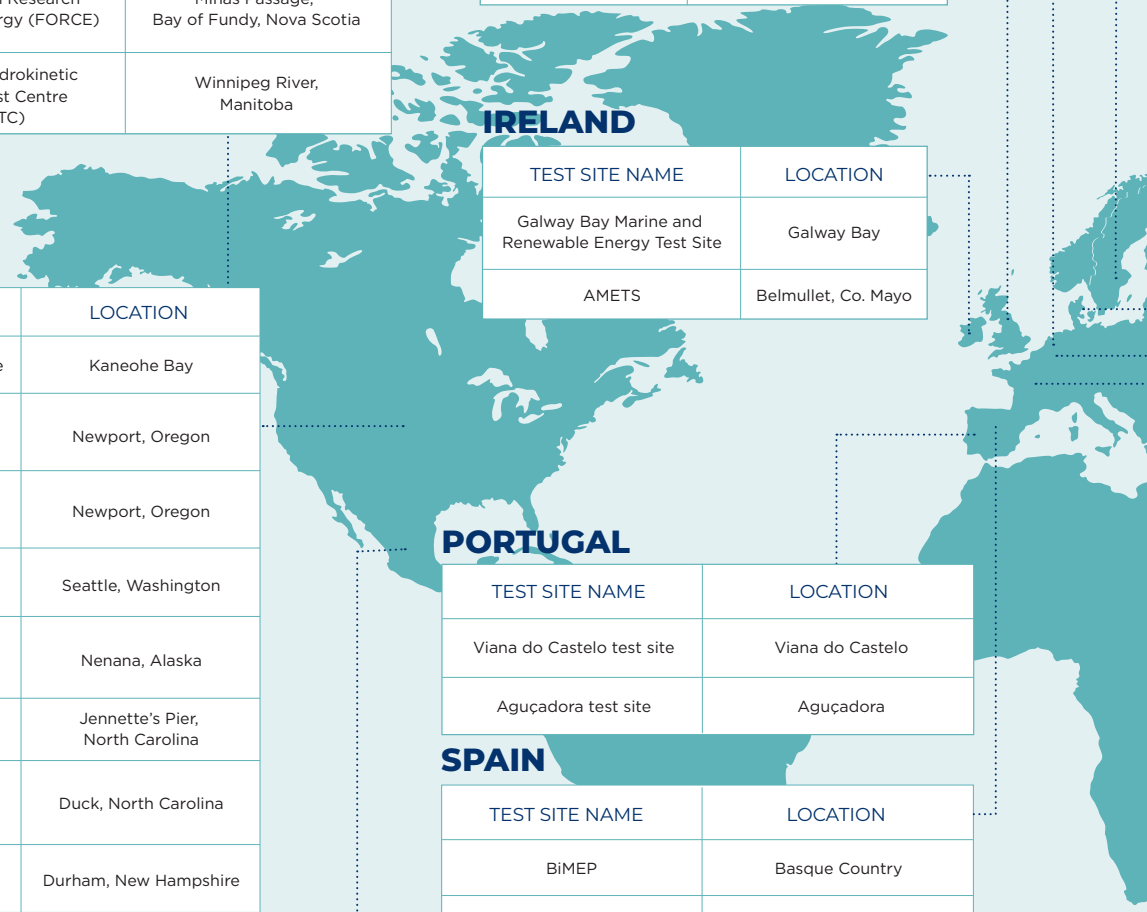
# Open sea test sites

Open sea testing facilities have evolved into crucial hubs for driving innovation and advancing ocean energy development across diverse countries. Recognized as key innovation centers, these facilities offer invaluable hands-on experience throughout the entire life cycle of prototypes. From installation and operation to maintenance and decommissioning, these facilities provide developers with a practical learning ground, fostering expertise and refining best practices.

Open sea testing facilities also serve as relevant support systems for standardizing procedures in the ocean energy domain. Each open sea test site worldwide provides unique services tailored to the specific needs of developers.

Working together to overcome these shared challenges, the IEA-OES has teamed up with the International WATERS network to develop a centralized online database that comprehensively catalogs information about the infrastructure, equipment, services, and testing programs available at each open sea test center. By consolidating this wealth of information, the database aims to facilitate seamless collaboration, knowledge exchange, and collective problem-solving within the ocean energy community.

This database was launched in 2023:
https://www.internationalwaters.info/



## 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 |

## 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 |

## 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 | Kaneohe Bay |
| 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 |

Photo courtesy of Nova Innovation

# 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.

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.

## Strategic Objectives 2022 - 2027

### Stimulate research, development and deployment

**Objective** — 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 to become involved

**Objective** — 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** — 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

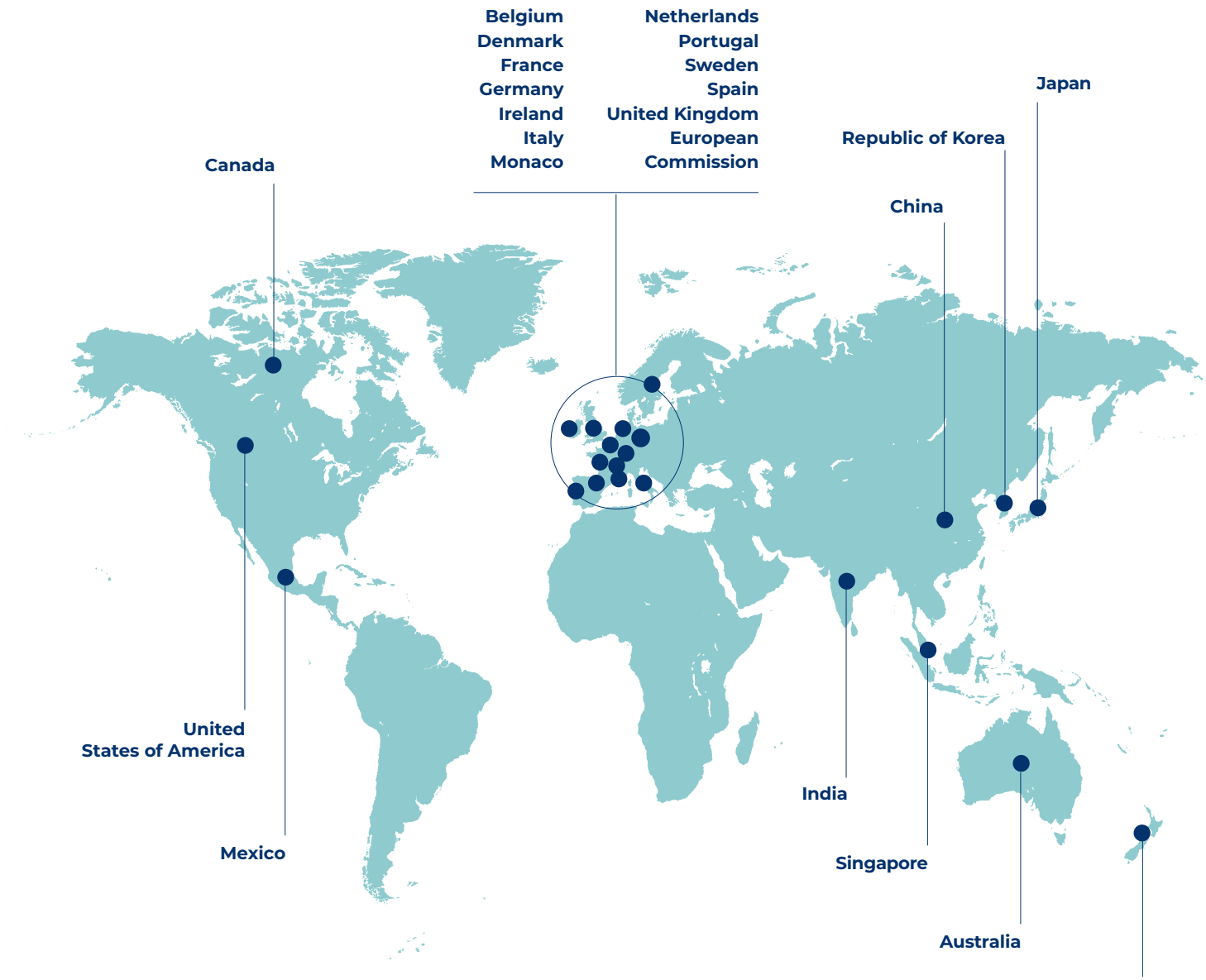
**Objective** — Enhance cooperation with stakeholders and international organizations to share expertise and pool resources

- 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 2023, 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 | Laboratório Nacional de Energia e Geologia (LNEG) |
| | Denmark | Ministry of Climate, Energy and Utilities, Danish Energy Agency |
| | 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 | France Energies Marines |
| | European Commission | European Commission |
| 2018 | Australia | Blue Economy Cooperative Research Centre (BE CRC) |

# 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 is based in Lisbon, Portugal and is run by WavEC Offshore Renewables.

In 2023, two ExCo meetings were held, one online and one presential:

- The 47th ExCo meeting was held as a Virtual meeting in two separate sessions on 22-23 March 2023 with 18 and 15 participants in each session.
- The 48th ExCo meeting was held on the 23-24 October 2023, in The Hague, in the Netherlands with 17 participants. In the same week, the Ocean Energy Europe (OEE) annual conference took place in the Hague.

48th ExCo Meeting, 23-24 October 2023, The Hague, the Netherlands

# Work programme

The Collaborative research work carried out by the OES is structured into specific projects, using two distinct approaches:

- **Large projects** conducted by a group of countries interested in the topic to which only participants in the project contribute. Whenever three or more contracting parties support a proposal and sufficient funding is raised, a new research project can be established. One of the proposing parties will usually become the Operating Agent, accountable for the delivery of the project and management of its dedicated budget. Participation by ExCo members is voluntary and usually by cost-sharing, task-sharing or both – "Bottom-Up" approach.
- **Small projects** of interest to all members, usually financed by the Common Fund, so all members are effectively contributing equally to these deliverables. Usually, an interested volunteer member prepares the Terms of Reference of any proposed Task. The delegates are invited to bid to participate in this work; applications are evaluated and selected by a sub-committee of 3-4 voluntary ExCo members. The work is then undertaken by a group of members - both through cost- and task-sharing - and may include participation of external experts – "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 | Germany | 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 | Portugal | Active |
| **9** | International Ocean Energy Technology Roadmap | UK | Active |
| **10** | Wave Energy Converters Modelling Verification and Validation | Denmark | Active |
| **11** | Investigation and Evaluation of OTEC Resource | Japan | 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.

# 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:

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

The IEA-OES is part of the Working Party on Renewable Energy Technologies (REWP). In 2023, IEA-OES participated in two IEA REWP meetings:

- 83rd REWP Meeting, hybrid meeting format, 15-16 March 2023
- 84th REWP meeting, India, 6-7 November 2023

The IEA-OES was also present at the 5th TCP Universal Meeting that took place on 25-26 October in Paris.


Photo courtesy of Orbital Marine Power

# 02.
# COMMUNICATION AND DISSEMINATION

# Overview in 2023

## January

## February

## March

**Reports**
Annual Report 2022

**Meetings**
IEA REWP83 Meeting
47th OES ExCo Meeting

## April

**Presentation**
IEA TC 114 Plenary meeting, Edinburgh

## May

**Reports**
Tidal Energy Highlights

## June

**Reports**
Wave Energy Highlights

**Presentation**
Seaenergy, France

**Webinars**
Ocean Energy Outlook in Europe

## July

## August

## September

**Webinars**
Ocean Energy Outlook in the USA & Canada

## October

**Reports**
Ocean Energy in Islands and Remote Locations: Interviews

Update of the International Evaluation and Guidance Framework for Ocean Energy Technology

**Meetings**
48th OES ExCo Meeting

## November

**Reports**
Ocean Energy and Net Zero: An International Roadmap

**Meetings**
IEA REWP84 Meeting

**Presentation**
China Ocean Energy Forum

## December

**Meetings**
COP28
Presentation of OES International Vision

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): the primary source of communicating the activities of OES, publications and general outputs of each task to a wider audience. It includes a restricted area for the ExCo delegates with information to be discussed in each ExCo meeting and a repository of all presentations in meetings.
- **Social media:** in order to increase the OES programme's visibility, news are also promoted through LinkedIn and twitter.
- **Annual Report**, the IEA-OES flagship document and a marker for industry development; it includes detailed information on national activities from country members.
- **Brochures** dedicated to wave and tidal current energy projects highlighting relevant recent developments in the sector.
- **Interviews to stakeholders**: in 2023 the key topic for the publication with interviews was "*Ocean Energy in Islands*".
- **Technical publications**: several publications were released during the year as outcomes of the Tasks and promoting ocean energy activities and projects.
- **Webinars**: country webinars were organised with presentations from OES Delegates on policies, R&D and technology development.
- **Participation in Events**: the delegates usually collaborate with international events promoting OES.
- **Video** available on YouTube channel about ocean energy for the general public.

# OES webinars

JUNE 2023

## Ocean Energy Outlook in Europe

Speakers:

- Matthijs Soede, Senior Policy Officer at European Commission & Chairman of IEA-OES
- Evdokia Tapoglou, OES Delegate, European Commission
- Nicolas Ruiz, OES Delegate to France, France Energies Marines
- Henry Jeffrey, OES Delegate to UK, Edinburgh University

SEPTEMBER 2023

## Ocean Energy Outlook in USA and Canada

Speakers:

- Matthijs Soede, Senior Policy Officer at European Commission & Chairman of IEA-OES
- Elisa Obermann, OES Delegate to Canada, Marine Renewables Canada – Discussing the Ocean Energy Landscape in Canada
- Tim Ramsey, OES Delegate to the USA, Department of Energy – Providing Insights on the Ocean Energy Landscape in the USA
- Katie Peterson, NREL – Presenting the new Worldwide WebGis Database on Ocean Energy

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/

# Interviews to stakeholders


## Ocean Energy in Islands and Remote Locations

The interviews explore the objectives, site selection, technical considerations, socio-economic impacts, environmental considerations, and future prospects of ocean energy projects in islands and remote locations. Together, they provide a comprehensive resource for those interested in the promising field of ocean energy in isolated communities worldwide.

**Featured Projects and Interviews:**

- King Island UniWave200 Project – Paul Geason (Australia)
- Nova Innovation Tidal Array at Shetland Islands – Kate Smith (UK)
- Minesto's Tidal Energy Kite at Faroe Islands – Patrik Pettersson (UK & Sweden)
- SABELLA D10 Project at Ushant Island – Robin Falcone (France)
- ORPC's RivGen Power System in the Village of Igiugig, Alaska – Stuart Davies (USA)

Experts share significant lessons derived from their experiences in implementing ocean energy projects in such unique settings. They offer guidance on applying these insights to future projects in similar contexts, emphasizing the importance of adaptable technologies and community-driven approaches. They also share their plans and aspirations for scaling up existing projects or replicating them in other isolated areas, reaffirming their commitment to sustainable energy solutions for communities worldwide. The publication includes 10 key messages that serve as guiding principles for the future of ocean energy in isolated regions.

# Highlights on ocean energy

The brochure titled **"Advances in Tidal Current Energy"** highlights significant achievements in tidal energy. It showcases various international tidal energy projects, reflecting the widespread interest and progress in this field.

The brochure, titled **"Advances in Wave Energy"** showcases significant progress in the wave energy sector. It details various international projects demonstrating advancements in wave energy technology. It covers prototypes, demonstrations, and deployment of wave energy devices in different parts of the world.

# International conference on ocean energy

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. The upcoming ICOE conference is scheduled for 18-20 September 2024 in Australia, hosted at the Melbourne Convention and Exhibition Centre by the Blue Economy CRC. The event was officially launched in 2023.

A notable aspect of the collaboration with ICOE is the IEA-OES's responsibility for the selection of the host country. This responsibility not only reflects a commitment to the success of ICOE but also demonstrates the IEA-OES influence in shaping the global discourse on ocean energy.


ICOE 2016
Edinburgh
ICOE 2012
Dublin
ICOE 2018
Normandie
ICOE 2014
Halifax
ICOE 2006
Bremerhaven
ICOE 2008
Brest
ICOE 2010
Bilbao
ICOE-OEE 2022
Donostia/San Sebastián
ICOE 2024
Melbourne
ICOE 2021
Virtual

# 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 2023 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 2024.

**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 2023, OES sponsored both the European Symposium and North America Symposium organized by INORE.

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.

The OES set up a collaboration with the International WATERS network to create a centralised global database, populated with information on the infrastructure, equipment, services and test programmes available at each test centre. In 2023, the database was public released during an International Test Centre Symposium hosted by EMEC in Orkney, Scotland, inviting operational and planned test sites from around the world to discuss common issues and agree actions for collaborating for the good of the marine energy sector.


International WaTERS 2023 workshop, 1-2 November 2023, Orkney, Scotland

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.

In 2023, the UK Delegate, Henry Jeffrey, represented the IEA-OES at the IEC TC 114 Plenary Meeting held in Edinburgh.

**WECANET**, a collaborative networking platform funded by the European commission (COST Action) that creates the space for dialogue between all stakeholders in wave energy. WECANET has a strong link with the OES task on wave energy numerical modelling (https://www.wecanet.eu/).

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.

Since 2022, OES has been collaborating with SEETIP Ocean on the collection of data from European countries.


Photo courtesy of SIMEC Atlantis Energy

# 03.

# KEY TASK ACHIEVEMENTS

# 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

The work of OES-Environmental continued through 2023, as part of phase 4, which will end in 2024. The tasks performed by OES-Environmental during 2023 included:

- Expanding the knowledge base on the environmental effects of MRE for the marine renewable energy (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 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 the environmental effects of MRE in "new topics" 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 and other underserved areas, 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.
- Developing, compiling, and disseminating educational resources on the environmental effects of MRE.
- Initiating the development of the *2024 State of the Science* report on the environmental effects of marine renewable energy development around the world.

Sixteen nations are currently participating in Phase 4 of OES-Environmental: Australia, Canada, China, Denmark, France, India, Ire-

land, Japan, Mexico, Monaco, Portugal, Singapore, Spain, Sweden, the United Kingdom (UK), and the United States (U.S.). The U.S. Department of Energy continues to lead the initiative for the US, with Pacific Northwest National Laboratory (PNNL), one of the Department of Energy (DOE)'s national laboratories, serving as the Operating Agent and implementing the project.

## 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 newsletter.

## Metadata on MRE Projects and Research Studies

OES-Environmental collects information on MRE developments for which environmental data have been collected. We call these records "metadata forms". The collection of past and present deployments stretches over a decade and is hosted on ***Tethys***. During 2023, PNNL staff continued to focus on collecting new metadata forms, with the support of Aquatera and help from OES-Environmental country analysts particularly project forms, and updating outdated forms for marine energy project sites and research studies (see OES-Environmental Metadata page on ***Tethys***). As of December 15, 2023, there are 203 metadata forms – 144 project sites and 54 research studies on ***Tethys***. 15 metadata forms were added and 45 updated within the last 12 months – 42 project sites and three research studies. Of the 198 metadata forms, 128 no longer require updates – 76 project sites and 52 research studies (projects were completed, never deployed, no longer in the water, or canceled; research studies were completed). The metadata forms continue to feed into the Monitoring Datasets Discoverability Matrix - OES-Environmental's interactive tool that classifies monitoring datasets from already permitted/consented projects, analogous industries, and research studies. These forms cover six key environmental stressors and are highlighted in the Management Measures Tool, OES-Environmental's online searchable tool to find management (or mitigation) measures used in past or current marine energy projects.

## Risk Retirement

During 2023, PNNL developed risk retirement processes for entanglement and collision risk stressor-receptor interactions and continued to build on the state of knowledge on displacement as a priority stressor of interest for MRE development. Guidance documents for both entanglement and collision risk were drafted and published on ***Tethys*** in early 2023. These documents are intended for use by regulators and advisors as they carry out their decision-making during permitting processes and by developers and consultants as they prepare consent and license applications. Additional country-specific guidance documents were completed and published on ***Tethys*** in 2023 for Japan, China, Spain, and Scotland.

## Outreach and Engagement

For existing audiences which includes international regulators, advisors, developers, consultants, and researchers, OES-Environmental continues to work on sharing updates on projects that have been consented, engaging with ongoing monitoring programs, and sharing research findings. In order to ensure that the work is reaching wide audiences, a combination of surveys, workshops, and development of resources were conducted to assist in applying background knowledge for the development of new projects and expansion of the industry.

## Working with OES-Environmental Analysts

During 2023, PNNL continued to organize and host meetings with the OES-Environmental country analysts every 3 months to coordinate cooperative work. During these meetings the OES-E community discusses current activities, receives input and feedback from OES-Environmental country analysts on these activities, and provides an opportunity to learn about current MRE development in each OES country. Each country analyst is asked to present an update on MRE development and environmental research in their respective countries and regions at least once every two years. The analysts were also heavily involved in the new topics focus of OES-Environmental (see New Topics About Environmental Effects section below for more details), acting as workgroup leaders and primary authors.

As part of their work with OES-Environmental, each analyst continually shares updated OES-Environmental activities and outreach information within their country, as well as providing contacts with organizations in their country

to identify relevant monitoring programs, data collection, research findings, and implementation of programs. The OES-Environmental analysts also engage their nations' regulators, reaching out to colleagues in their respective fields to initiate investigations into key areas of environmental effects that will assist the MRE industry.

## Workshops

OES-Environmental hosted two in-person interactive workshops on mitigation and monitoring efforts around marine energy devices on June 21, 2023, at the Ocean Renewable Energy Conference (OREC - https://tethys.pnnl.gov/events/ocean-renewable-energy-conference-2023) in Portland, Oregon, and on September 6, 2023, at the European Wave and Tidal Energy Conference (EWTEC - https://tethys.pnnl.gov/events/15th-european-wave-tidal-energy-conference-ewtec-2023) in Bilbao, Spain. These workshops provided multiple examples of monitoring and mitigation efforts completed around deployed MRE devices globally, reviewed monitoring best practices, and discussed monitoring technologies for collision risk and underwater noise. The OREC workshop, attended by 25 people mostly from the US, involved three breakout groups who discussed the consenting, planning, installation, and monitoring of two hypothetical wave energy sites and one tidal energy site. The EWTEC workshop, attended by 40 people from 12 countries, presented the monitoring measures, instruments, and data systems used for monitoring collision risk and underwater noise at existing marine energy projects. The workshop involved two breakout groups who discussed data collection and monitoring strategies for collision risk around tidal projects and underwater noise around wave projects, both at the scale of single devices and arrays.

## Webinars

On January 19, 2023, OES-Environmental delivered a webinar to the international marine energy community to share tools used for designing and siting marine energy projects. The tools highlighted in the webinar were OES-Environmental's Management Measures Tool, AZTI's Wave Energy Converter Environmental Risk Assessment (WEC ERA) Tool (Spain), and Kearns & West's Marine Energy Environmental Toolkit for Permitting and Licensing (US). The webinar included presentations describing each tool, as well as demonstrations of the use of each tool. This webinar served to announce the updated Management Measures Tool on ***Tethys*** and to highlight the new features. There were 256 individuals registered, representing 19 different countries, and 110 attendees. The recording has been viewed 136 times. The webinar was recorded and is available on ***Tethys*** here.

OES-Environmental hosted its annual public webinar "Coordinating and Disseminating Research on Environmental Effects of Marine Renewable Energy" on September 28th, 2023. The webinar provided updates on progress over the last year and insight into what is to come in the 2024 State of the Science Report. The important role of coordinating and disseminating research on the environmental effects of MRE and practical applications of OES-Environmental resources was discussed. Two presenters – one from PNNL's Triton initiative and another from the University of St. Andrews Sea Mammal Research Unit – presented their efforts to expand the understanding of underwater noise and collision risk stressors, respectively. There were 240 individuals registered, 95 attendees, and the recording has been viewed 111 times. This public webinar was recorded and is available here.

## Expert Forums

On September 26th, 2023, OES-Environmental hosted an expert forum on collision risk. The forum was organized to support drafting the collision risk section of the 2024 State of the Science Report. The goal of the event was to gather subject matter experts online to collect feedback on the draft collision risk section and move forward on the pathway to risk retirement. Experts on marine mammals, fish, and seabirds participated in the forum. There were 25 attendees for this event from seven countries.

On November 29th, 2023, OES-Environmental hosted an expert forum on social and economic effects of marine energy. The forum was organized to support the socioeconomic section of the 2024 State of the Science Report. The goal of the event was to collect feedback on the draft socio-economic section from subject matter experts and to provide insight into trends in socio-economic research that are pertinent to MRE. There were 18 participants at the forum from eight countries.

## Conferences

As a part of OES-Environmental's outreach, the team attended and presented at numerous conferences in 2023. These presentations and workshops catered to a variety of audiences and detailed the work being done by OES-Environmental (see Table 1).

**Table 1.** OES-Environmental outreach events at conferences in 2023.

| Date | Event | Contribution |
|---|---|---|
| **4 April 2023** | Ocean Visions Biennial Summit | **Presentation:** Supporting solutions to climate mitigation, energy, and coastal resilience |
| **21-22 June 2023** | Ocean Renewable Energy Conference (OREC) 2023 | **Workshop:** Monitoring and mitigation for MRE devices<br>**Panel presentation:** Moving from science to permitting for environmental effects of marine renewable energy |
| **3-7 September 2023** | European Wave and Tidal Energy Conference (EWTEC) 2023 | **Presentations:**<br>• Environmental effects of MRE: advancing the industry through broad outreach and engagement<br>• Siting tidal energy projects through resource characterization and environmental considerations<br>• Choose your own marine energy adventure game: collision risk<br>**Workshop:** Instrumentation for environmental monitoring around marine energy devices |
| **11-14 September 2023** | International Council for the Exploration of the Sea (ICES) Annual Science Conference 2023 | **Presentation:** Effects and management implications of emerging marine renewable energy technologies |
| **4-6 December 2023** | Marine Renewables Canada Conference | **Presentation:** Understanding risks of tidal energy – environmental effects from the international perspective |

## *2024 State of the Science* report

During 2023, OES-Environmental initiated the development of the *2024 State of the Science* report on the environmental effects of marine renewable energy development around the world. The team assessed the scientific literature that has been contributed since 2020, determined the content of the report, developed an annotated report outline, identified authors for each chapter of the report, drafted initial chapters and began the review process, involving a wide range of experts. Table 2 details the outlines of the report including the section and chapter titles.

The final draft of the 2024 State of the Science Report will be released at OREC 2024 which takes place on 20 – 23 May 2024 in Portland, Oregon, U.S. This draft will be publicly available for comments during six weeks. These comments will then be incorporated into the final version of the 2024 State of the Science Report, which will be released at the International Conference on Ocean Energy (ICOE) 2024 which takes place on 17 – 19 September 2024 in Melbourne, Australia.

**Table 2.** Final outline of the *2024 State of the Science* report on environmental effects of marine renewable energy development around the world.

| Section | Chapter |
|---|---|
| Executive Summary | |
| **A.** Introduction | **1.** Marine Renewable Energy and Ocean Energy Systems |
| | **2.** Status of Environmental Effects for Marine Renewable Energy Projects Around the World |
| **B.** Updating the State of the Science | **3.** Marine Renewable Energy: Environmental Effects<br>• Collision Risk<br>• Underwater Noise<br>• Electromagnetic Fields<br>• Changes in Habitat<br>• Changes in Oceanographic Systems<br>• Entanglement<br>• Displacement |
| **C.** Human Dimensions of Marine Renewable Energy | **4.** Social and Economic Effects of Marine Renewable Energy |
| | **5.** Stakeholder Engagement for Marine Renewable Energy |
| **D.** Resources to Advance Marine Renewable Energy | **6.** Strategies to Aid Consenting Process for Marine Renewable Energy<br>• Risk Retirement and Data Transferability<br>• Adaptive Management<br>• Marine Spatial Planning<br>• Additional Tools to Aid Consenting |
| | **7.** Education and Outreach around Environmental Effects of Marine Renewable Energy |
| | **8.** Marine Renewable Energy Data and Information Systems |
| **E.** Beyond Stressor-receptor Interactions | **9.** Beyond Single Marine Renewable Energy Devices |
| | **10.** Environmental Effects of Marine Renewable Energy in Tropical and Subtropical Ecosystems |
| **F.** Looking Ahead | **11.** Summary and Path Forward |

# 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 this Task have been successfully realized through the implementation of workshops, discussions, webinars, and collaborative efforts, culminating in the publication of four comprehensive reports:

### This Framework guides the technology development process, presenting:

- **Six technology development stages:** the development process split into defined stages from Concept Creation to Commercial-Scale Array Demonstration
- **Stage Activities**: clearly defined engineering and project activities for each stage, providing consistency in expectation between developers and investors
- **Nine Evaluation Areas:** the key areas in which the success of technology should be measured, in order to demonstrate progress and achieved performance
- **Evaluation Criteria (or metrics):** the parameters used to evaluate success in each Evaluation Area

**This is a joint publication from the IEA-OES and the International Electrotechnical Commission (IEC).**

The pathway from early-stage technology to commercial exploitation requires a varying mix of support and guidance, from public sector funding through various types of private investment. The goals of these supporters are wide ranging, from socio-economic growth and domestic infrastructure requirements, through to pure financial gain. Despite the differing objectives of these parties, consensus among them on the development path and the fundamental characteristics of an attractive technology enables the support provision to operate more efficiently and with a higher likelihood of success. This reports discusses four such sources of guidance and is written by the providers who are collaborating to ensure they deliver a complementary and coherent set of recommendations: IEA-OES, IEC TC 114 and IECRE.



There are many standards and specifications that guide technology developers through the detailed scientific and engineering processes required in the ocean energy sector, but there was no guidance available for public funders wishing to support this technology development activity.

**This publication help funders to:**

- Design effective programmes using a stage gate process
- Maximise the efficiency of public funding by enabling effective technology selection decisions
- Accelerate ocean energy development by focusing funding on the best technologies

This updated report, published in 2023, represents a significant evolution of the framework, now including Environmental Acceptability, a key consideration in technology development. **This addition is an example of the document's responsiveness to user feedback and emerging industry needs.**

# WAVE ENERGY CONVERTERS MODELLING

**COORDINATOR**
Dr. Kim Nielsen, Development v. Kim Nielsen

**PARTICIPATING COUNTRIES**
Canada, China, Denmark, France, Ireland, Republic of Korea, The Netherlands, Belgium, Portugal, Spain, Sweden, UK, and 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 2023

Work is ongoing studying an OWC the "OWC case" and a rigid body in the shape of a sphere the "Sphere case". During 2023 the Danish partners obtained funding from EUDP for another 3-year period of the OES Task 10 (the third three-year project) and the new EUDP project is coordinated by Aalborg University (Morten Kramer). During 2023 Ramboll applied to the Teamer program in the USA for funding for NREL and Sandia to perform specific CFD calculations using Open foam and Dual SPHysics contributing to the sphere case simulations under OES Task 10. The Teamer project application has been granted and work is ongoing in collaboration with the OES Task 10 partners interested in CFD simulations.

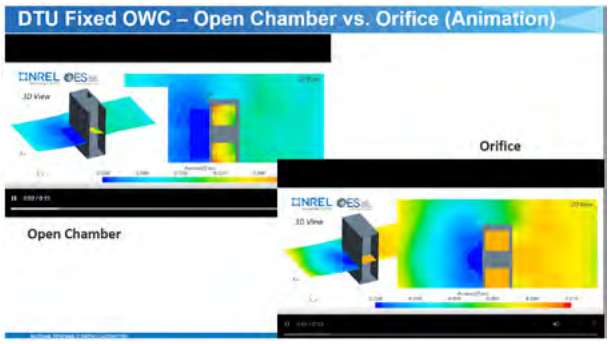
**The OWC case:** In 2023 the numerical simulation of the DTU OWC small-scale model test has continued. This test case was prepared in 2021 with a single OWC chamber placed on the side wall of a 0.6-meter-wide wave flume, as shown in the figure below. In this way the test represents a mirrored periodic array of chambers with a distance between there centerlines of 1.2 meters.

During 2023 progress has been made on the numerical simulation of these challenging valve cases and results compiled in a paper that will be submitted to the Journal of Ocean Engineering and Marine Energy.

The oscillating motion of the water in the chamber has been tested in three different configurations:

- Air is damped via an orifice in both upstroke and downstroke.
- Air is drawn through the orifice on the downstroke and vented through a valve on the upstroke.
- Air is pushed through the orifice on the up-stroke and vented through a valve on the downstroke.

The three setups have been measured. During 2023 progress has been made on the numerical simulation of these challenging valve cases and results compiled in a paper that will be submitted to the Journal of Ocean Engineering and Marine Energy.




Visualization of NREL's CFD simulations of the Double chamber

**The Sphere case:** is running in parallel, the development of test cases using a sphere to validate the hydrodynamic loads related to radiation and diffraction as well as waves generated in the basin has continued with an experimental setup at Aalborg University.

To measure wave loads on a fixed sphere the AAU team has developed a new set-up, with the sphere suspended between pretensioned wires – three to the test basin floor and three lines to a frame above the basin. The experimental data is used to validate the accuracy of the vertical and horizontal wave exciting force predicted using different numerical models such as:

- Linear potential flow models (including weakly non-linear effects, like fully non-linear Froude-Krylov forces (including higher order harmonics).
- Higher order potential flow models (possibly including drag/slamming etc.)
- RANS models
- Other models

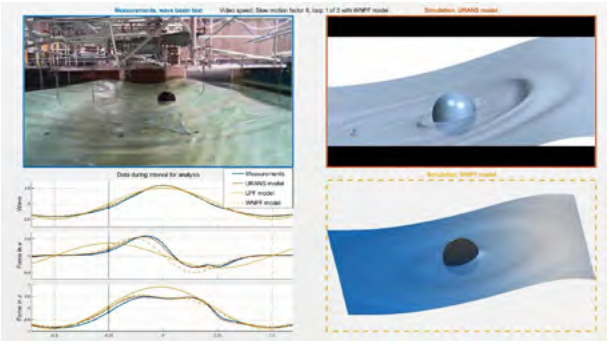


Illustration of the experimental setup of the pretensioned fixed Sphere

## ACKNOWLEDGEMENT

The project was initiated with supported by Bob Thresher from NREL and today Thanh Toan Tran is the point of support. Thanks also to Morten Kramer and Jacob Andersen from Aalborg University, and Harry Bingham from DTU for their lead on presenting the results in recent and upcoming journal papers. Thanks to the WECANET for support and cooperation, to EUDP for their continued support of the Danish team, and to the Swedish Energy Agency for supporting the Swedish team. Thanks to Teamer for the support to the project.

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# 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

Given that the majority of Earth is covered with water, interest in extracting tidal energy to generate electricity is growing. The development and refinement of methods for this purpose are gaining traction among researchers. In the realm of tidal power resources, identifying suitable sites and estimating potential energy yield are crucial steps. Countries with extensive coastlines featuring bays and estuaries experience significant variations in tidal currents. These areas, characterized by high current velocities, are prime locations for converting tidal energy into electrical power. Efforts are underway to develop models that identify locations with high flow velocities and analyze these areas for average power density. This process facilitates the selection of sites for tidal power plant installation.

However, the accuracy of these models depends on the quality and detail of the input data. Moreover, the reliability of model predictions varies with the hydrodynamic phenomena they are designed to simulate, ranging from three-dimensional simulations to two-dimensional depth-averaged simulations. Despite these differences, such models are invaluable for identifying potential sites for tidal energy extraction, subject to further verification by field data.

The widespread use of various tools and techniques to assess tidal resources underscores the need for standardized modeling practices. This standardization can boost confidence among stakeholders in the viability of tidal energy. Consequently, the International Tidal Energy Working Group, under the IEA-OES, focuses on conducting resource studies, sharing methodologies, and striving to establish a standardized approach to modeling tidal energy extraction.

The primary objective of this initiative is to develop a guideline report on tidal energy resource modeling. This involves a common case study examining various factors and comparing different modeling strategies. The effort will also compare model predictions with experimental data and discuss assumptions used in the models, such as the impact of seabed friction.

Ultimately, the project aims to discuss and develop a standardized methodology for tidal energy modeling. This includes examining factors that influence the modeling of ocean sites and the assumptions underlying these simulations. Formed as an international collaboration of tidal energy researchers, the working group is dedicated to accurate modeling and establishing guidelines for tidal energy resource assessment.

Workshops to facilitate this collaborative effort are organized and hosted by the Energy Research Institute @ NTU (ERI@N), Singapore, via teleconferencing on a semi-annual basis, drawing participants from international tidal energy teams worldwide.

## ACHIEVEMENTS

The workshop organized in 2023 focused on developing a standardized methodology for modeling tidal energy harnessing, incorporating the study of various influencing factors and underlying assumptions in simulations. It aimed at enhancing the accuracy of tidal energy resource modeling and establishing guidelines for this process. The scope of work included:

- Mapping tidal resources globally using ocean models for potential case studies.
- Characterizing ocean conditions with observation data and coupled wave-tide models to optimize resilience and yield.
- Making power predictions to assess suitability for end-users through techno-economic analysis.

The objectives were to:

- Showcase different ocean modeling strategies used by international experts.
- Discuss challenges encountered in tidal resource modeling.
- Compare results from various ocean models for both temperate and tropical case studies, using common input and validation data, to address concerns in tidal resource modeling.
- Understand how to present tidal model results according to EMEC guidelines.
- Introduce available databases for ocean modeling.
- Highlight the range of ocean models available, both commercial and open-source.

This comprehensive approach aimed to foster a collaborative international effort in improving tidal energy resource assessment and modeling, contributing to the broader adoption and optimization of tidal energy technologies.

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

- In temperate waters, surface roughness influences the estimates of tidal kinetic energy in the area identified for stream-array implementation with a reduction of available power by 30% by rising $z_0$ from 3.5 to 50 mm.
- Waves reduce tidal velocities by a small amount in 40 m water depth which is mainly attributed to waves increasing the apparent bed roughness. A strong linear relationship was found ($R^2$ of 94%) between the wave height and the net power available over a tidal cycle (both theoretical and practical tidal Stream Energy resource). Therefore, the wave climate, including wave direction (relative to the current), should be considered when selecting sites suitable for tidal Stream Energy arrays.
- Turbine arrays could cause significant changes in the flow field of a location. Increased numbers of rows and turbines deployed resulted in a deficit of about 0.5–0.6 m/s. This corresponds to decreases in current speeds of about 25 – 30 % average. Stronger current velocities was observed on the sides, closer to the banks due to the geometry of the strait and the proximity of turbines to the banks and near-shore shallow waters.

As a further work, the international working group identified an Indonesian site of tropical waters with available validation data as case study. The International members were asked to include the various additional parameters such as wind wave generation (as mentioned earlier) in the new case study and were asked to simulate based on their chosen codes and with their modelling expertise for numerical comparison study. The teams completed the simulations, and a high level technical report was submitted to OES. Further joint journal publications in Top tier journals are in progress.

# 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 work, a comprehensive final report, is anticipated to be published in 2024, offering valuable insights into the economic aspects of OTEC implementation.

# OCEAN ENERGY AND DESALINATION

**PROJECT TEAM**

This study was commissioned to Pure Marine Gen and coordinated by Dr Purnima Jalihal

## BACKGROUND

The surge in global population, industrialization, climate shifts, and water crises has spurred a depletion of freshwater resources. Policymakers are increasingly turning to desalination processes, utilizing seawater to meet rising domestic and industrial water needs.

Despite the development of 18,500 desalination plants worldwide, challenges persist, including complex process design, brine discharge management, capital investments, scaling, chemical treatments, and environmental threats. Integrating renewables could revolutionize desalination, providing cost-effective clean drinking water. Among the innovations is a Low Temperature Thermal Desalination (LTTD) plant powered by Ocean Thermal Energy Conversion (OTEC), a solution tailored for water-scarce islands.

Challenges arise in implementing such technologies on islands, requiring attention to logistics, land availability, ecological sensitivity, work methodologies, and weather constraints. Notably, wave-powered desalination and tidal systems are gaining traction. Examples include an OWC-based wave energy system powering Reverse Osmosis desalination and Quebec's ONEKA proposing a wave-to-pressure system, bypassing electrical conversion.

These advancements underscore the evolving landscape of desalination, emphasizing sustainability and technology to address global freshwater demands.

## OBJECTIVES

The main aim of the task is 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 will require an exhaustive examination of existing literature, research publications, industry requirements, and relevant findings from experimental and demonstration projects.

The overall scope of this activity involves the following tasks:

- **Objective 1:** 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.
- **Objective 2:** Document the current status and power requirements of desalination plants and ocean energy sources (OTEC, waves, tides). Include ongoing research in IEA-OES regions, highlighting the socioeconomic impact and technological challenges associated with implementing these projects.

Despite the development of 18,500 desalination plants worldwide, challenges persist, including complex process design, brine discharge management, capital investments, scaling, chemical treatments, and environmental threats. Integrating renewables could revolutionize desalination, providing cost-effective clean drinking water.

# 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 $CO_2$ 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 is 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.

## METHODOLOGY

The methodology for developing the new vision by the IEA-OES involves a multi-faceted approach addressing several critical areas to chart a definitive pathway towards achieving the sector's future targets. Here's a breakdown of the steps involved in this methodology:

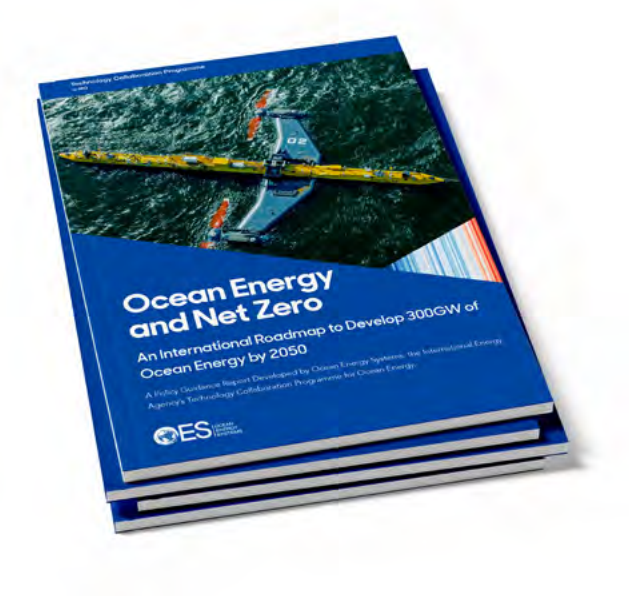
- Summary of both the present and future global development plans for the sector, including barriers to commercialisation, supply chain evolution and technology improvements.

- Thorough evaluation of both technological and non-technological challenges. As the sector progresses towards higher Technology Readiness Levels (TRLs), identifying and addressing these challenges becomes crucial.
- The methodology includes seeking and incorporating guidance from relevant bodies and experts to ensure that the sector receives the support needed for technological innovation. This step is vital for facilitating the advancements required to overcome identified challenges and propel the sector forward.
- Highlighting the potential economic benefits, such as job creation and gross value added to national and international economies, is another key aspect of the methodology. Clear presentation of these figures is essential for garnering continued financial and legislative support, demonstrating the sector's potential contribution to economic growth and sustainability.
- Overall, a series of recommendations will be formulated and put forward to accelerate the development of tidal stream and wave technologies.

## ACHIEVEMENTS

In alignment with the COP28 gathering, the IEA-OES luached 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.

Ocean energy, including but not limited to wave and tidal stream, is poised to play a pivotal role in the global energy landscape. By 2050, the ocean energy sector forecasts a global total installed capacity of 300GW. 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.




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.

Ocean energy, including but not limited to wave and tidal stream, is poised to play a pivotal role in the global energy landscape. By 2050, the ocean energy sector forecasts a global total installed capacity of 300GW. 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.

## Key policy recommendations from the IEA-OES Roadmap

**1.** **Market support is the foundation of a comprehensive policy programme:**
Led at a country-by-country level, **the immediate application of a long-term and sustained market support is key** to strengthening and accelerating deployments in the ocean energy sector. The exact form of which a policy pull mechanism takes should be decided at a national level, however ensuring it is applied immediately, continuously and visibly is key to ensuring that all nations feel the shared obligation to follow a similar route. A market support mechanism, supporting a technology that has achieved an optimum cost reduction rate, **should be considered a priority of any government wishing to establish a commercial ocean energy sector** and is vital to stimulating ocean energy deployment across the globe.

**2.** **Accelerated innovation is key to enabling long-term cost reductions:**
**A well-funded and sustained technology innovation programme**, actively pursuing international collaboration, **is vital to ensuring that technological innovation occurs at a significant rate** and helps to **lower the overall investment** required to provide a long-term market support mechanism. Any technology innovation programme should be focussed to target identified challenge areas that will increase overall device performance and reduce development, deployment maintenance and disposal costs. Technology innovation programmes are well-suited for international collaboration, where **active engagement in collaborative learning across multiple nations is essential** to drive accelerated cost-reductions.

**3.** **An optimal balance of market support & technology innovation funding must be struck:**
While long-term support for market support mechanisms is key to achieving a commercial ocean energy sector, the overall cost of attaining this target can be **massively reduced through the application of sustained innovation**, achieved through coordinated support for technology innovation programmes. Striking the correct balance between both market support and technology innovation programmes is a complex task, **but it is vital to minimising the overall associated costs**.

**4.** **Immediate action on infrastructure development is vital:**
While existing infrastructure is well-positioned to handle the short-term requirements of the sector, the **rapid expected growth will require large-scale global infrastructure development projects to begin immediately**. Opportunities to share space, resources and skills with the offshore wind sector should be actively investigated, given the significant overlap in technology. This large-scale global infrastructure development will need to begin immediately, to ensure that long lead times and unexpected delays, potentially resulting from a shortage of workers or raw materials, **do not hinder the progress of the overall ocean energy sector**.

**5.** **The regulatory and legislative framework should help, not hinder:**
The ocean energy sector should be **underpinned by a robust and efficient regulatory and legislative framework** that provides the levels of support required to ensure that sector growth happens in line with forecasted timelines. The role of an effective regulatory and legislative framework in helping to overcome these challenges efficiently **should not be understated**. Where possible, individual nations should seek to form collaborative frameworks that acknowledge and incorporate instances of best practice, identified standards, clear consenting and make use of novel processes, such as adaptive management.


Photo courtesy of Tocardo

# 04.

# INTERNATIONAL ACTIVITIES ON OCEAN ENERGY

# AUSTRALIA

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## OVERVIEW

The year saw continual progress with developments in ocean energy, policy and enabling R&D initiatives to strengthen the expansion of Australia's blue economy. Key achievements for 2023 highlighted in this report include the:

- Continued development of supporting policy and consultation for offshore wind to support the Offshore Electricity Infrastructure Act 2021 which facilitates and regulates the development of the offshore renewable energy sector.
- The Australian Government leading the development of a Sustainable Ocean Plan for Australia that will set a shared vision for their ocean to 2040 and identify actions to help grow their ocean economy sustainably.
- Considerable progress with wave energy projects, with Carnegie Clean Energy securing funding and contracts through EuropeWavePCP for prototype deployment in Spain.
- Wave energy deployments planned in 2024, including the MoorPower™ pilot off Fremantle waters WA, led by Carnegie Clean Energy, and the M4 wave energy project off Albany WA, led by the University of Western Australia, and new companies emerging such as WaveX and Marine Renewable Energy Solutions (MarRen) planning activities in Australia and overseas.
- Research activities at the Blue Economy CRC, MERA, several Universities and other bodies to further support ocean energy developments and industry growth.
- Blue Economy CRC to host the International Conference on Ocean Energy (ICOE) in 2024 in Melbourne, Australia – the first time ICOE will be in the southern hemisphere.

## SUPPORTING POLICIES FOR OCEAN ENERGY

### National Strategy – Policy Support

In 2023 major developments in climate, environment, and energy policy at both the Commonwealth and State level were progressed. Each Australian state has stated or committed to reaching

net zero by 2050 or earlier. To support these aims, the Net Zero Economy Agency commenced in the Commonwealth Department of the Prime Minister and Cabinet in July 2023 as a precursor to establishing a legislated Net Zero Authority.

## Notice of Proposal to Declare Areas for Offshore Wind

Underpinned by the passing of the Offshore Electricity Infrastructure Act 2021, the supporting legislation passed in 2022, and the declaration in 2022 of the Gippsland, Victora area, the Hunter area in NSW was declared suitable for offshore renewable energy in July 2023. Other regions that will be considered for future offshore wind energy projects that are at consultation and proposal stage include the Illawarra in NSW, the Southern Ocean region off Portland in Victoria, the Bass Straight region off Northern Tasmania, with decisions pending for declaration of the Indian Ocean region off Perth/Bunbury in WA.

## Preliminary Decisions on Feasibility Licenses for Offshore Wind Areas in Bass Strait off Gippsland, Victoria

Preliminary decisions on feasibility licences were announced in December 2023. Of the 37 applicants, 6 are now under preliminary consideration for the granting of feasibility licences; 6 are under preliminary consideration to progress through the overlapping application process, where applicants will be invited to revise and resubmit their applications to remove overlap with other equally meritorious applicants; a preliminary decision has been made to not to proceed to grant a feasibility licence in relation to the remaining 25 applications, on the basis that they are not as meritorious as overlapping applications, subject to further consultation with those applicants.

## Powering Australia Plan

The Government has committed $23 billion to grow and modernise Australia's electricity grid, boosting energy performance and supporting electrification. Powering Australia policies include:

- Rewiring the Nation, which provides $20 billion in concessional loans and equity for investment in transmission infrastructure projects.
- Powering the Regions Fund, which provides more than $1.3 billion to support the decarbonisation of existing industries and the development of new clean energy industries.

## Hydrogen Headstart Program

In October 2023 the Government announced it will invest $2.0 billion in the new Hydrogen Headstart Program, providing revenue support for large-scale renewable hydrogen projects through competitive hydrogen production contracts.

## National Reconstruction Fund

The National Reconstruction Fund was established by the Commonwealth Government's to build Australia's industrial base, with up to $3 billion from the $15 billion NRF directed toward clean energy investments such as wind turbine manufacturing and hydrogen electrolysers.

## Capacity Investment Scheme

Following on from the announcement of the Capacity Investment Scheme (CIS) in 2022, in November 2023 the Australian Government announced an expansion of the scheme to target a total of 32 GW of new capacity nationally to be rolled out from 2024 to 2027, made up of:

- 23 GW of renewable capacity representing $52 billion in investment
- 9 GW of clean dispatchable capacity representing $15 billion in investment (an additional 7.9 GW to the 1.1 GW already in progress through the first stage of the CIS).

## Australian Sustainable Ocean Plan: DCCEEW (Dept of Climate Change, Energy, Environment and Water)

The Australian Government is leading the development of a Sustainable Ocean Plan for Australia, with a draft plan anticipated by the end of 2024, that will set a shared vision for their ocean to 2040 and identify actions to help grow their ocean economy sustainably. The plan is national in scope and builds upon Ocean Decade Australia's White Paper, which is the output of Australia's inaugural Ocean Business Leaders' Summit held in March 2023 which identifies an urgent need for comprehensive ocean policy.

## Ocean Business Leaders' Summit in Sydney, March 2023

Members of the Australian Ocean Energy Group (AOEG) and Blue Economy CRC participated in the Ocean Business Leader's Summit, led by Ocean Decade Australia. Blue Economy CRC and AOEG were also invited and participated in several stakeholder engagement sessions for

the Sustainable Ocean Plan, providing opportunities to incorporate ocean energy into the plans for ocean governance, government leadership, planning & coordination and ongoing management.

### National Marine Energy Standards Committee – EL066

The National Marine Energy Standards Committee completed its third full year of operation after forming in 2020. It is a Mirror Committee to the International Electrotechnical Commission on Marine Energy Standards, better known as IEC TC 114 Marine Energy – wave, tidal and other water converters. The Australian committee sits within Standards Australia which is the nation's peak non-government, not-for-profit standards organisation.

### Ocean Energy Policy Initiatives by Australian States and Territories

In March and December 2023, the Victorian Government released two further Offshore Implementation Statements to further outline the government's plans for the establishment of an offshore wind industry. Victoria also joined the Global Offshore Wind Alliance as the first sub-national member. In New South Wales (NSW), the state-government controlled development body EnergyCo continued early stage planning of Renewable Energy Zones including two that are adjacent to proposed Commonwealth Offshore Zones for wind energy. Additionally, EnergyCo has identified priority transmission projects aimed at supporting the overall progress of energy developments in the region and commenced construction of transmission and battery projects. The Tasmanian Government continued to support the development of major national renewable energy projects through the Tasmanian Renewable Energy Action Plan including Project Marinus, and commenced stakeholder engagement for the declared Renewable Energy Zones. In Western Australia, the State Government has announced in November 2023 it will invest more than $700M to upgrade the State's main electricity network and unlock renewable energy generation opportunities, putting Western Australia on track to become a global renewable energy powerhouse. A Lower Carbon Grant Program will be established in 2024 with an endowment of $40M to provide funding for local innovations and projects which support decarbonisation in Western Australia. The funding will also support the development of a Greentech Hub to support and grow local emerging and established green technology businesses and drive innovation in Western Australia.

## 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

Several national funding programs are in place which support ocean energy developments in Australia. Programmes with a track record of supporting ocean energy activities include:

### Commonwealth Funding Bodies

The Australian Commonwealth funding bodies were described in detail in previous reports and support continues from the following bodies including:

- The Australian Renewable Energy Agency (ARENA) who support the acceleration of pre-commercial innovation through funding opportunities.
- Cooperative Research Centre (CRC) program which supports Australian industries ability to compete and produce, by helping industry partner with the research sector to solve industry identified issues, including funding for the Blue Economy CRC detailed further below.
- National Energy Resources Australia (NERA) wound up its existing activities in July 2023. However, NERA continued its startup support programmes including "Lets Pitch 2023" held at the AOG Conference in Perth in March 2023, where Wave Powered Generator (WPG) technology developer WaveX, was one of the winning pitches and subsequently formed part of a consortium of cleantech businesses on an AusTrade delegation to CleanTech Asia Forum in Singapore in May 2023.
- Australian Research Council (ARC) which administers several active ocean energy projects across several Australian universities, including new projects in 2023 to the University of Western Australia, RMIT, Swinburne University, the University of Adelaide and the University of New South Wales.
- Clean Energy Finance Council (CEFC) aiming to catalyse private sector investment in Australia's clean

energy sector and provide concessional funding for interconnector projects.

## State Funding

Apart from public funding programs provided by the Commonwealth, State Government funds are actively contributing to the research and development (R&D) initiatives in the field of ocean energy. Examples include the ongoing commitment from the Western Australia (WA) Government to support Marine Energy Research Australia (MERA). Additionally, the WA Government Department of Jobs Tourism Science and Innovation (JTSI) has supported WaveX with local funding for tank testing and enhanced numerical modelling through MERA at the University of Western Australia (UWA). WaveX was also the recipient of funding through Blue Gravity Ideastarter Fund, a program for innovative blue economy ventures supported by JTSI, HOSX, Spacecubed / Lotterywest and City of Cockburn in Western Australia, to further the non-technical aspects of the business, such as Market Analysis and Competition Landscape Reporting. Additional financial backing is also being extended by the Victorian Government through the Energy Innovation Fund (EIF) for offshore renewable energy projects, and the New South Wales (NSW) Government's Clean Technology Research and Development Grants Program.

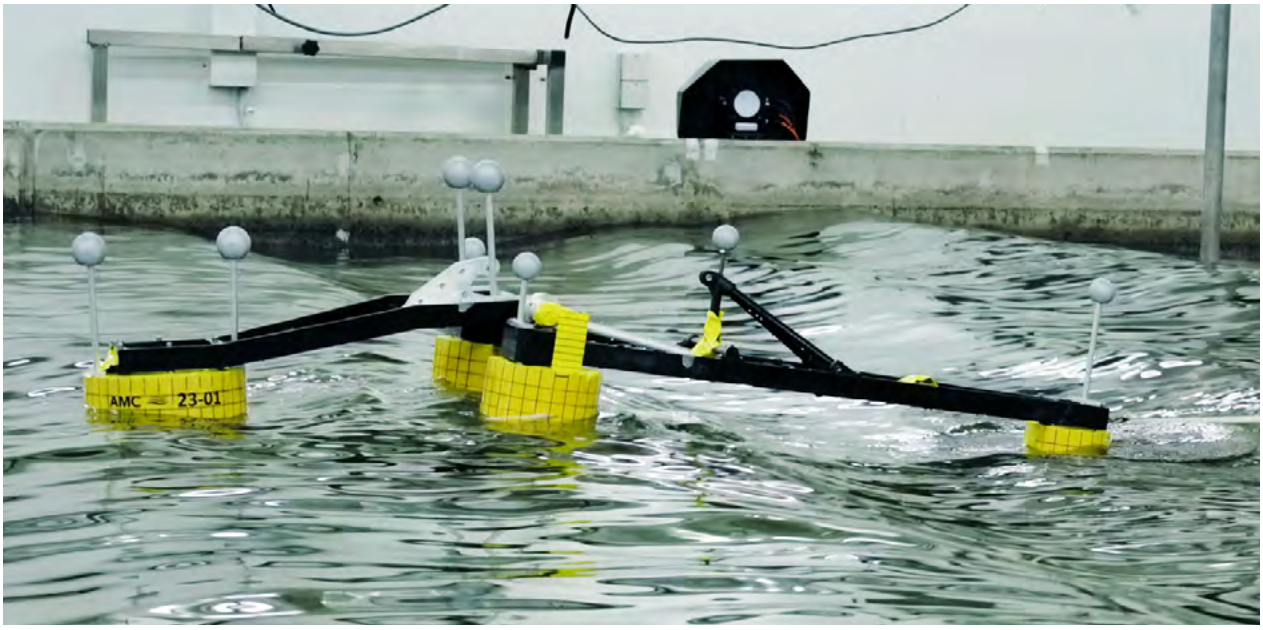
**RESEARCH & DEVELOPMENT**

Significant investment in ocean energy R&D projects occurred in 2023 through the following initiatives:

## Blue Economy Cooperative Research Centre

The Blue Economy CRC-Co Ltd is an independent not-for-profit company established under the Australian Government's Cooperative Research Centre Program. Australia is positioned adjacent to the world's largest markets for seafood and energy and has enormous opportunity to grow sustainable marine industries – our blue economy. Established in 2019, Blue Economy CRC is one of the largest funded cooperative research efforts (> AU$300 million program) and brings the aquaculture, offshore engineering and renewable energy sectors together to address the challenges of offshore food and energy production. During 2023 the Blue Economy CRC continued to build on its impressive portfolio of projects to actively support and underpin the growth of ocean energy in Australia. Highlights of progress in 2023 include:

- Commissioning 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 ocean energy MoorPower™ pilot off Fremantle waters WA, led by Carnegie Clean Energy, and the M4 wave energy project off Albany WA, led by the University of Western Australia, were also readied for commissioning, with testing of a scaled M4 model in the Australian Maritime College, University of Tasmania's Model Test Basin completed in 2023.
- Led by Carnegie Clean Energy, the MoTWEC project developed and tested a novel energy storage element, the Mooring Tensioner, enabling the use of rotary electrical generators for WECs, which the company will apply to its developments of their CETO technology.
- Permit approvals for the Blue Economy CRC Hydrogen Microgrid, which will see the Blue Economy CRC introduce the first Green Hydrogen DC Microgrid to Tasmania in 2024, with plans to move future production offshore powered by offshore renewable energy.
- Projects with the University of Queensland's Civil Engineering researchers continued to develop solutions for co-location and integration of offshore aquaculture (fish and seaweed) farms and renewable energy (wind, wave, solar) farms. A seaweed farm powered by solar energy is being trialled in Cebu waters in the Philippines by The Climate Foundation. Ongoing developments also include structural/hydrodynamic modelling and optimisation of the integrated/co-located aquaculture and renewable energy farms.
- A project to identify a framework for Marine Spatial Planning. This project has engaged with over 100 external stakeholders during 2023 through focus groups, the project Advisory Committee and one-on-one meetings to understand the needs of government, industry and organisations.
- A data infrastructure project to bring together digital experts, data scientists, engagement specialists,




The M4 wave energy device undergoing testing in the Australian Maritime College, University of Tasmania's wave basin

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.

- Development of new risk-management procedures and decision-making tools to address complexities in the design, commission and operation of new ocean energy technologies, mainly due to the uncertainties involved with planning and managing their life cycle, given the newness of concepts, randomness of the offshore environment and lack of reliable procedures.
- Ethics values and social licence research that will produce a world-first account of the ethical values at stake in the Blue Economy.
- Pre-conditions for the Development of Offshore Wind Energy in Australia, which is developing resources to support industry pursue ethical best practice, improve knowledge of policy and regulatory arrangements, and understand social values and supply chain constraints.

## Marine Energy Research Australia (MERA)

Marine Energy Research Australia (MERA) is a research centre of the University of Western Australia (UWA), established late 2017 to support the development of offshore renewable energy in Australia and worldwide. Its HQ is located in Albany in Southwestern Australia, with a node in Perth on the UWA campus. The centre is supported financially by the WA State Government through the Department of Primary Industries and Regional Development and by the Blue Economy Research Centre. In 2023, MERA has continued its engagement with several projects in wave energy and in offshore wind, while progressing the Albany M4 ("Moored MultiModal Multibody") Project. In realtion to wave energy:

- A 1/5 scale of the M4 wave energy device developed by the University of Manchester. Manufacturing has been undertaken locally and is nearly completed (Jan 2024). The PTO is currently being dry tested with completion expected by the end of February 2024. Environmental approval, mooring design and permitting are all completed, such that deployment is scheduled for early September 2024. The wave energy converter will operate for six months. Data about wave conditions, the hydrodynamic response of the device, the energy produced, and its environmental impact will be made available in the public domain.
- UWA, CorPower Ocean and the Australian Ocean Energy Group have worked together through 2022 and 2023 on the Australian Research Council Linkage Project "Efficiently unlocking full-scale WEC dynamics for industry cost reduction" (LP210100397). This program aims to develop efficient methods for nonlinear WEC hydrodynamics. In the past year new simple models have been developed and tested on

bespoke experiments conducted at UWA, with results presented at IWWWFB and EWTEC. Further details available at: https://oceanenergygroup.org.au/unlocking-wave-energy-converters-hydrodynamics/

- WaveX (former ROC-Tech) is pursuing its collaboration with MERA with additional 1:100 physical model testing of the D-Spar wave energy converter to be undertaken at the UWA Coastal and Engineering Laboratory in 2024.

## AZURA Ocean Technologies

AZURA Ocean Technology continued its commercialisation program with the core generation technology additionally adapted into modular floating systems (up to 200kW) and infrastructure fixed systems (up to 25kW) as a further market-led development emerging from their larger floating systems. Coupled with the onboard desalination system development, AZURA can now provide a robust solution for many applications.

## Marine Renewable Energy Solutions (MarRen)

Marine Renewable Energy Solutions (MaRen.Energy) has been established following a restructuring of MAKO Tidal Turbines and Altum Green Energy businesses. The technology and management team from ALTUM have formed MaRen, meaning this new group benefits from over 40 years' of cumulative experience in tidal energy and will be able to re-establish launch customer and Government relationships in Australia and Southeast Asia. Driven by the needs of potential customers, over time MaRen intends to develop energy solutions based on other forms of marine renewable energy as well as energy storage options. MaRen is based in Sydney, Australia with a presence in Singapore and the Philippines. The company will continue the engineering approach of MAKO and Altum - small modular horizontal axis tidal turbines to be deployed in arrays for coastal communities and businesses as well as in rivers and canals.

## Deloitte Emissions Solutions (DES)

In 2023 Deloitte Australia collaborated with ExxonMobil Australia to review emerging large-scale Ocean Carbon technologies suitable for Australian offshore deployment. The strategic opportunity to advance commercialisation of next-generation ocean climate technologies via use of under-utilised or 'end of life' operational assets, requires further assessment but could potentially launch commercially viable new markets by co-locating offshore energy and mariculture infrastructure, in addition to ocean alkalinity enhancements and direct ocean capture of carbon dioxide.

## 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 2022-2023.

## Carnegie Clean Energy

Carnegie Clean Energy and its international subsidiaries continue progressing its core wave energy technologies, including CETO and MoorPower along defined commercialisation pathways. In 2023, Carnegie secured contracts and funding to deliver the deployment of a CETO prototype at the Biscay Marine Energy Platform (BiMEP) in the Basque Country. Carnegie's subsidiary CETO Wave Energy Ireland was awarded €3.75 million (A$6.0m) EuropeWave Phase 3 contract to deploy CETO following a competitive selection process. This was complemented by the subsequent award of €1.2m (A$1.9m) funding to Carnegie's subsidiary Carnegie Technologies Spain from the Spanish Government's Renmarinas Demos funding scheme. The Spanish funding will support further enhancements to the CETO deployment at BiMEP. Carnegie and its subsidiaries will deliver these funded activities together under a joint endeavor named the ACHIEVE Programme. The ACHIEVE Programme will deliver a full design, manufacture, deployment and operations of a CETO unit at BiMEP. CETO deployment is planned for 2025 followed by 2 years of operations. These contract awards are a strong validation of the CETO research and development work undertaken by Carnegie and its subsidiaries. In 2023, this included delivery of a Front End Engineering Design, tank testing, power take-off testing and additional associated commercial and certification activities. As part of the EU-funded EuropeWave Program, the CETO technology was independently verified by industry experts and ranked first overall across categories including levelized cost of energy (LCOE), generation performance, reliability and survivability.

During the year, Carnegie also significantly advanced the development of its MoorPower technology. Carnegie's MoorPower technology is a spin-off that incorporates core aspects of CETO technology and know-how into a novel wave energy converter system for use in offshore energy demand applications. The initial market is the

offshore aquaculture sector. As the aquaculture sector moves operations further offshore, new challenges are encountered to access clean and reliable energy. In October 2021, Carnegie launched the $3.4m MoorPower Scaled Demonstrator Project with support from the Blue Economy CRC and a consortium of partners including aquaculture players Huon Aquaculture and Tassal. This important project will take MoorPower from concept to an operating prototype and allow future users to see the technology in action. During 2023, the MoorPower scaled demonstrator was manufactured, assembled and tested at Carnegie's research facility in North Fremantle, Western Australia with deployment completed and operations underway in January 2024.

Carnegie also delivered significant research and development activities related to components of its CETO and MoorPower technologies including through the Mooring Tensioner Project with the Blue Economy CRC and a consortium of partners. Carnegie and its subsidiaries also continue active engagement with international projects including being awarded CETP funding for its participation in the WECHULL+ Project, investigating novel concrete materials for wave energy converters.

## WaveX

WaveX is a private Western Australian company that relaunched the Wave Powered Generator (WPG) IP held by ROC Technologies, in January 2023. Since then and in close collaboration with UWA, WaveX' proprietary WPG's have accelerated up the TRL scale, with the successful deployment of their 1:40 scale model in a representative environment of the Swan River. This project was part of the Riverlabs program run by UWA, a program supported by Woodside Energy Ltd through FutureLabs, where the device reliably generated mechanical power via an eddy current brake PTO (passive). This was only possible due to the fundamental design of the WaveX WPG – namely no foundations, no underwater moving parts, and simple yet robust hull, mooring and power cable design leveraging existing oil and gas concepts.

In 2024, WaveX has plans to deploy a much larger prototype in an open-water environment, to fully demonstrate their PTO integration (active), structure survivability, shared anchors and dynamic inter-array cables, with a philosophy of leveraging known solutions to minimize development risk. This will be accounted for in a Statement of Feasibility, currently engaged with an independent 3rd party to deliver by Q2 2024.

## Wave Swell Energy Ltd

As reported in the previous annual OES Report, Wave Swell Energy (WSE) successfully operated its UniWave200 demonstration unit at King Island, Tasmania, during 2021 and 2022. The WEC was decommissioned in late 2022. As part of its funding agreement with the Australian Renewable Energy Agency (ARENA), the unit has since been successfully re-floated and towed from its deployment location on crown land south of the Grassy Harbour to an industrial site north of the harbour, where it was resettled on the shoreline. All components of the WEC have subsequently been recycled and/or repurposed (this process is near to complete).

The project proved to be a major success, with WSE having demonstrated both the technology and the company's ability to design, construct, transport, deploy, operate, maintain, decommission and, finally, recycle the WEC, thereby demonstrating the technology is capable of a full sustainable lifecycle.

Pacific Northwest National Laboratory (PNNL), part of the US Department of Energy, collaborated with WSE in regard to the project, analysing a full wave-to-grid conversion efficiency of close to 50% or more for waves greater than 1 metre in height. Data from the project and analysis of the results is currently part of paper lead-authored by PNNL that has been submitted for publication to a major international peer-reviewed journal on renewable energy.

During 2023, WSE continued to make commercial progress, developing a pipeline of potential future projects, with strong engagement in the US and the Pacific Islands. The company has also been in commercial negotiations with a European based developer regarding licencing of the technology for an offshore floating application and has been working with US authorities with respect to integration of the technology into coastal structures (CSI). 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. WSE has also been working with a large US technology conglomerate in regard to combining it's technology with a highly novel concept to increase generation output and, therefore, reduce the levelised cost of energy. This work is ongoing.

WSE commissioned ITP Renewables, a specialist renewable energy engineering group, to assist in modelling and optimising an autonomous renewable grid with a combination of wind, solar, wave and storage. The modelling

demonstrated that inclusion of WSE's technology in the mix resulted in an 11% reduction in the cost of electricity, a 14% reduction in the capital cost and an 11% reduction in the lifetime operating cost. The modelling revealed the addition of the diverse wave resource resulted in a material reduction to the volume of generation capacity and storage required to deliver electricity reliably to meet demand.

## Australia-China Joint Research Centre of Offshore Wind and Wave Energy Harnessing: University of Adelaide

The Australia-China Joint Research Centre for Offshore Wind and Wave Energy Project was officially completed at the end of 2023. The JRC was led by the led by the University of Adelaide and Shanghai Jiao Tong University. The Centre included collaboration with five Australian partners, supported by the Australian Department of Industry, Science, Energy and Resources, the Chinese Ministry of Science and Technology and six Chinese partners. Research outcomes include:

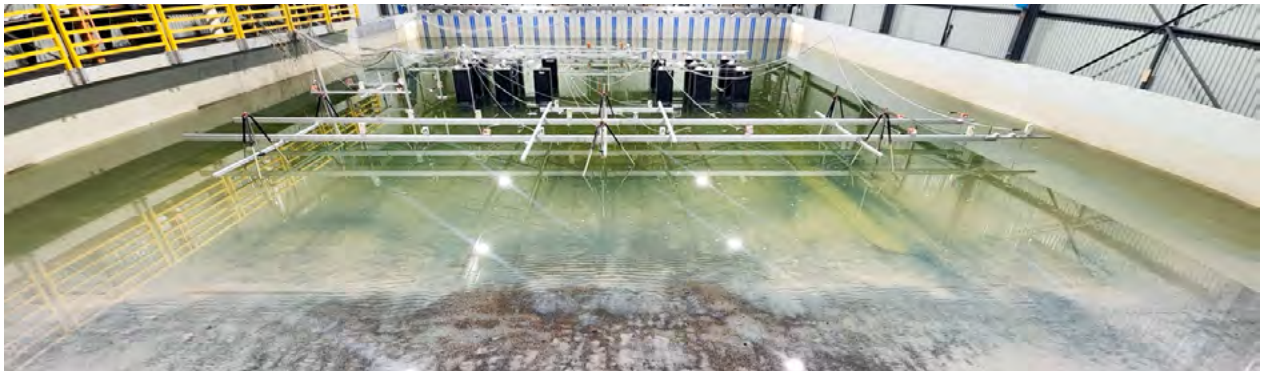
- Scientific site selection protocols and techno-economic cost models were developed for wind and wave energy harnessing.
- Optimal sea sites in Australia for hybrid power harnessing were identified.
- Techno-economic analysis of energy variability and energy storage system for a co-located offshore wind and wave farm demonstrated solid evidence in the cost and performance benefits of hybrid wind- and wave- power generation in some Australian sea sites.
- Scale-model wave tank experiments on co-located wind- and wave- power harnessing system were conducted at Australian Maritime College's Model Test Basin in intermediate sea conditions, and at Shanghai Jiao Tong University's Multi-Function Towing Tank in deep sea conditions.

## Australian Research Council Industry Fellowship Project on Wave Energy: University of Adelaide

Supported by the Australian Research Council and in partnership with Carnegie Clean Energy, the University of Adelaide (project IE230100545) will 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 that will effectively predict, model and respond to wave activity, maximising energy production and resulting in an overall reduction in the cost of renewable energy.

## Australian Research Council Linkage Project on Wave Energy: Swinburne University

Funded by the Australian Research Council, 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 Adelaide 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 has commenced, 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.



Experimental testing of optimised arrays of OWCs in the University of New South Wales Water Research Laboratory 3D wave basin

### Australian Research Council Discovery Project on Wave Energy: RMIT University

Supported by the Australian Research Council (ARC), RMIT's Discovery Project grant aims to develop a novel speed amplified flux-switching electromagnetic wave energy harvester that takes advantage of the hydrodynamic forces from ocean surface heave movement to convert wave kinetic energy to electrical energy. A prototype of the novel speed amplified mechanism was built and validated by lab testing in 2022, with the publication of results in 2023.

In addition to the abovementioned projects and research, many of the Universities continue to be active in ocean energy R&D (and supervising Masters and PhD students).

**TECHNOLOGY DEMONSTRATION**

## Projects in the Water

### WaveX

In close collaboration with UWA, WaveX' proprietary WPG's was accelerated up the TRL scale with the completion of a successful deployment of their 1:40 scale model in a representative environment of the Swan River, Perth, Australia.

## Projects Planned for Deployment

### Carnegie Clean Energy

Planned and current deployments by Carnegie Clean Energy include: Carnegie's subsidiary CETO Wave Energy Ireland and Carnegie Technologies Spain will deploy a CETO unit at BiMEP in the Basque Country, Spain in 2025 with a contract from the EuropeWave PCP Programme and support from the Spanish Government's Renmarinas Demos Programme. Carnegie is planning the deployment of their scaled demonstrator of the MoorPower (a CETO-derived wave energy technology for the aquaculture sector) in January 2024 in Western Australia. Carnegie is also currently testing the MoT-WEC mooring tensioner technology in North Fremantle, Western Australia, with testing undertaken in 2023 and still ongoing in 2024.

MoorPower built in 2023 and deployed in January 2024 operating at the offshore test site at Rous Head, Fremantle WA

### Marine Energy Research Australia (MERA), UWA

MERA is planning the deployment of the M4 ("Moored MultiModal Multibody") wave energy converter (WEC) in King George Sound, Albany, demonstrating the capacity to power the aquaculture industry in early September 2024.

### Marine Renewable Energy Solutions (MarRen)

MaRen is planning the initial demonstration of its products at a tidal site and a canal system in the Philippines in 2024. MaRen is also in discussions with potential customers in Australia, Singapore and elsewhere in the Philippines.

### AZURA-EHL Australia

AZURA secured an MOU for an energy generation system for deployment for a Pacific nation and is part of a collaborative microgrid development project for a shore-based aquaculture facility. With additional technical project scoping and FEED underway for applications within Australia, New Zealand, and the Pacific, 2024 will be a breakthrough year for AZURA.

### WaveX

WaveX in collaboration with UWA is in the early stages of planning for the W5 project using WaveX WPG 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 a number of hardware and control system innovations for the first time at prototype scale, in addition to researching the collaborative nature of wave energy, wind and solar via an onshore micro-grid.

## SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

### WaveX

WaveX via its existing oil and gas industry contacts and membership of the Australia-Korea Business Council (AKBC), WaveX 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 2025/2026.

### National Marine Energy Standards Committee – EL066

The Marine Energy standard committee continued work in standards development, with members collaborating with international expert committees on tidal resource assessment and characterizations and biofouling of marine energy devices.

## RELEVANT NATIONAL EVENTS

# Relevant Events in 2023

### OMAE 2023

The Blue Economy Symposium was organised for the first time within the 42nd OMAE 2023 conference during June 2023 in Melbourne, Australia. Research Director Irene presented a keynote lecture on the Challenges of the Blue Economy for Sustainable Offshore Development followed by 32 lively presentations covering many aspects of the Blue Economy CRC research activities including aquaculture farm infrastructure, offshore renewable energy devices, offshore development policies, and legislations and ethics.

### Blue Economy CRC's 4th Annual Participants Workshop

The Blue Economy CRC's 4th Annual Participants Workshop, themed 'IMPACT' was held in May 2023 in Perth, Australia. A total of nearly 160 attendees from our participant organisations attended the workshop in person, which consisted of two full days of sessions, discussions, panels and networking with a third day offsite visiting our local partner facilities.

### Blue Economy CRC Webinar Series

During 2023 the Blue Economy CRC hosted 5 webinars on ocean energy, offshore wind and development opportunities. See webinar recordings at: https://blueeconomycrc.com.au/webinars/.

### Blue Economy CRC PhD Summer School

The first Blue Economy CRC PhD Summer School was held in Albany, Western Australia in January 2023. All PhD Scholars were invited to attend with opportunities to present their work, learn from keynote lectures, participate in workshop/group activities, and expand their professional networks.

### Oceans Decade Ocean Business Leaders' Summit – Sydney

The 2023 Ocean Business Leaders' Summit brought together 257 participants representing First Nations, industry, business, investment and finance, philanthropy, community, science, engineering, innovation and young people. The Summit also included State and Federal Government representatives, defence and representation from the Pacific community.

## Relevant Events Planned for 2024 in Australia

- The highly anticipated 10th International Conference on Ocean Energy (ICOE 2024), 17-19 September 2024 in Melbourne, Australia.
- Australian representation at the 2024 Technical Committee No. 114: Marine Energy – Wave, tidal and other water current converters Plenary, 15-19 April 2024 in Jeju, South Korea.
- Blue Economy CRC 5th Participants Workshop, 4-6 June 2024 in Kingscliff, Australia.
- 30th International Towing Tank Conference (ITTC), 22-27 September 2024 in Hobart, Australia. The ITTC Specialist Committee for Marine Renewable Energy will provide an update on the state-of-the-art hydrodynamic testing of ocean energy devices.

# BELGIUM

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## OVERVIEW

Ghent University is coordinating 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 targets 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 a pioneer in investigating parks of energy devices.

Ghent University is a 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.

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 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 a 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 $CO_2$ 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 energy.

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 the 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 the 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 partners, 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.

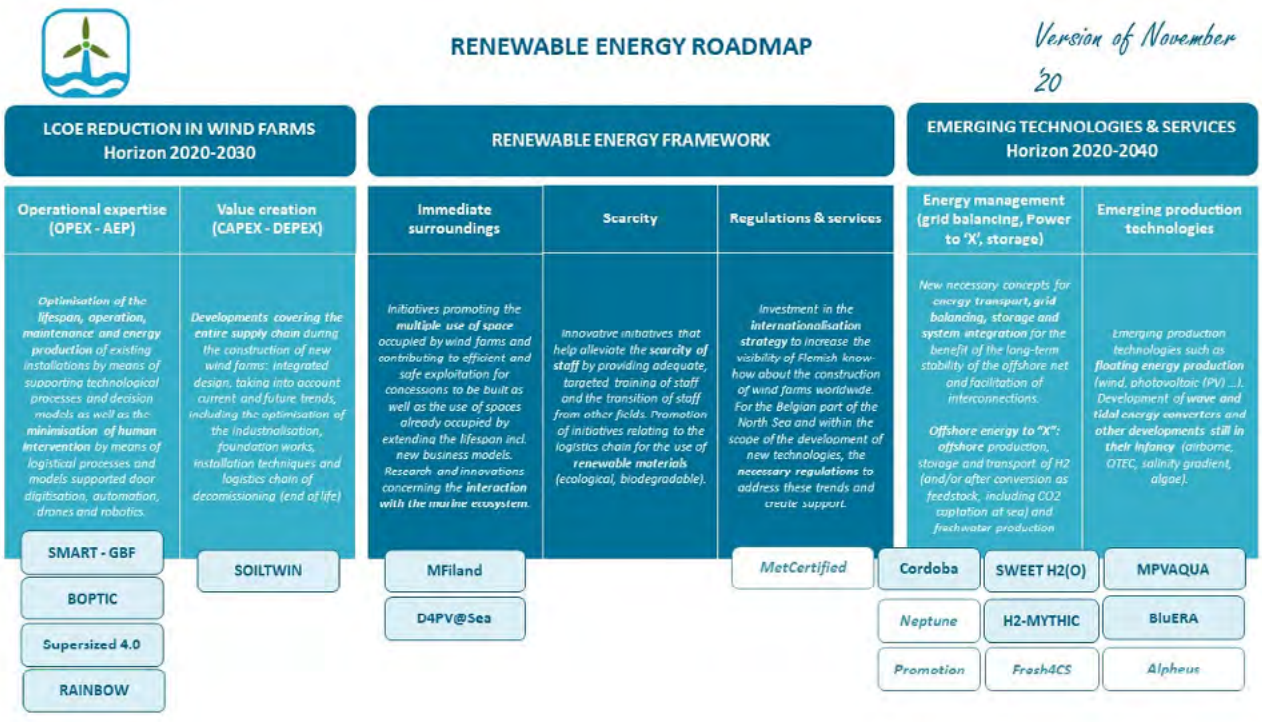
The Blue Cluster is focused on innovation and internationalization trajectories to stimulate blue growth but acts also as a sector federation defending the stakes of a sustainable blue industry. The cluster is an important networking organization bringing together many companies that work (often partially) 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. Below the Renewable Energy Roadmap of the Blue Cluster is presented.

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 projects "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 under 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 Energy Transition Fund aims at research and development in the field of energy. The budget of the Energy Transition Fund for the year 2022 amounts to 25 million euros, which can be awarded as a subsidy to projects that meet all relevant conditions and relate to research and development, investment in research infrastructure, innovation clusters or innovation by SMEs.

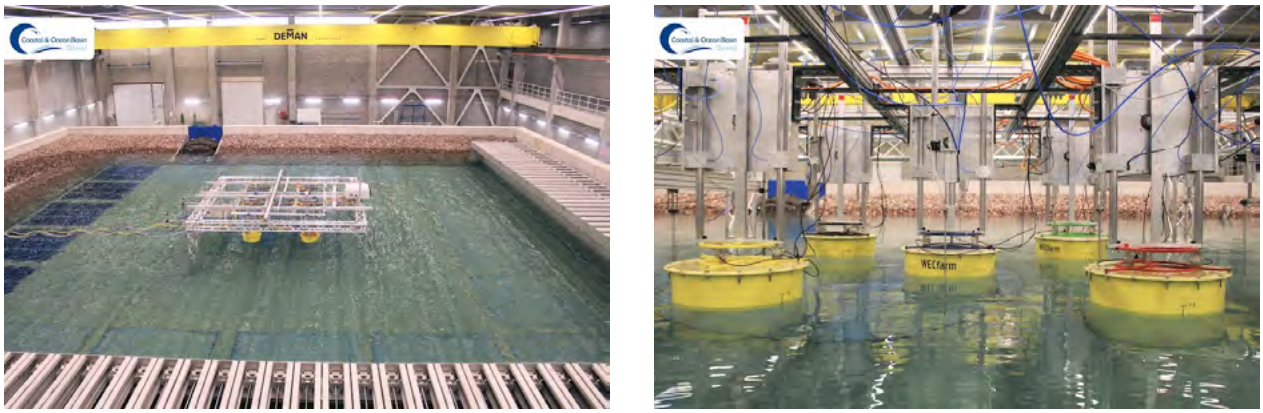
The Blue Cluster has a dedicated budget from Flanders Innovation & Entrepreneurship to co-fund industry driven R&D projects on the subject of offshore renewable energy. The projects have to involve at least 3 Flemish companies and have to respond to the roadmap mentioned above. The annual budget for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

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 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/basins 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. 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.



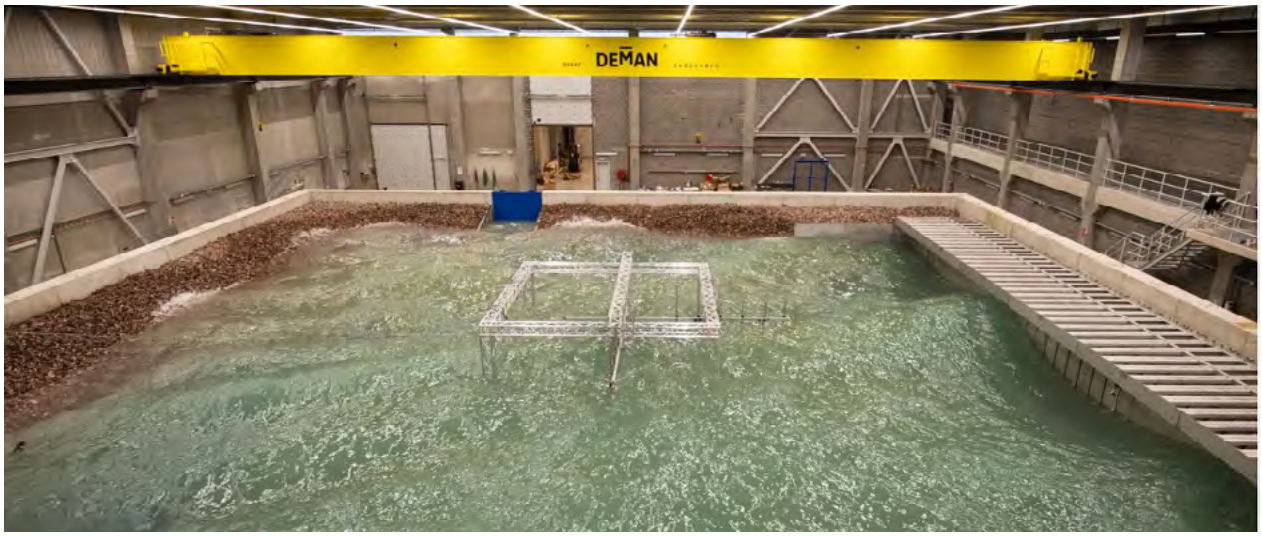

The experimental setup of the five-WEC array the Coastal and Ocean Basin Ostend: overview (left) and detail (right).

## Coastal & Ocean Basin (COB)

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 m long by 30 m wide and has a variable water depth up to 1.4 m, 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 over 4 m. The facility is fully equipped with a state-of-the-art Qualisys motion tracking system.

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).

1 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.

## WECANet

The European COST Action CA17105 "**WECANet** (www.wecanet.eu) is a network of 31 countries dedicated to Marine Renewable Energy, with a focus on Wave Energy. It is coordinated by the Coastal Engineering Research Group of Ghent University (UGent-CERG, http://awww.ugent.be). WECANet is funded through the HORIZON2020 Framework Programme by COST (European Cooperation in Science and Technology, www.cost.eu), a funding agency for research and innovation networks. WECANet targets scientific excellence and inclusiveness by fostering training, networking and collaboration in Europe for wave energy. In 2023, WECANet funded research collaborations through Short Term Scientific Missions, online international meetings, dissemination activities and scientific publications on wave energy. WECANet supports actively OES-IEA activities.

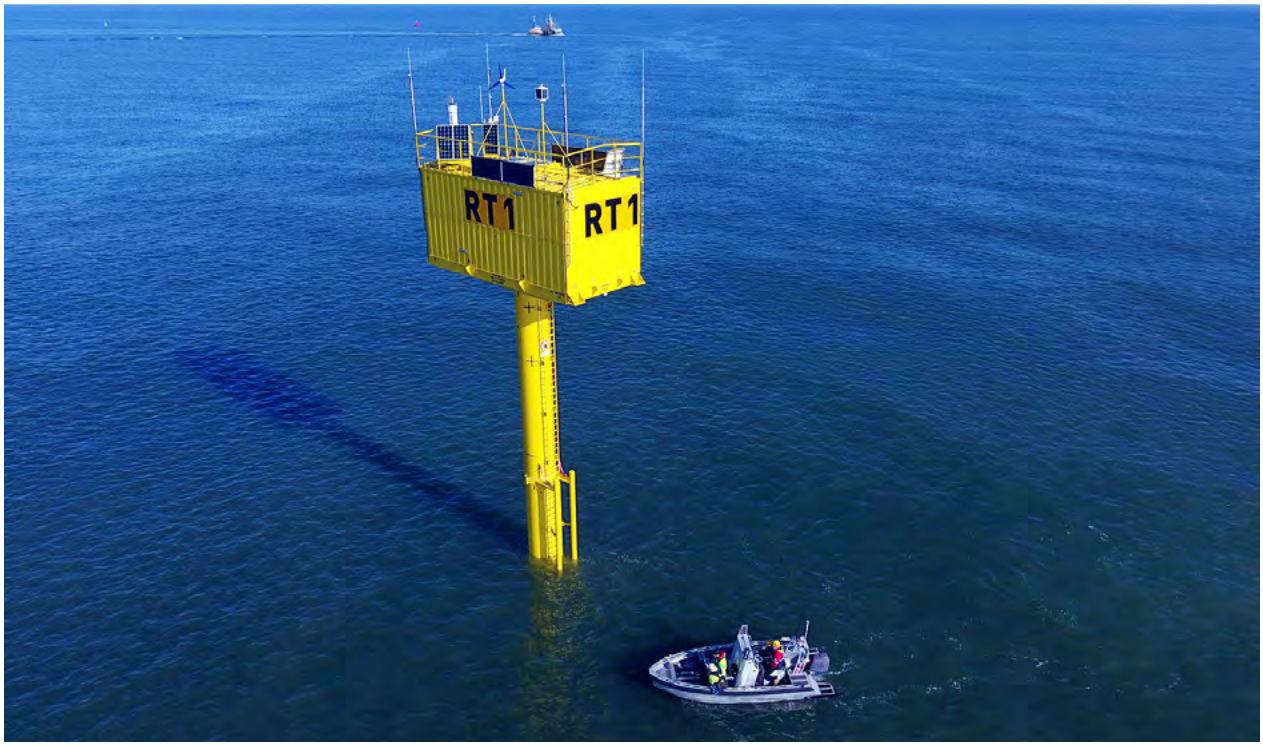
## MARINERG-i

The Coastal Engineering Research Group of Ghent University (UGent-CERG) is a 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 "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 to provide 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 prototypes 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 to offer a grid connection by 2023 for offshore renewable energy projects. 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 is 4 m. The testing zone is delimited by a circular area with a diameter of 440 m.


Location of the Blue Accelerator test site (left); Interior of the Blue Accelerator platform (right)



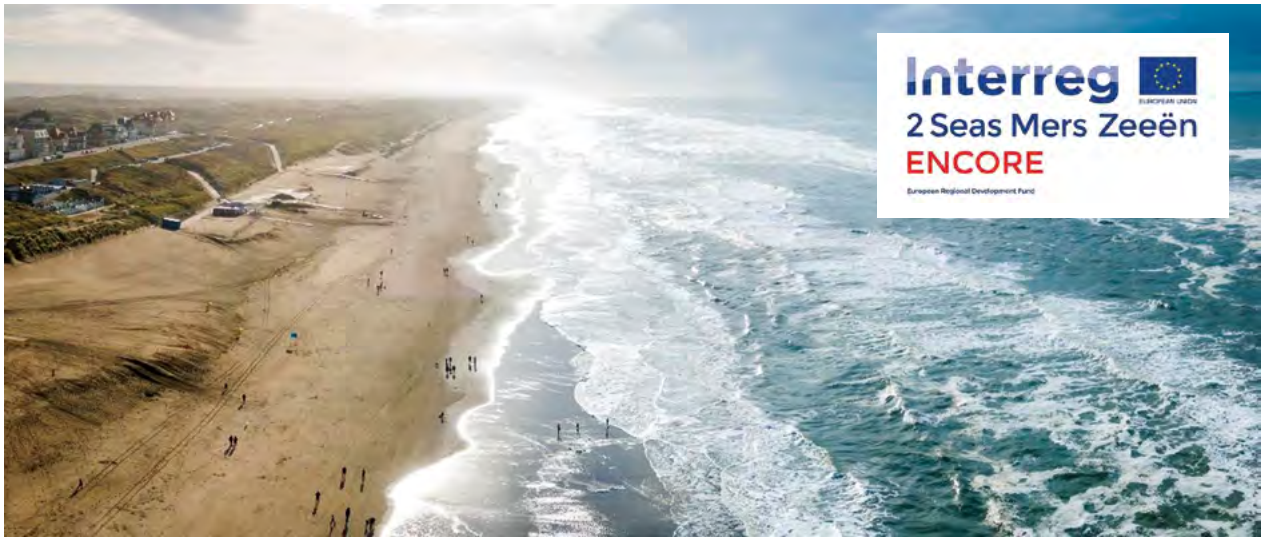

The Blue Accelerator open sea test site at Ostend, Belgium

## 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.

## ENCORE: Energising Coasts with Offshore Renewable Energy

Through its Interreg 2 Seas Programme, Europe awards 5.9 million euro to the ENCORE project. The goal of the



project is to advance the rapidly emerging offshore renewable energy sector. ENCORE offers advanced technical and business support services to accelerate the offshore renewable energy sector in the 2 Seas region. As part of the service portfolio, international certification schemes will be applied to reduce risks and increase investor confidence and to attract new capital to the sector. An education & training programme will be developed to train and prepare new young talent in the sector. In each country, regional impact campaigns will be set up to involve supply chain and stakeholders in the project. Services will be delivered to five next generation ORE companies, covering new technologies; river current technology: Water2Energy (NL) and EEL Energy, offshore floating solar: Oceans of Energy (NL) and wave energy: Teamwork Technology (NL). From Belgium, Power-Link is responsible for project communication and dissemination and the UGent-CERG researchers are acting as service providers to the participating technology developers. More information at: www.energisingcoasts.eu

## CORDOBA

This project is funded by the Blue Cluster (VLAIO) and run between 2021 and 2023 with the following partners: Elicio, Marlinks, Yuso, Enersynt and KUL. In the offshore energy sector, the aim is to achieve a cost-effective, holistic and sustainable design and operation of hybrid offshore connections (HOV) and offshore grids. These challenges are addressed in three main areas: by developing an optimisation model for the design of offshore networks, by developing a coordinated control model for HOV and by thoroughly examining the effect of system design on the network support services. Furthermore, an investment participation and remuneration model is being drawn up for HOV so that multiple investors can develop different parts of the hybrid offshore network at different times and earn back their investments in a reliable manner at the same time. The project has many payback effects for the Flemish economy, and an impact analysis by the partners has shown that a successful Cordoba project may trigger a growth in employment of around 26 FTEs and € 23 million in investments.

## SMARAGD - SMart Autonomous Reliable Aquatic Goods Drone

This project run between 2021 and 2023 with the following partners: GEOxyz, MULTI.engineering, e-Bo Enterprises and ERPA Industrial Supplier. The objective is to create an autonomous vehicle to improve the efficiency and effectiveness of offshore maintenance activities and to provide a solution on an actual need for adequate support.

## OPIN

Sirris from Belgium is a partner in OPIN (Ocean Power Innovation Network), an Interreg North West 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 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 EMEC in Orkney, this 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. 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. Power-Link from UGent had a role in communication and dissemination. More information at: 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, joined forces to shape a pan-European blue energy cluster with a focus 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. This project is supported by the EU COSME programme. More information at: https://www.blauwecluster.be/project/elbe-plus-european-leaders-blue-energy

## Soiltwin

There's a recognized discrepancy in the offshore energy industry between the expected and actual performance of monopile foundations, leading to less than ideal fa-

tigue designs and higher costs. This is largely attributed to inaccuracies in modeling the soil-structure interaction, particularly for short, large-diameter piles like monopiles. To address this, Ghent University and Vrije Universiteit Brussel are collaborating to refine these models, using finite element analysis, lab experiments at the Coastal and Ocean Basin (COB), and on-site data. More information at: https://owi-lab.be/soiltwin

## EnerGhentIC

EnerGhentIC is the interdisciplinary community of Ghent University researchers working on the energy challenge, with a focus on three main activities: (1) to stimulate research and valorisation in amongst other offshore wind, wave & tidal energy, (2) to 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 a 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 defense 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/

## RELEVANT NATIONAL EVENTS

- **July 2023:** The Blue Growth Summer School organised by Ghent University
- **March 2023:** Final Conference of the WECANet COST Action CA17105 organised by UGent-CERG (https://www.wecanet.eu/) in Ghent, 6-7 March 2023
- **March 2023:** ENCORE stakeholder event organised by UGent (www.energisingcoasts.eu)

# CANADA

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## OVERVIEW

2023 saw considerable progress on legislative and regulatory initiatives as well as funding to stimulate the marine renewable energy industry in Canada, cutting-edge research into the tidal industry in Nova Scotia's Bay of Fundy, and critical partnerships formed.

At the federal level, the Government of Canada introduced legislation to enable the development and growth of offshore renewable energy and established a Task Force with industry, key stakeholders, and the Province of Nova Scotia to address regulatory challenges faced by the tidal industry. The provincial government in British Columbia invested $2M in the University of Victoria Pacific Regional Institute for Marine Energy Discovery's (PRIMED) Blind Channel Test Centre, which will support tidal turbine research. In Nova Scotia, the Fundy Ocean Research Centre for Energy (FORCE) lead a number of research initiatives to better understand and retire risks related to fish interactions with tidal energy devices. Finally, a major partnership was announced between Eauclaire Tidal and Orbital Marine Power to deliver Orbital's floating tidal stream turbine technology to Eauclaire's berth at the FORCE site.

## 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 May 2023, the Government of Canada introduced 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*** into the House of Commons, thereby initiating the legislative process to enact the Bill as law.

Bill C-49 was drafted together with the provinces of Nova Scotia and Newfoundland and Labrador and will establish a joint management regime for offshore renewable energy development by amending existing legislation to expand the mandates of the Canada-Nova Scotia Offshore Petroleum Board (CNSOPB) and Canada-Newfoundland and Labrador Petroleum Board (C-NLOPB) to include the regulation of offshore renewable energy. These changes will establish the legislative framework and lifecycle regulators for offshore renewable energy projects such as offshore wind, wave, and tidal energy off the coasts of Nova Scotia and Newfoundland and Labrador.

Bill C-49 is currently being considered in the federal House of Commons. Once the federal act is granted Royal Assent, the legislatures of Nova Scotia and Newfoundland and Labrador would introduce and pass mirror legislation. Subsequently, the Offshore Petroleum Boards would become 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. The federal and provincial joint management regimes are expected to be enacted by 2025.

Bill C-49 will also run parallel to the governments' Regional Assessments of Offshore Wind Development off the coasts of Nova Scotia and Newfoundland and Labrador, both of which launched in March 2023. The Regional Assessments will help identify optimal areas for wind development and provide information and analysis to inform the regulatory review of future offshore wind development projects that would be regulated under the proposed amended Accord Acts.

In 2023, the Government of Canada continued its pre-engagement efforts on the proposed federal Canada Offshore Renewable Energy Regulations (CORER), which will establish comprehensive requirements related to safety, security, and environmental protection for the offshore renewable energy sector under the ***Canadian Energy Regulator Act***. The proposed Canada Offshore Renewable Energy Regulations will 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 will 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. The next step will be the pre-publication of the draft regulations in Part 1 of the ***Canada Gazette*** for public comments, which is expected to occur in early 2024.

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 2023, the Government of Canada also announced draft Clean Electricity Regulations, designed to help Canada achieve a net-zero electricity grid by 2035, in close collaboration with provinces, territories, Indigenous partners, industry, and others. The draft regulations aim to support the decarbonization of the remainder of Canada's grid while meeting the needs of increasing demand for electricity. As drafted, they would cut over 340 megatonnes of greenhouse gas pollution between 2024 and 2050.

Fisheries and Oceans Canada (DFO) is responsible for ensuring that Canada's aquatic ecosystems remain healthy for future generations while supporting important economic opportunities like marine renewable energy for Canadians and coastal communities. In this respect, DFO is supports the marine renewable energy sector through its Blue Economy Strategy, through Marine Spatial Planning (MSP), and as a regulator of impacts to fish and fish habitat.

In December 2019, the Minister of Fisheries, Oceans and the Canadian Coast Guard was mandated to lead the development of a Blue Economy Strategy in which restored ocean health supports coastal communities and Indigenous peoples with long-term livelihoods in technologically advanced and resilient marine sectors. As part of this strategy, DFO, in partnership with the Treasury Board Secretariat, launched the Blue Economy Regulatory Review in 2022.

In 2022-2023, a public engagement process was conducted and a What We Heard Report is forthcoming. A Regulatory Roadmap is also being developed in partnership with several other government departments to tackle regulatory and operational challenges and explore innovative approaches to seize emerging opportunities and foster a sustainable blue economy.

In June 2023, the Government of Canada established the Task Force on Sustainable Tidal Energy Development in the Bay of Fundy (the "Tidal Taskforce"), an initiative aimed at addressing regulatory challenges faced by the tidal industry.

Another area of focus for DFO is Marine Spatial Planning (MSP), a process for managing ocean spaces to achieve a range of ecological, economic, cultural and social objectives. In 2023, DFO launched the Canada Marine Planning Atlas - an interactive mapping tool that allows users to view and interact with data relevant to marine spatial planning. The department is working towards four first-generation marine spatial planning frameworks by 2024, which will build a strong foundation for collaborative planning and showcase steps taken and outputs from the MSP process to date.

## Tidal Task Force

In June 2023, the Government of Canada established the Task Force on Sustainable Tidal Energy Development in the Bay of Fundy (the "Tidal Taskforce"), an initiative aimed at addressing regulatory challenges faced by the tidal industry. The purpose of the Task Force is 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

The Tidal Task Force is chaired by DFO and Natural Resources Canada (NRCan) and includes Marine Renewables Canada, the Fundy Ocean Research Centre for Energy (FORCE), and the Province of Nova Scotia as members. In September, DFO and NRCan released an Interim Report on the work underway by the Tidal Taskforce, which addressed regulatory challenges and the Tidal Taskforce's Action Plan. A final report is expected to be released sometime in 2024.

## Nova Scotia

Nova Scotia Department of Natural Resources and Renewables (DNRR) introduced amendments to the ***Marine Renewable-energy Act***, which received Royal Assent on April 22, 2022. The amendments provide greater clarity regarding the Act's licensing system to address industry concerns, improve the administration of the Act's Demonstration Permit Program, and update the Act in response to lessons learned through the ongoing administration of the legislation.

Notable amendments include:

- Changes to the licence framework to allow projects to be sited closer to one another and to share common infrastructure, such as anchors or moorings. Allowing infrastructure to be shared has the potential to further reduce the amount of deployed infrastructure, reduce project costs, and support project investment decisions and project planning, ultimately leading to more project deployments. This will also add greater clarity around the rights provided with a license and the geographic area of a licence.
- Improvements to the administration of the Demonstration Permit Program that will create a competitive evaluation process instead of providing permits on a first-come, first-served basis. The process will ensure the projects that offer the best value to Nova Scotians and are in the best position to succeed are approved.

## British Columbia

In 2022 and 2023, the government of British Columbia launched its first Coastal Marine Strategy, which lays out the Province's plan for addressing priorities for coastal-marine ecosystem health and community well-being. Public consultation was held throughout 2023, a What We Heard Report was released in August 2023, and the Strategy is expected to be released in Spring 2024.

The Province of British Columbia provided $2 million to PRIMED to support the establishment of the Blind Channel Test Centre. This initiative will support research on tidal turbines and other renewable energy sources such as wind, solar and low-carbon hydrogen. The project will compare these new technologies and test how they perform in conditions on the West Coast of Canada, one of the most energetic tidal and wave climates in the world.

# Market Incentives

## Government of Canada

As opportunities and interest in Canada's marine renewable energy sector increase, the Government of Canada's 2023 Budget outlines measures that will help support and drive project development and growth in our ocean energy sectors. These measures 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;
- 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; and
- $20 billion from the Canada Infrastructure Bank to support clean electricity investments.

In November 2023, the Government of Canada's 2023 Fall Economic Statement clarified that all the above Investment Tax Credits would become available in 2024.

In October 2023, the Impact Assessment Agency of Canada (IAAC) opened funding for the public to provide feedback on several upcoming regulatory initiatives, including a review of the ***Physical Activities Regulations*** which establishes a threshold for tidal and offshore wind projects to undergo an impact assessment.

## Nova Scotia

Nova Scotia continues to be the sole province in Canada offering a targeted market incentive for in-stream tidal energy. Under Nova Scotia's ***Marine Renewable Energy Act,*** projects that receive a demonstration permit can receive a power purchase agreement (PPA) of up to 15 years. Any utility in Nova Scotia is required to procure all electricity under the PPA. The framework caps the demonstration permitting program at a total of 10 MW. Four companies at the FORCE test site have approvals under Nova Scotia's feed-in tariff (FIT) program, which offers an established rate of 53 cents/kWh and a 15-year power purchase agreement with Nova Scotia Power, the province's electric utility, and licenses under the Act: 1) DP Energy; 2) reconcept; 3) Big Moon Power; and 4) Eauclaire Tidal. The FIT program is now closed, and no PPA may be entered into pursuant to this program after December 31, 2021, in accordance with the legislation.

In other areas of the Bay of Fundy, projects have received a PPA with the electrical utility via Nova Scotia's demonstration permit program, including NewEast Energy, Nova Innovation, and Jupiter Hydro who received approvals between 2018-2020 and are at various stages of development.

# Public Funding Programmes

In May 2023, Canada's Ocean Supercluster launched a Call for Proposals under its new Scaled Renewable Ocean Energy Program, which seeks to increase the development of ocean technologies that generate electricity, reduce carbon emissions, and provide renewable energy sources. The call closed in October 2023 and the next steps are expected to be announced in 2024.

**RESEARCH & DEVELOPMENT**

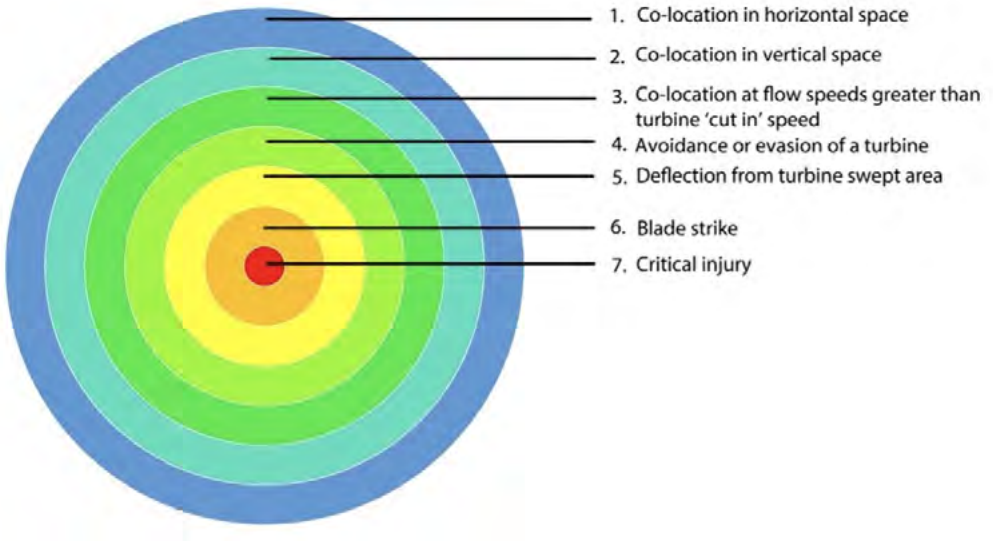
## HydroAware Project

In September 2023, Canada's Ocean Supercluster announced the HydroAware Project would be led by Innovasea, with partners FORCE, BigMoon Power, Nova Scotia Power Inc., New Brunswick Power Corporation, and DeepSense. The project aims to accelerate hydropower projects and advance fish monitoring technology in harsh marine environments using artificial intelligence.

## Fundy Ocean Research Centre for Energy (FORCE)

In 2023, FORCE served as co-chair of the Risk and Monitoring Working Group to the Government of Canada's Task Force on Sustainable Tidal Energy Development in the Bay of Fundy. The primary role of the working group is to build a work plan to evaluate and monitor the collision risk of fish with different designs of tidal stream energy devices during 2024-2026. In service of this core mandate, FORCE has partnered with Acadia University to advance a proposed Tidal Collision Risk Evaluation (T-CORE) project. This project supports the advancement of Canada's marine renewable energy sector by evaluating the risk of tidal stream turbines to fish. T-CORE proposes to address significant data gaps and concerns raised by DFO and others in relation to collision risk of marine animals with the rotating parts of tidal stream energy devices in Minas Passage, especially regarding risk to fish species of conservation concern, the effectiveness of monitoring technologies, and the accuracy and precision of collision risk models.

In 2023, promising research led by Dr. Brian Sanderson at Acadia University suggests the FORCE tidal test site is low risk for Atlantic salmon post-smolts. Sanderson's team conducted a number of experiments, including attaching fish tags to drifting buoys ('drifters'), to examine how well the acoustic tag transmissions are detected by receivers in the extremely turbulent waters at the FORCE test site in Minas Passage. Findings suggest that the strong currents of Minas Passage are expected to sweep most Atlantic salmon post-smolts to the south of the FORCE site.




T-Core framework for quantifying the likelihood of a collision risk for fish and operational tidal energy turbines. Adapted from Copping et al. (2017)

FORCE also continued its work on the ***Risk Assessment Program (RAP) for Tidal Energy*** funded by NRCan's Emerging Renewable Power Program (ERPP) to support greater regulatory clarity around tidal project development. Through RAP, a science-based tool has been developed to address a key question in the tidal energy permitting process: estimating the probability that valued fishes will encounter an offshore energy device at the FORCE site. To date, RAP has acquired tag detection data from 22 different telemetry projects and environmental data, demonstrating FORCE's ability to coordinate with dozens of collaborators and synthesize multiple types of data to answer questions about marine species' interactions with ocean energy devices. The first phase of the RAP combined available knowledge on selected fish species' movements and habitat use in the FORCE project area derived from detections of acoustically tagged fish, with local physical oceanographic data to develop predictive species-specific distribution models (SDMs) for Minas Passage. That information was a critical first step to understanding the likelihood of fish overlapping in space and time with proposed tidal energy devices in the region. Throughout 2023, FORCE collaborated with Dr. Andrea Copping, a senior research scientist at Pacific Northwest National Laboratory (US Department of Energy), to publish a paper on collision risk.

Fish tagging led by Mi'kmaw Conservation Group as part of 2020-2023 Risk Assessment Program

In 2023, FORCE partnered with multiple groups and companies to advance environmental monitoring of tidal energy devices in the Bay of Fundy. A partnership with the Eastern Shore Fishermen's Protective Association (ESFPA) and Little Hope Management Committee (LHMC) helped build regional capacity for the use and application of hydroacoustics, and to provide hands on training and guidance during the development of a standard operating procedure documentation for the correct use of the Kongsberg EK80 BWBT echosounder and associated post-processing so that ESFPA & LHMC can lead those elements of this work going forward. In addition, partnerships with OSC, Innovasea, DeepSense (Dalhousie U), BigMoon, Nova Scotia Power and New Brunswick Power helped develop an AI Tagless Fish Tracking Program to help tidal/hydropower companies gather more conclusive fish tracking evidence. This project will use AI to drive two important strategic capability breakthroughs in fish tracking technologies, specifically reliable fish tracking in extremely harsh marine environments and improved availability of fish tracking insights from extremely remote sites.

## National Research Council (NRC)

National Research Council Canada's Ocean, Coastal and River Engineering Research Centre (NRC-OCRE) is conducting ongoing research to characterize the hydrokinetic energy (HKE) resources of Canadian rivers and to improve the performance of HKE turbines. To aid HKE developers and communities in locating areas of high resource potential, remotely sensed data and analytical methods were leveraged to estimate the HKE energy in all Canadian rivers at 100-meter spacing intervals. Additionally, the HKE at specific promising river sites was explored in Ontario, Quebec, and Nunavut via field data collection, numerical modelling, and close collaboration with the University of Ottawa. Most notably, through field investigation and hydrodynamic modelling, the river HKE potential in the Canadian Arctic, which was originally thought to be not feasible for development because of cold weather conditions, has been found to have the potential for resource development at specific river sites. Additionally, NRC-OCRE in collaboration with CanmetEnergy-Ottawa is planning a 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. Ongoing research in 2024 will include dissemination of the national HKE database in maps, GIS applications, and other means that are most useful for developers and communities. 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

The marine research and development (R&D) carried out this year at NRCan's CanmetENERGY-Ottawa (CE-O) concluded the final phase of the 2019-2022 project cycle within the Canadian Federal Internal Energy Programs - the Program of Energy Research and Development (PERD) and the Energy Innovation Program (EIP). In the current year, CE-O has sustained its commitment to technical development and resource assessment activities. The datasets, which identify open-water areas with high energy and sufficiently strong currents to inhibit ice formation, are now available on the Federal Geospatial Platform (FGP). This publication substantiates the identification of promising high-energy locations for hydrokinetic energy development. CE-O and ORPC have launched a site characterization project on the St. Lawrence River aimed at enhancing and broadening hydrokinetic resource assessments. This involves the collection of specialized river flow data using Acoustic Current Profiler (ADCP) and Remotely Piloted Aircraft System (RPAS). The gathered data will play a crucial role in developing calibrated numerical models and pioneering techniques for assessing River Hydrokinetic Energy (RHE) resources.

NRC, CE-O and Laval University have collaboratively commissioned general guidelines for simulating hydrokinetic turbine arrays and for the layout of hydrokinetic turbine arrays in rivers. The guidelines provided a uniform methodology that ensured consistency and accuracy in the estimation, measurement, characterization, and analysis of the hydrokinetic resource at sites that could be suitable for the installation of an individual or array of turbines.

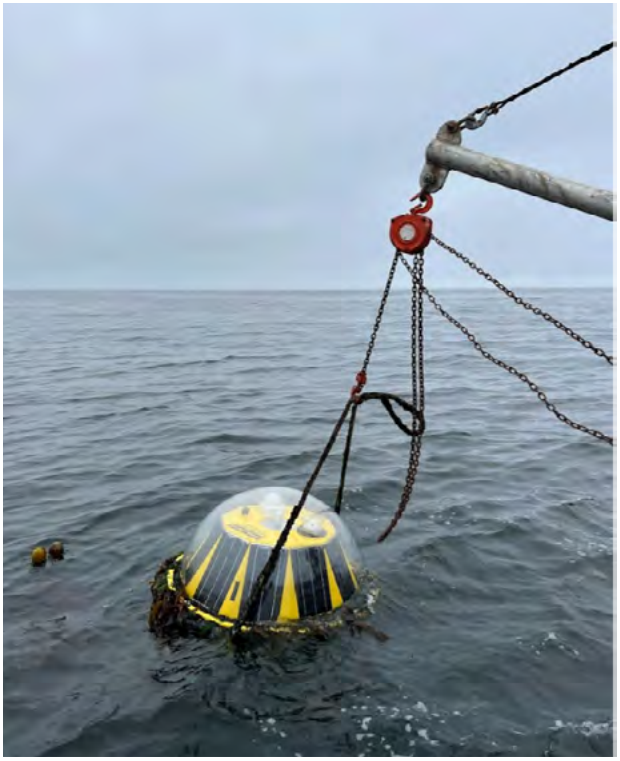
CE-O and Laval University also conducted a comprehensive study to evaluate the impact of cavitation on the performance of hydrokinetic turbines, focusing particularly on crossflow turbines. The goal was to gain a better understanding of cavitation and identify potential preventive measures. As part of this initiative, an inventory of existing cavitation models was examined against well-documented experimental benchmark cases, resulting in the development of key recommendations for high-fidelity cavitation simulations.

CE-O's endeavors for the new 2023-2028 PERD-EIP project cycle aim to provide technical support for the development of Marine Renewable Energy (MRE) in Canada, advancing marine technologies to higher Technology Readiness Levels (TRL). The project encompasses both river hydrokinetic energy (RHE) and tidal current energy (TCE) technologies, focusing on three specific aspects. These include enhancing resource assessment tools and datasets to support MRE development at community and utility levels; advancing technical solutions to improve MRE system efficiency, reliability, component life, and reduce overall costs; and facilitating medium-to-long-term community-based demonstrations of MRE systems to showcase their technical and economic viability.

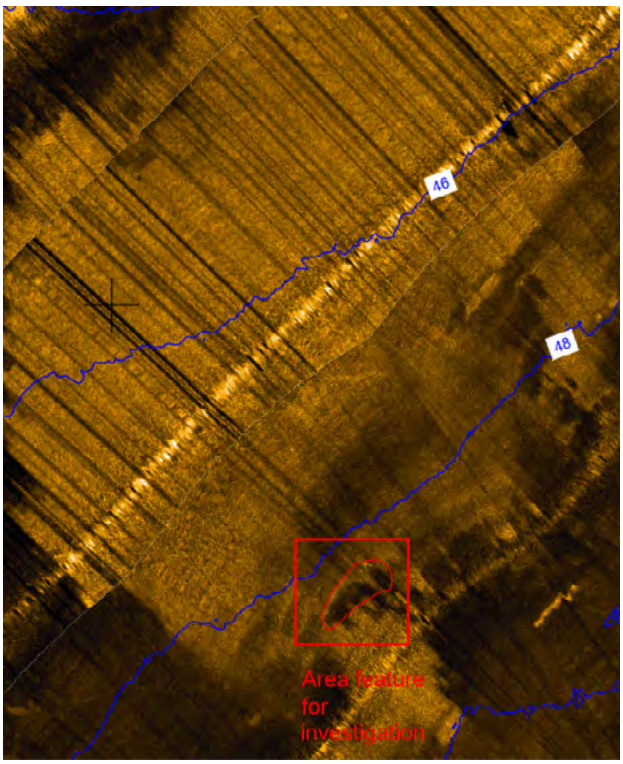
## University of Victoria (UVic)

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 2023 included:

- **Yuquot Wave Energy Project:** The Mowachaht/Muchalaht First Nation led Yuquot Wave Energy Project continues to progress with project partners PRIMED, Barkley Project Group, CalWave Power Technologies, Canpac Marine Services, and Environmental Dynamics Inc. The Nation has identified the development of key infrastructure, including reliable renewable energy, to be of high priority to support the reoccupation of Yuquot. Based on previously completed feasibility assessments, the proposed microgrid will be a hybrid system composed of diesel, solar, battery, and wave energy converter (WEC) technologies. CalWave was selected as the wave developer partner in August 2023



Triaxys buoy recovery




Site sidescan bathymetry survey

after a detailed request for information and selection process. The feasibility and design study, funded by the TD Ready Challenge, has an expected timeline of July 2023 to February 2025 and will progress the CalWave X100 point absorber WEC and associated infrastructure components to a pre-construction phase for integration into the developing microgrid. Once complete, the Nation and team will have all the necessary information to make a decision on whether or not to pursue full funding for project buildout. The project team completed site identification and selection, deployed two TRIAXYs wave measurement buoys, multibeam and sidescan bathymetry surveys, ROV surveys, community engagement activities, and feasibility works in 2023. 2024 will be a big year for the project including environmental data collection, a regulatory workshop to familiarize agencies with wave energy technology and the project, design activities, costing assessments, and more. The project will be a first of its kind in Canada and will look to pave the way for future projects.

- **Accelerating Community Energy Transformation Project:** In 2023, UVic received $83.6M in funding from the Government to launch the Accelerating Community Energy Transformation (ACET) project. This is a collaborative initiative led by UVic that brings together over 40 partners, including Indigenous knowledge keepers and community leaders, to create innovative place-based solutions for energy system transformation. ACET will help transform regional economies, inform inclusive national policies, and integrate breakthrough renewable energy technologies that position Canada as a world leader in reducing greenhouse gas emissions and achieving net-zero goals. UVic held a kick-off event in November 2023 that brought together over 100 academic, government and community partners eager to support and engage with ACET.

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 2023, FORCE continued to support tidal energy projects at its site led by BigMoon Power DP Energy, and Eauclaire Tidal (*see section 4.3 for more details*).

### Blind Channel Test Centre

PRIMED has been working with partners Mavi Innovations Inc. (Mavi) and Blind Channel Resort (BCR) on the development of a tidal demonstration centre and an integrated hybrid renewable energy system (HRES) at Blind Channel. This project builds upon the 2017 Mavi turbine deployment to create a unique demonstration site focused on developing and proving the technical and economic pathways for Integrating Tidal Energy Converters (TECs) into community-scale hybrid energy systems. It will demonstrate the operation of the Hybrid Renewable Energy System (HRES) while proving the diesel displacement potential of TEC technology in such systems.

The demonstration tidal turbine (referred to as the resident turbine) will be integrated into the onshore HRES: consisting of diesel generators, solar PV, battery energy storage, power conversion and conditioning equipment, and local and global controllers. The resident turbine is expected to have a rated capacity of approximately 2 kW. The project is currently wrapping up a front-end engineering and design study funded by the BC Ministry of Energy Mines and Low Carbon Innovation. Part of this work includes inspecting existing infrastructure to identify components that can be reused or require replacement. Procurement, construction, and installation activities will begin in 2024.

Longer-term planning is also underway for the expansion of the site to allow for additional developers' devices to be swapped with the resident turbine and trialled at the site. As the energy needs of many remote communities are larger than that of the BCR, the Test phase will see the deployment of larger-scale devices (potentially up to 120 kW rated capacity) by collaborating companies. The infrastruc-


Anchor block inspection (June 2023)

ture, developed during the initial Demonstration phase, will create a venue where developers can de-risk their devices, demonstrate grid integrated performance, and implement suitable environmental monitoring protocols.

This will allow subsequent community-led projects to be developed more efficiently along with allowing communities to witness technologies operating first-hand, rather than dispersing assets and resources across several projects. This phase will also examine how to utilize surplus power productively to decarbonize community economies.

## Projects in the Water

### Ocean Renewable Power Company (ORPC) Canada

In 2023, ORPC Canada began working with clean energy developer Tarquti to assess potential for hydrokinetic power system use in Nunavik, the northernmost region of Quebec. A recent technical and economic study produced with global engineering consultancy Hatch shows that marine hydrokinetics could play a role in decarbonizing an off-grid coastal community in Nunavik heavily reliant on diesel generation.

The company continued its demonstration project of a RivGen Power System at the Canadian Hydrokinetic Turbine Test Centre in Manitoba, installed in 2022. To further connect with the largest remote community market in North America, ORPC Canada hosted an informational exchange at the end of 2023 for remote and indigenous communities at the U.S. Embassy in Ottawa, with support from the U.S. Commercial Service. Leadership from Igiugig, Alaska, a U.S. remote tribal community with whom ORPC has had a multi-year partnership, highlighted the challenges and successes of transitioning a rural, diesel-dependent community to a grid system powered by renewable energy, with ORPC's devices providing baseload power from local water resources. ORPC looks forward to continuing to support local energy transition goals across Canada in 2024.

## Projects Planned for Deployment

### Big Moon Power

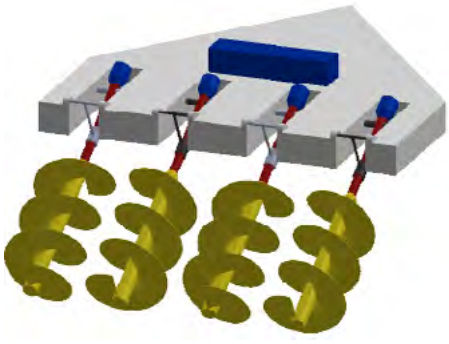
In 2023, Big Moon Power continued activities to prepare its "Falcon" tidal energy barge for deployment at FORCE. Notably, Big Moon made preparations to transport anchors for its device to the FORCE site. The Falcon has a large kinetic wheel suspended between the pontoons of a 30-metre barge anchored to the ocean floor. The barge swivels to face the current in both directions and the wheel moves in the same direction as the water column.

### DP Energy

DP Energy is continuing with the planning of and working with DFO on the consenting for Phase 1 of the 9 MW Uisce Tapa project, which will deploy 6 Andritz Hammerfest Hydro (AHH) Mk1 turbines at the FORCE site in Nova Scotia.

### Jupiter Hydro

In June 2023, Jupiter Hydro received a Letter of Advice from the Department of Fisheries and Oceans Canada after consideration of environmental risks and regulatory



Jupiter Hydro device design

requirements the project must meet under the *Fisheries Act*. The company will move forward with its two-phased project in the Bay of Fundy, beginning with the testing of a non-grid connected 1 MW prototype followed by a 2 MW demonstration.

### New Energy Corporation

New Energy Corporation, through its wholly owned subsidiary NewEast Energy, has been working towards the deployment of its 800 kW project in the Bay of Fundy's Minas Passage. Four of New Energy's EnviroGenTM Power generators will be installed as part of a floating grid-connected array.

Also in Canada, New Energy is developing two additional tidal energy projects on the East and West coasts featuring smaller 25 kW EnviroGen turbine systems. The purpose of these projects is part of the off-diesel initiative in Canada and providing a clean, predictable energy source to remote communities along the coast and other major bodies of water. Internationally, New Energy has been developing a foothold in the region of Southeast Asia and has recently delivered 5 turbines to Singapore for implementation in an industrial plant setting which are being installed through a local partner.

### Nova Innovation

Nova Innovation is continuing the development of its 1.5 MW tidal energy project in Petit Passage, Nova Scotia with fabrication complete and the first phase (500 kW) targeted for deployment in 2024. In 2023, Nova continued to make progress on achieving Phase 1 of this project, including renewed community and Mi'kmaq engagement efforts, reaffirming Nova's plans to commence work on the first of 5 approved turbines. Nova Innovation is currently arranging the logistics, contractors, and scheduling necessary for a deployment in 2024 of the first of the Phase 1 turbines in Petit Passage.

### Eauclaire Tidal & Orbital Marine Power

In 2023, Eauclaire Tidal partnered with Orbital Marine Power to deliver Orbital's floating tidal stream turbine technology to Eauclaire's berth at the FORCE site. The agreement covers one 2.4 MW O2-X machine to be deployed at FORCE following the permitting process under the *Fisheries Act*.

### Yourbrook Energy Systems

In 2023, Yourbrook received funding from NRCan's Clean Energy for Rural and Remote Communities program for the Kamdis Tidal Power Demonstration Project on Haida Gwaii in British Columbia. The $1.3 million investment over 2 years will go towards Front End Engineering and Design.

### Oneka Technologies

Oneka, a Québec based clean tech company, has continued to demonstrate its wave-powered desalination technology across the world. In 2023, on top of $13M in equity raised, Oneka received $14.1M in grant funding to scale up its technology to utility-scale, creating a desalination "Glacier" system. Oneka also received Canadian federal funding to deploy its technology in Chile and funding from the United States' Department of Energy to further accelerate the technology development and also develop a freshwater emergency relief application system. In 2023, Oneka also partnered with the City of Fort Bragg in California on the State's first wave-powered desalination demonstration site.

**RELEVANT NATIONAL EVENTS**

## Relevant Events in 2023

- **Marine Renewables Canada 2023 Annual Conference** December 4-6 Ottawa, Ontario

## Relevant Events Planned for 2024

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

# CHINA

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## OVERVIEW

In 2023, in order to achieve the goal of "carbon peaking and carbon neutrality", China has implemented a series of plans and policies to promote green and low-carbon development and adopted a series of practical action measures to support the accelerated development of scale and effective ocean energy and other new energy. China will continue to promote the scale utilization of ocean energy, implement a number of large-scale demonstration projects of tidal wave energy and wave energy, support the development of new ocean energy technologies, expand the application scenarios of ocean energy, and accelerate the development of China's ocean energy industrialization.

## SUPPORTING POLICIES FOR OCEAN ENERGY

### National Strategy

In August 2023, The National Development and Reform Commission(NDRC) of China and other ministries jointly issued the Implementation Plan for Green and Low-carbon Advanced Technology Demonstration Projects, proposing that through the implementation of green and low-carbon advanced technology demonstration projects, support the implementation of demonstration projects including marine clean energy such as wave energy, tidal current energy and OTEC, promote the transformation and application of green and low-carbon technology achievements, and explore effective paths for carbon reduction in key areas.

### Market Incentives

In July 2023, NDRC and other ministries jointly issued ***the Notice on the full coverage of renewable energy green electricity certifi-***

***cates, to promote renewable energy electricity consumption***, proposing to issue green certificates to all the electricity produced by renewable energy power generation projects such as ocean energy power generation, in order to achieve full coverage of green certificates.

## Public Funding Programmes

In 2023, 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, and a new round of support programme was launched in June.

**RESEARCH & DEVELOPMENT**

## Wave Energy

In 2023, Guangdong Grid Co., China Southern Power Grid(CSG), led the joint development of China's first megawatt-class floating wave energy generation device, the "Nankun", and has been deployed to open sea test. The " Nankun " is a triangular structure, that is strong in typhoon resistance and provides clean power supply for the island and other fields.

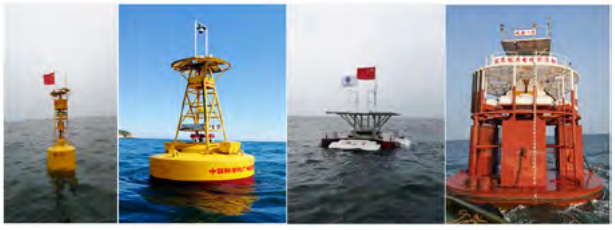
Guangzhou Institute of Energy Conversion (GIEC) has carried out continuous research on miniaturization wave energy power supply devices and successfully developed a variety of WEC in power supply buoys. At present, GIEC is carrying out the development of 3 kW and 10 kW large wave energy powered buoys and has been deployed to sea trials.

The research team of Dalian University of Technology has developed an ocean buoy powered by wave energy and solar energy based on the principle of floating OWC. By the end of 2023, the buoy has been in sea trial operation for more than 1 year.

Ocean University of China (OUC) has developed the OWC wave energy power supply system for ocean buoys. By the end of 2023, the buoy has been in sea trial operation for more than 1 year.

In 2023, GIEC, Harbin Engineering University (HEU) and other research institutions have carried out various types of wave energy technology research and tests.

Nan Kun in sea trial operation



Hailing, Haixing, Guanhai series of wave energy buoys

wave energy - solar energy ocean buoy in sea trial operation

OWC ocean buoy in sea trial operation

GIEC Single floating OWC device test

## Tidal Current Energy

Zhejiang University, Northeast Normal University, Guodian United Power Technology Co., Hangzhou River Hydropower Technology Co., etc. have carried out research on tidal current energy utilization technologies, developed several prototypes, and deployed to sea trials.

## OTEC

In August 2023, China's first 20kW Marine floating thermoelectric power generation device, developed by the Guangzhou Marine Geological Survey, successfully completed its first sea test.

In June 2023, Guangdong Laboratory of Southern Marine Science and Engineering (Zhanjiang) completed the research and construction of 50 kW OTEC generation system and experimental test platform. The platform is composed of ocean temperature difference power generation system, water supply system and control system, which can simulate the surface warm sea water and deep cold seawater conditions required for temperature difference energy experiments.

20 kW Floating OTEC generating device in sea trial operation


50 kW OTEC generation system and experimental test platform

Testing in Zhoushan Test Site

**TECHNOLOGY DEMONSTRATION**

## Existing Open Sea Test Sites

In 2023, The Ministry of Natural Resources(MNR) of China continues to promote the construction of the National Marine Comprehensive Test Site. The National Ocean Technology Center (NOTC) has obtained the China Inspection Body and Laboratory Mandatory Approval (CMA) certificate, the first CMA qualified organization in China to test the power characteristics and power quality characteristics of wave energy and tidal current energy generation devices. In 2023, NOTC has completed the field test of the tidal current energy turbine developed by the China Three Gorges Corporation, and issued the first CMA test report.

## Projects in the Water

**Wanshan 1 MW (2×500 kW) Wave Energy Demonstration Project.** In 2023, 500 kW wave energy power generation devices "Zhoushan" and "Changshan" wave energy power generation devices have completed con-

struction and sea trials, the construction of engineering infrastructure has been completed, and will be put into demonstration operation in the near future.

**Wave Energy Aquaculture platform.** In 2023, "Penghu" wave energy aquaculture platform continued to maintain stable operation, successfully completed multi-species and multi-season aquaculture demonstration, and achieved good demonstration and economic effect. As a successful case of "green development" combining ocean energy and aquaculture, the platform has formed a series of products that can meet the needs of different users.

**LHD Tidal Current Energy Demonstration Project.** The continuous operation time of the LHD tidal current energy demonstration project has exceeded 6 years until December 2023. In March 2022, China's first megawatt-class tidal current energy turbine "Endeavour" completed the deployment and realized grid operation. As of December 2023, "Endeavour" has been in continuous operation for more than 20 months, with a cumulative grid-connected generation of more than 2.9 million kWh.

**Zhoushan Tidal Current Energy Demonstration Project.** In 2023, the Zhoushan tidal current energy demonstration project was developed by the China Three Gorges Corporation. The project has completed the technical upgrade and installation of the tidal current energy generating unit, and carry out grid-connected demonstration operation.

500 kW "Zhoushan" "Changshan" WEC devices

Various types of deep-water aquaculture platforms

LHD demonstration project in operation

## SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

As part of the Third Belt and Road Forum for International Cooperation, the Thematic Forum on Maritime Cooperation was held in Beijing on October 18, 2023. The Forum issued the ***Belt and Road Blue Cooperation Initiative***, proposing to promote the sustainable utilization of marine resources, encourage the development of marine renewable energy, seawater desalination, sustainable fisheries, and so on, so that the sustainable utilization of marine resources benefits all mankind.

## RELEVANT NATIONAL EVENTS

On 23-25 November, the China Marine Economy Expo 2023 was held in Shenzhen. As part of CMEE2023, the 2023 China Marine Renewable Energy Industry Development Forum was held on 23 November. The Forum carried out exchanges and discussions on international ocean energy development trends, policy planning, technological innovation, application demonstration, public services, international cooperation and other hot issues. Peng Wei, Chinese delegate of OES, delivered a keynote speech at the forum. Chinese alternate delegate of OES made a presentation on behalf of OES.

Forum keynote presentation


OES presentation

# DENMARK

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## OVERVIEW

Danish Wave Energy technologies are under continuous development and today some of the frontrunners are companies like Exowave, Wavepiston, Floating Power Plant, Crestwing, WaveDragon and Weptos.

**Exowave** aims to achieve 250 MW of wave power by 2030 through a phased approach, with the upcoming Phase 2 involving the installation of a 100 kW hydraulic power unit in the North Sea in 2024. Meanwhile, **Wavepiston** is in the process of deploying a full-scale prototype at the Plocan test site in Gran Canarias, featuring a series of submerged plates connected to a platform for power generation and desalination.

**Floating Power Plant** has secured a notable grant of 26 million euros from The European Commission's Innovation Fund. This funding will support their pioneering demonstrator project at Plocan in Gran Canaria. **Weptos**, recipient of funding from EUDP, is set to design and manufacture the first rotors and a portion of the power train, with plans to install its initial commercial 1 MW machine in 2025. **Crestwing** is currently conducting the final scaled tests while simultaneously gearing up for the manufacturing and certification of the first approximately 2.5 MW system.

## SUPPORTING POLICIES FOR OCEAN ENERGY

### National Strategy

The Danish strategy for the development of wave energy was prepared in 2013 with the support of EUDP and Energinet DK. There is no specific Danish policy for "Wave Energy" – however there is an increased awareness and interest because of successful dissemination of ongoing projects. The Danish Partnership for wave energy is promoting the sector and the new EU requirement for 5% new energy technologies in the renewable energy expansion gives increased political awareness.

Just before the end of the year it was announced that DanWEC was selected to receive financial support of 200.000 € from the Danish State budget. This support will help to find a new framework involving the Port of Hanstholm as a partner running the test site, with broad support from the Energy Agency and the Partnership for Wave Power.

## Market Incentives

The European Commission has been actively supporting the development and deployment of wave energy through their Innovation Fund. In a significant endorsement of innovation in sustainable energy, Floating Power Plant has been selected as a recipient of a notable grant amounting of 26 million euros. This funding, allocated for their pioneering demonstrator project in Gran Canaria, underscores the European Union's recognition of the project's substantial potential in driving forward sustainable energy solutions.

## Public Funding Programmes

EUDP's board of direction organized in 2023 a session to obtain more information and updates on wave power, showing a renewed interest in wave power.

In 2023, Floating Power Plant, Wavepiston and Weptos were on the list of successful applicants to the EUDP calls and were rewarded significant grants for R&D projects initiated in Q2-2023 and or starting in 2024.

### RESEARCH & DEVELOPMENT

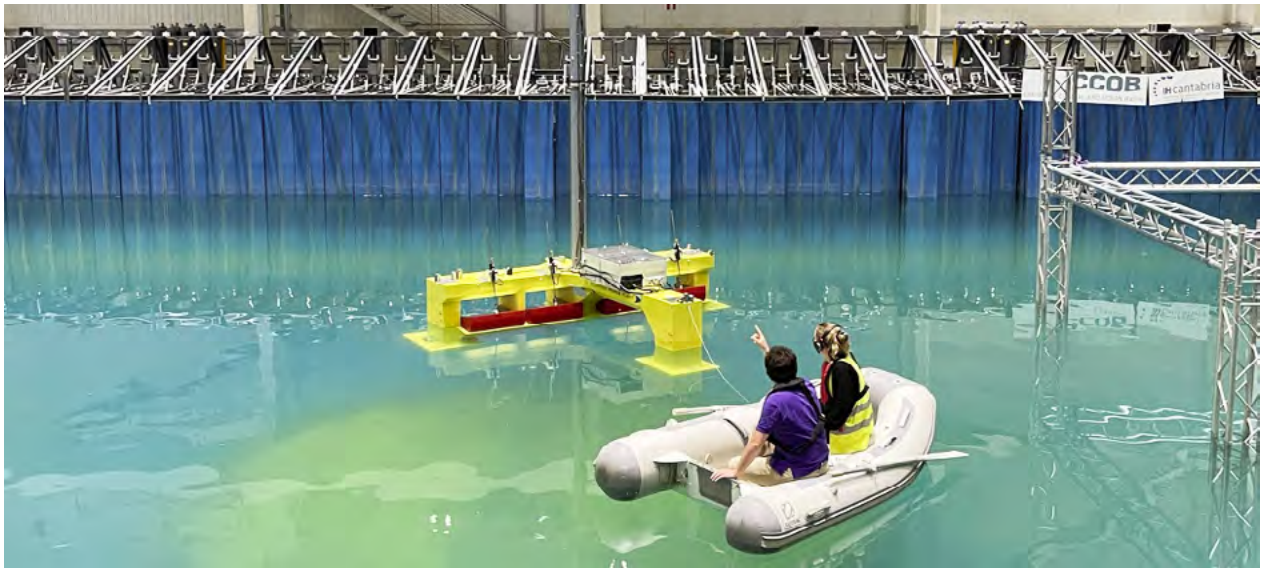
**IEC Standards -** Dansk Standard is the Danish partner under the international collaboration on standards IEC TC 114: Marine energy – Wave, tidal and other water current converters. In 2023 the specification IEC TS 62600-103 ED2 *"Guidelines for the early-stage development of wave energy converters – Best practices and recommended procedures for the testing of pre-prototype"* was sent out for consultation. This specification is especially relevant for the first phases of WEC development from laboratory tests to first sea trail in real environment.

**Wavepiston** initiated the EUDP supported project, *"Composites, Hybrid testing and SImulations for a disruptive Wave Energy Converter"* (COHSI-WEC), to improve their energy collectors and energy efficiency. A consortium with Wavepiston as coordinator was awarded the grant for the Horizon Europe call *"Development of innovative power take-off and control systems for wave energy devices"*.

**Exowave** is working towards establishing 250 MW wave power in 2030 – with 5 phases; the next phase 2 is the installation of a plant with 100 kW hydraulic power in 2024.

**Crestwing** Crestwing is working on further development of their PTO for implementation in their 1:4 prototype of a hinged raft named "Tordenskjold", in the sheltered sea Kattegat.

**Floating Power Plant** is developing their commercial-scale semi-submersible platform. This will be exe-




Floating Power Plant under laboratory testing

Weptos under laboratory testing

cuted in two distinct phases. Initially, the platform will be equipped with a wind turbine generator and a hydrogen system, aiming to demonstrate the combination of floating wind technology and hydrogen production systems. Following this, the second phase of the project will involve an enhancement of the platform, integrating wave energy converters. This addition of wave absorbers will further demonstrate the potential of the platform's multiple power take-off systems. Floating Power Plant has been awarded funding by the EUDP – under the Danish Department of Energy, a significant step toward refining the tools, critical for designing and optimizing their innovative platform designs. This financial support is pivotal in enabling the company to enhance its design processes, thereby laying a solid foundation for the future commercialization of these platforms.

**Weptos** has scaled up activities and established a new office in Fredericia, focusing on realizing its Roadmap to Commercialization. The design of the Weptos WEC has been optimized, leading to significant weight reductions, and thereby cast savings. In August 2023, performance testing of a 1:15 scale model with the new lean design was tested in the wave basin at Aalborg University, verifying the performance of the updated lean design. A significant step towards the goal of commercialization was achieved as EUDP awarded funding of a project which will design and produce the first parts of the 1 MW Weptos WEC, as well as conducting experimental testing for detailed performance and extreme loading characterization feeding into the final design of main structure and mooring arrangement, as well as the development of an LCoE calculation tool for Weptos.

**Wave Star** is ready to scale up from half scale to full scale 6 MW Wave Star wave machine and looking for investors who want to join the project.

**Crestwing** is currently performing the last tests of the 1:4 prototype "Tordenskiold", financed by EUDP. A technoeconomic and fluid dynamic study of the C-WEC is being done by DTU, Aarhus University, Stanford University and Harvard University. In parallel, Crestwing is preparing for the next development step; manufacturing and receiving full IEC certification for the 2.5 MW C-WEC system. By starting this project in 2025, Crestwing aims for having its first full-scale large-scale park in the ocean by 2030. Crestwing is currently looking for investors and partners for this project.

**Resen Waves** focus on providing autonomous wave powered instruments in the sea with real time data communication to shore, which minimizes expensive ship operation for collecting data and replace of batteries.

**Ramboll** (Kim Nielsen), continues collaboration with Sandia and NREL on the project WaveSparck with the focus on structured innovation and assessment methodologies in the USA.

**Julia F. Chozas** has her own consulting company working on several EU-funded projects with focus on especially O&M and LCOE. During the VALID project, she cooperated with CorPower, IDOM and Wavepiston and has assisted Carnegie the financial modeling of their CETO technology under the EuropeWave project. Julia is also a partner in the new WEPTOS project (EUDP) starting up.

**OctoMar** (Christian Grant), is assisting testing at sea in Nissum Bredning and at DanWEC, Christian is also now the chairman of the Nordic Folkecenter.

**DTU** has ongoing research collaborations with RESEN Waves A/S, KNSwing, Wavepiston and Crestwing. Generic research on improved tools for predicting WEC performance and loading is also ongoing.

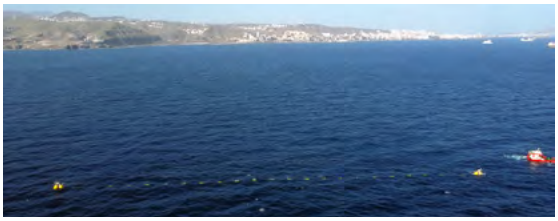
TECHNOLOGY DEMONSTRATION

## Existing Open Sea Test Sites

The Danish test site for wave energy converters **DanWEC** is located west of the Port of Hanstholm. The test site has been driven as a foundation-owned company, but this is in a transition phase into a new form of venture, where the Port of Hanstholm will manage the markings of the site and the wave and current measurements. The permits for testing will be given by the coastal authorities (this has always been the case) and the measurements of performance of each device will be done by external partners. DanWEC has for 10 years collected wave and current data. In addition, there is a seabed survey in terms of depths, sediment, and bottom conditions. This data is now handled by Aalborg University.

## Projects in the Water

**Wavepiston** has been working on the installation of their full-scale prototype (up to 250 kW) at Plocan in Gran Canaria for power production and desalination. All infra-structure components were installed in 2023. Commissioning is planned for Q1-2024.



Full-scale Wavepiston string (250 meter) installed at the PLOCAN test site

## Projects Planned for Deployment

**Exowave**, as part of the Danish public funded EUDP project "250 MW wave power in the North Sea by 2030, phase I", has executed design, wave tank test, engineering, and procurement activities of a 100 kW peak power / 35 kW average power WEC. The onshore FAT is scheduled to the first half of 2024 and the offshore demonstration on the second half of 2024. Onshore, the hydraulic power will be converted to electrical power connected to the grid. The site is just south of Hanstholm Harbour at the Danish west coast to the North Sea.

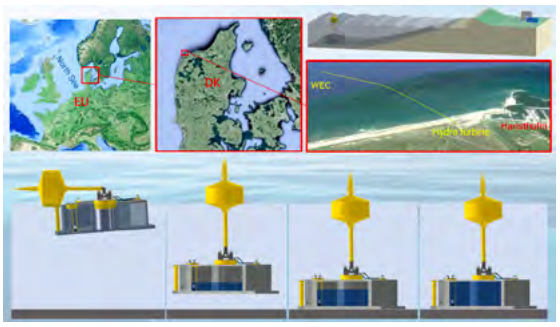


Illustration of Exowave prototype planned for installation and connection to Hanstholm

**Floating Power Plant** has plans for the deployment of an advanced semi-submersible platform off the coast of Gran Canaria in 2026. This state-of-the-art facility will be outfitted with a robust 4.3 MW Wind Turbine, a highly efficient 0.8 MW Wave Energy Converter system, and a comprehensive Hydrogen (H2) system. The latter includes a 1 MW electrolyser, a substantial 48 MWh energy storage capacity, and a 1.2 MW fuel cell. With these technologies combined, the platform is projected to generate a remarkable 11.05 GWh of energy annually. Moreover, over the first decade of its operation, it is expected to contribute significantly to environmental preservation by avoiding the emission of 25,557 tonnes of $CO_2$, marking a major milestone in sustainable energy production.


Visualisation of the full-scale Floating Power Plant concept


Crestwing' prototype "Tordenskiold" on the Pier in Frederikshavn

**Crestwing** in December 2022 achieved support from the Danish funding program EUDP for upgrading the PTO system and additional offshore testing in Kattegat by Frederikshavn. The prototype "Tordenskiold" has been lifted out of the water and is now standing on the Pier. The upgrade of the PTO includes a larger generator, incorporation of a maximum power point tracker (MPPT), and a micro-grid that enables a grid connection. The work with the electronics is carried out in collaboration with Aalborg University and Logimatic who designs maritime Scada systems. The operation will be finished by late summer 2024 where Tordenskiold again will be launched for a new round of offshore testing.

## SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

The international cooperation on numerical modelling OES Task 10 Numerical Models for Wave Energy Systems received funding from EUDP for a third three-year project supporting the Danish group of Task 10 participants. Aalborg University (Morten Kramer) is coordinating the project.

In addition, Ramboll applied to the Teamer programme in the USA for funding for NREL and Sandia to perform specific CFD calculations contributing to the OES Task 10. This Teamer project application was also successfully granted.

## RELEVANT NATIONAL EVENTS

From June 13 to15, 2024, the annual political meeting called **"Folkemødet"** is scheduled to take place on the Danish island of Bornholm 2024. Exowave, in collaboration with the Danish Partnership and other interested developers, will actively promote wave energy during this event.

In an effort to further advance wave energy, the Danish Partnership, in partnership with the Danish law firm Horten, plans to establish April 18 as a dedicated day, named **"the day of wave power"**. During this event, selected Wave Energy Converter (WEC) developers are planned to present their cases to an invited audience consisting of politicians and investors.

# EUROPEAN COMMISSION

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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 the new approach for a sustainable blue economy in the EU[1].

In October 2023 the European Commission presented a new communication **'Delivering on the EU offshore renewable energy ambitions'[2]**. It proposes to increase the EU'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 SET-plan[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 2023. The Innovation Fund support programme has been launched in 2020 and published new calls in 2022 with deadlines in 2024.

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 - 2023 Status Report on Technology Development, Trends, Value Chains and Markets'[4].

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/clean-energy-technology-observatory-ceto/ceto-reports-2023_en

SUPPORTING POLICIES FOR OCEAN ENERGY

# European Strategy

The European Commission presented the European Green Deal[5] 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'[6] 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 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 the EU 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.** 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.

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 now Portugal provides an indicative target of 0.2 GW for the development of ocean energy to contribute to the objective of 1GW 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 - 2023 Status Report on Technology Development, Trends, Value Chains and Markets'[7] 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

5
6 COM(2023) 668 final
7 https://setis.ec.europa.eu/publications/clean-energy-technology-observatory-ceto/ceto-reports-2023_en

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.

In May 2023, the Commission launched the European Blue Forum for users of the sea to facilitate a dialogue in an open and prospective approach between science and stakeholders involved in marine protection, energy, maritime industry and transport, fisheries and aquaculture, tourism and health. Additionally on fisheries, the Commission is strongly engaged with the sector and regional advisory councils to facilitate exchanges of knowledge and dialogue.

## 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 the European Union 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 the EU 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. This Readiness Assistance progamme has been set up including an exclusive coaching programme for high potential companies with innovative and sustainable solutions for the Blue Economy. Businesses and projects selected for the programme will receive coaching tailored to their readiness levels and business objectives. The programme is impact-driven, with a focus on providing business support to help companies build capacities for growth and attract investment. Mature businesses can get tailored advisory services to secure private equity and venture capital finance by investors and investment-readiness experts. The wave energy developer Wavepiston benefitted already from the Blue Invest assistance programme (https://oceans-and-fisheries.ec.europa.eu/ocean/blue-economy/blueinvest_en). 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 the EU.

## 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 will be funded (SEASTAR and EURO-TIDES).

A call for the development of innovative power take-off and control systems for wave energy devices (EU funding budget 8 million Euro) was opened in 2023, it is expected that 2 projects funded under this call will start in the first half of 2024.

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.

A call for the development of critical technologies for the future ocean energy farms (EU funding budget 8 million Euro) will be opened in September 2024.

The Innovation Fund launched also in 2023 calls to help with the demonstration of first-of-a-kind highly innovative projects. A specific call was opened for mid-sized

projects besides the call for large-scale and small-scale https://ec.europa.eu/commission/presscorner/detail/en/IP_23_5948 . In this call for mid-sized projects a higher degree of innovation is expected, but not yet large scale demonstration or commercial production. 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. At the end of 2023 it opened a call for proposals to facilitate the implementation of Maritime Spatial Planning (MSP) in the EU, including through the effective application of Directive 2014/89 establishing a framework for MSP. This call is intended to fund projects developing innovative responses to tackle specific challenges that EU Members States might encounter when putting into effect, monitoring and/or revising their maritime spatial plans.

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.

## 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. Two tidal energy farm projects started in 2023 with the aim to demonstrate the arrays 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 2023 a project was funded with the focus of minimizing environmental impacts, and more specifically the acoustic footprint and a second one on combining Hydrogen production with wave energy. 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.

| Year | Acronym | Title | Technology developer | Focus |
|---|---|---|---|---|
| **2023** | EURO-TIDES | EUROpean Tidal energy pilot farm focused on Industrial Design, Environmental mitigation and Sustainability | Orbital Marin Power Ltd (UK) | EURO-TIDES has been to deliver a 9.6 MW farm of four 2.4MW Orbital tidal energy devices of the same series. The farm will operate in full operational conditions for >10 yrs, expected deployment in 2027. |
| **2023** | SEASTAR | Sustainable European Advanced Subsea Tidal Array | Nova Innovation Ltd | In the SEASTAR project, coordinator Nova Innovation (Nova) leads a world-class team to deliver a 4MW array of 16 tidal stream turbines at the EMEC Fall of Warness tidal site in Orkney - 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 | For renewable energies to be sustainable in the future, their impact and harmful effects on the environment should be minimum. Off-coustics 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** | Green-H2Wave | Producing Green Hydrogen Using Power of Ocean Waves | Wave to Energy | The main objective of this project proposal is to boost the Technology Readiness Level 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, thus unlocking the massive deployment of Offshore FPV. |
| **2022** | PLOTEC | Tested Optimised Floating Ocean Thermal Energy Conversion Platform | PLOCAN | The project is to achieve a successful demonstration of the novel designs and materials for an ocean thermal energy conversion (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** | NATUR-SEA-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. It will develop innovative structural designs capable of handling the marine conditions, at the same time ensuring the durability and minimizing (un)installation costs. |

| | | | | |
|---|---|---|---|---|
| **2022** | WEDUSEA | Wave Energy Demonstration at utility Scale to Enable Arrays | New Wave Technologies Ltd (Ocean Energy) | The project led by Irish Wave Energy Developer, Ocean Energy, 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. |
| **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. To do this, the project uses an innovative 'pre-commercial procurement' approach to identify and fund the most promising wave energy technologies from developers across Europe. |
| **2020** | Valid | Verification through Accelerated testing Leading to Improved wave energy Designs | Corpower | Development and validation of a new test rig platform and procedures for accelerated hybrid testing to improve the reliability and survivability of the components and subsystems that form Wave Energy Converters |
| **2020** | Impact | Innovative Methods for wave energy Pathways Acceleration through novel Criteria and Test rigs | | To develop and demonstrate a next-generation 250kW Dual Hardware-In-the-Loop (DHIL) testing platform for Wave Energy Converters (WECs) |
| **2020** | MUSICA | Combined RES systems to optimise space on small islands | SINN Power GmbH | MUSICA project has developed a replicable smart multi-usage of space (MUS) platform for the concurrent use of three types of renewable energy – wind, PV and wave – at small islands and so-called green services to support aquaculture. |

An overview of awarded Innovation Fund projects is presented in the table below. These will be milestones for the ocean energy sector. Due to its nature the actual deployment of the innovative demonstrators/arrays might take some years.

| Year | Acronym | Title | Technology developer | Focus |
|---|---|---|---|---|
| **2024** | SAO | The Saoirse Wave Energy Project | Corpower ocean | The Saoirse wave energy project will be located off the west coast of Clare, and consist of a **5MW wave energy conversion array** of approximately 15-16 wave energy units, some 4 km from the coast. Expected entry into operation Q1/2030. |
| **2024** | SEAWORTHY | Sustainable dispatchable Energy enabled by wAve-Wind OffshoRe plaTforms with onboard Hydrogen | Floating Power Plant (DK) | Seaworthy is a 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.<br><br>The goal of the demonstrator, to be tested in Spain, is to advance proprietary PNS-P2X technology from TRL6 to TRL8, by building, testing and operating prototype at a scale considered suitable representative for validation of commercial-scale applications. Expected entry into operation 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) seek to promote a growth and job based recovery in the EU in the Blue Economy. The fund supports coastal communities in diversifying their economies, finances 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 some smaller projects in the past years focussing on environmental aspects supporting ocean energy technology development.

The table below presents the list of Ocean Energy EMFF/EMFAF projects awarded since 2020. More information about the projects and results can be found via the EMFF datahub

| 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 [point absorber type] wave energy converter integrated with battery storage. This technology has been developed by us over the past 10 years as a wave energy converter which will now be hybridized with photovoltaic capacity. The real innovation of the project will be the technical compatibility that we will enable between our 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 will prepare AW-Energy to deliver the world's first large-scale WaveFarm, with up to 24 integrated WaveRoller units. Two public energy companies stand ready as customers for pilot developments: in Sri Lanka (5 MW,) and Indonesia (10 MW). |
| **2020** | SafeWave | Streamlining the Assessment of environmental efFEcts of WAVE energy | CorPower, GEPS, Wello Oy | Improvement of the current knowledge on the environmental effects and risks of WE through the collection, processing, analysis and sharing of environmental data around devices operating at sea and modelling of cumulative impacts of future larger scale WE deployments. |

## 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

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=COM%3A2023%3A652%3AFIN&qid=1698155403554

Clean Energy Technology Observatory: Ocean energy in the European Union - 2023 Status Report on Technology Development, Trends, Value Chains and Markets
https://setis.ec.europa.eu/ocean-energy-european-union-0_en

The EU Blue economy report 2023
https://op.europa.eu/en/publication-detail/-/publication/9a345396-f9e9-11ed-a05c-01aa75ed71a1

# FRANCE

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## OVERVIEW

The French ocean energy activity was marked by the creation of the Open-C foundation whose objective is to gather all the test sites dedicated to ocean energy and floating offshore wind. Two WEC technologies were tested at Saint Anne du Portzic test site, part of Open-C. Regarding tidal energy, one pilot farm of 7 2.5 MW turbines will be installed in 2026 in the Alderney race, which will be a major milestone for the French tidal sector.

On the policy side, the long-term energy plan is currently under revision and should incorporate figures for the Ocean Renewable Energies (ORE) capacities at the horizon 2040.

## SUPPORTING POLICIES FOR OCEAN ENERGY

### National Strategy

The French President E. Macron announced at the French Maritime Days that targets for the tidal energy deployment volume will be set in the next French energy project plan. This is an important step since no quantitative objectives were set, until then in the French strategic energy roadmap.

### Market Incentives

The French government invests in ocean energy system as shown by the Flowatt project (see below) that benefit from a 75 M€ public investment and a feed-in-tariff the secure the business model of the farm.

### Public Funding Programmes

Since 2012, France Energies Marines, the research institute dedicated to Offshore Renewable Energies deployed different projects every year dealing with offshore wind and ocean energy.

In parallel the French Agency for the Environment and Energy (ADEME) supports the deployment of prototypes of ocean energy systems.

## RESEARCH & DEVELOPMENT

In France, different projects derived relevant results for the Ocean Energy System deployment. The France Energies Marines DIMPACT project provides new methods to account for breaking wave loads on ocean energy systems, while the MONAMOOR project ended up with important results regarding the mechanical properties of nylon ropes that may be relevant to any floating ocean energy systems to reduce loads of the systems. Finally, the France Energies Marines OPTILE explores how a mix of offshore renewable systems can be a reliable source of energy for isolated territories.

## TECHNOLOGY DEMONSTRATION

### Existing Open Sea Test Sites

The French ORE activities in France in 2023 were marked by the deployment and testing of wave energy prototypes.

At the newly created Open-C foundation the validation of the FLOWATT tidal energy pilot farm.

On the policy side, the long-term energy plan is currently under revision and should incorporate figures for the ORE capacities at horizon 2040.

The Open-C Foundation was created in 2023 to gather all the test sites dedicated to ORE and floating offshore wind. It therefore comprises :

- Paimpol Brehat test site, in Brittany, able to host multi-megawatt tidal turbines
- Saint Anne-du-Portzic, in Britanny test site dedicated to intermediate scale tidal, wave and floating wind test sites
- SEMREV test site, in Loire Atlantic, able to accommodate multi-megawatt floating offshore wind turbines
- SEENEOH river test site, in the Aquitaine region, with a hosting capacity for intermediate-scale tidal turbines
- MISTRAL test site, in the French Mediterranean Sea, that will host multi-megawatt floating offshore wind turbine

### Projects in the Water

Two wave energy technologies were tested at Saint Anne du Portzic test site, part of Open-C, and initiated by Ifremer. The first prototype is the **Legendre DIKWE** onshore concept that has been designed to be implemented on dikes. The tests were successful, and Legendre is now looking for opportunities for a proper deployment on a test site.

The second prototype is the **Seaturn concept**, also deployed at Saint Anne du Portzic test site. It is a ¼ scale prototype that hosts a turbine that uses compressed air to produce electricity.

Legendre DIKWE wave energy device (courtesy: GEPS TECHNO)

### Projects Planned for Deployment

The main project planned for deployment is the FLOWATT tidal pilot farm which comprises seven 2.5 MW **Hydroquest** vertical-axis turbines to be installed in the Alderney Race, the French most powerful tidal site. The consortium is made up of Hydroquest, CNM and Qair, to become operational in 2026.

## RELEVANT NATIONAL EVENTS

The **Seanergy Conference** is the main conference in France addressing ocean energy. In 2023 it was held in Paris (June 20-21). It addressed offshore wind energy and offshore renewable energies and gathered 2000 people.

The same event will be held in Nantes in 2024 (June 26-28).

# INDIA

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## OVERVIEW

India has an extensive coastline spanning approximately 7500 km with numerous islands, estuaries and gulfs. This vast coastal expanse offers opportunities for extracting ocean energy, for both grid and off-grid applications. Various resources such as waves, tidal currents, ocean thermal gradients, and salinity gradients hold the potential for energy extraction. 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, including calls for proposals from the Ministry of New and Renewable Energy (MNRE) and the MoES, 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, 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. Recently a national committee on Marine Energy Conversion Systems (ETD-54) of Bureau of Indian Standards (BIS) has been constituted to formulate standards towards development of ocean energy in India.

## Market Incentives

MNRE is funding various projects related to wave, tidal and desalination under its call for renewable energy. Call for funding proposals in ocean energy under Deep Ocean Mission (DOM) and REACHOUT program by MoES has been taken up recently. Few of the proposals under DOM have been awarded.

## Public Funding Programs

As part of the vertical on Energy and freshwater of the Deep Ocean Mission funded by MoES, a detailed project report for 10 MW closed cycle OTEC and 5 MLD capacity open cycle OTEC powered desalination plant has commenced. A new demonstration project towards generation of energy and freshwater on floating platform in the deep sea utilizing thermal gradient will also be carried out by NIOT.

Works towards implementation of an OTEC powered desalination plant of 100 $m^3$/day capacity at Kavaratti Island in UT Lakshadweep is currently under progress by NIOT. Detailed manufacturing design of process components was completed and site works for civil structure and welding of the very long cold water pipeline have commenced.

A study on potential of ocean energy resources wave, current and ocean thermal gradient in Indian waters has been taken up by Indian National Centre for Ocean Information Services (INCOIS), Hyderabad under MoES.

**RESEARCH & DEVELOPMENT**

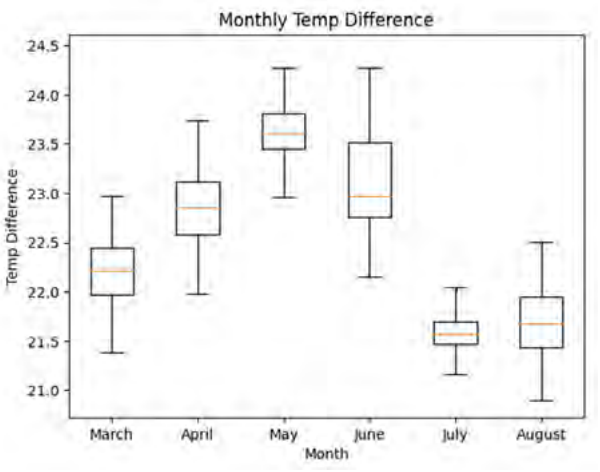
### Energy from ocean thermal gradient

The laboratory studies in Open Cycle OTEC and Low Temperature Thermal Desalination (LTTD) at NIOT were continued along with performance assessment of various components of OTEC and LTTD cycle. Control systems incorporating Machine Learning techniques for plant automation were developed and tested in the laboratory. These studies will be helpful for improving the performance of the integrated large capacity OTEC and Desalination plant.

Sizing and design of process equipments, platform and cold water conduit bundles are in progress for offshore demonstration project under Deep Ocean Mission.

NIOT team successfully deployed a surface buoy with a novel mooring configuration with subsea sensors up to 1000 m water depth for the first time for long term in situ measurements of current and temperature profiles off Lakshadweep Islands in the Arabian sea during 26-27 Feb 2023. This will help understand the long-term sub-sea environment towards the installation of the pipeline for the ongoing project at Kavaratti and also help in study of temporal variation of temperature profile for process design and EIA studies. Hourly current and temperature data corresponding to the varying depths are continuously transmitted through various communication modes and these can be accessed through an in-house developed mobile phone application.

Deployment of Surface buoy off Kavaratti




Temperature difference (recorded between S1 (5m ) and S8 (960m)

## Wave Energy

After successful development and demonstration of wave powered navigational buoy by NIOT, Kamarajar port Ltd. in Chennai has funded NIOT for a new buoy system to serve as a fairway buoy in their navigational channel.

## Saline water Lantern- ROSHNI

A low cost saline water lantern ROSHNI (***Renewable Ocean System for Harnessing Novel Illumination***) using the principle of ionization was developed by NIOT which can be used as a lamp and mobile charger unit making it useful in disaster prone areas for communication. The device consists only of two electrodes and saline water. The technology has been transferred to various industries.

ROSHNI


Grant Agreement with USTDA for design of OTEC plant

### SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

- MNRE hosted the IEA-REWP meeting during 6-7 Nov 2023 and all TCPs including OES made presentations.
- NIOT and United State Trade Development Agency (USTDA) has signed a Grant Agreement for a feasibility study to carry out Engineering Design and costing of 16 MW and 5 MW floating Ocean Thermal Energy Conversion (OTEC) power plant for Andaman & Nicobar Islands. The study will be carried out by US based consortium partners including one from India. Engineering Design and costing
- Shell International Exploration and Production, Inc funded NIOT for a baseline design report for a 1 MW net offshore OTEC plant and a scaling tool for a 1-5 MW net OTEC plant concept. The baseline design covers description/specification of technology, equipment, piping, process control and instrumentation solutions, offshore platform with cold water conduit and moorings.
- An international workshop on 'Energy, Water and Coastal Protection - A climate change perspective', was organized on 3 Oct 2023 at NIOT.
- 'International Workshop on Ocean Energy – Recent Trends' was organized during 30-31 Oct 2023 at Indian Institute of Technology (IIT) Madras, partially sponsored by NIOT.

# IRELAND

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## OVERVIEW

Ireland has one of the best offshore renewable energy resources in the world with a sea area of 490,000 km$^2$ which is approximately seven times the size of the country's landmass[1]. Because of Ireland's location at the Atlantic edge of the European Union, there is more offshore energy potential than most other countries in Europe, with significant long-term potential of offshore renewable energy (wind – fixed and floating, wave and tidal) within 200 km of the coastline.

Under the Programme for Government and the Climate Act 2021, 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 which consolidates the measure and actions to deliver on Ireland's carbon budgets and sectorial emissions ceiling set out by the previous Climate Action Plan (CAP 23). CAP23 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.

1 https://www.gov.ie/en/press-release/07331-transition-of-offshore-renewable-projects-announced/

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, the Designated Maritime Area Plan (DMAP) has been established to set out Ireland's future development for offshore renewable energy. The systemic, plan-led development regime will determine broad areas where offshore renewable energy projects can be deployed and will act as a management plan for a specific area in the maritime space. 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. This area will be refined through a process of public engagement and consultation, expert environmental impact assessments and other expert analysis of the maritime areas, to assess its suitability for offshore renewable energy development[3].

## The Marine Area Planning Act 2021

The Department of Housing, Local Government & Heritage have prepared the Marine Area Planning (MAP) Act 2021; The MAP Act 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 and the coastal local authorities. It will provide a modern, up-to-date regulatory and marine planning framework for offshore renewable energy developments beyond the limits of the foreshore (12 nautical miles). This will be an important foundation for investment in the offshore renewable energy sector as well as providing a more transparent, participative system for all marine stakeholders. The MAP Act streamlines 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. The agency will mandate the regulations of Ireland's maritime area and are responsible for:

- granting MACs to offshore developers,
- granting of Maritime Usage licence for specified activities
- ensure compliance and enforcement of MACs, maritime usage licences and offshore development consents
- managing the existing State Foreshore portfolio of leases and licence[4]

## 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

2 https://www.gov.ie/en/publication/a4a9a-national-marine-planning-framework/

3 https://www.gov.ie/en/publication/36d9a-designated-maritime-area-plan-dmap-proposal-for-offshore-renewable-energy/#:~:text=This%20first%20Designated%20Maritime%20Area,energy%20development%20may%20take%20place

4 https://www.gov.ie/en/press-release/9c75f-minister-obrien-announces-maritime-area-regulatory-authority-mara-establishment-day-and-new-ceo/

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.

## 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[5]

In 2023, Ireland ran its first ever offshore auction which was open to the six offshore projects under the first phase of the governments offshore wind programme. Over 3 GW of capacity has been procured from the 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[6]. The results of the ORESS 1 is a major step towards meeting the Irish Government goals of up to 80% renewable electricity by 2030 with an ambition of 7GW offshore wind capacity. Two more offshore auctions are currently planned but due to the relatively long development timelines of offshore wind projects, only the next auction can be expected to contribute towards Ireland's 2030 7 GW installed capacity target along with ORESS 1[7].

## 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 through results, outcomes and

Eleven ocean energy projects with a budget of €4.4million has been funded by the SEAI RD&D programme in the last 5 years. The projects funded have researched novel concepts in wave and tidal energy (including power take off systems, blades and rotors), foundations, structures, materials and cabling for wave and tidal devices.

Over €1 million has been funded to projects researching in novel concepts of power off take systems. Broader areas of research include spatial planning, resource mapping, ports infrastructure and transportation, ORE instal-

5 https://www.gov.ie/en/publication/36d8d2-renewable-electricity-support-scheme/

6 https://www.gov.ie/en/press-release/f2ac5-minister-ryan-welcomes-hugely-positive-provisional-results-of-first-offshore-wind-auction/

7 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/

lation, and operation and maintenance. Over €.8 million has been funded to projects researching in environmental impacts of ocean energy devices.

### SEAI/LIR NOTF Industry access programme

The Sustainable Energy Authority of Ireland (SEAI) and LIR National Ocean Test Facility (NOTF) in UCC MaREI designed and funded a pilot 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 2023, the programme opened a third call for applications of ORE technologies that are eligible to test their scaled-down physical model at the test site. Six wave and two tidal applications were successful from the competitive process making it the most successful call in terms of the number of granted applications.

To date, the LIR access programme has received 33 applications in which 19 have been successful through the competitive process. These successful projects have attained 91 testing days between them and have covered technology areas of wave (13 projects), tidal (four projects) and 2 additional projects.

**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, one ocean energy project has been funded through the programme. Further details about funded projects on the SEAI national energy research database[8]:

### 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 project will take these requirements and apply innovative design methodologies to advance the device concept in line with industry best practice, including the IEA-OES Evaluation and Guidance Framework for Ocean Energy Technology. The survivability and robustness of critical components will be demonstrated in a high-precision laboratory setting.

## EU Projects

Ocean Energy projects that Irish partners participated in during 2023 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. Many reports have been published to date including risk management, designs for port facilities construction, logistics, and support vessels, life cycle analysis and trial completion validation report. Irish Partner is MaREI-UCC.

8 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.

- **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 LiftWEC: Lift based Wave Energy Converter** is an innovative concept that explores the lift forces generated by wave-induced water velocities. By interacting with lift forces the LiftWEC concept has the advantage that the motion can be unidirectional. The lift-force can also be reduced to survive through harsh weather conditions. National University of Ireland Maynooth and University College Cork are the Irish project partners.
- **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. To date, all permits have been obtained and construction of an offshore Solar PV system is ongoing as well as implementing export cables and floating electrical infrastructure. 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. The project will also see the installation the next iteration of the Orbital turbine, integrated with a hydrogen production facility and battery storage at the European Marine Energy Centre (EMEC) in Orkney, Scotland. Irish partners are MaREI-UCC.
- **INTERREG Ireland-Wales Selkie:** project addresses identified gaps that are slowing the progression of the wave and tidal energy sectors. The aims of the project include Establish a cross-border network of Ocean Energy SMEs and supply chain companies; Conduct industry-academic collaborative R&D projects; Transfer R&D knowledge to the MRE sector SME stakeholders, thereby advancing the technology sector as a whole; Assist Irish and Welsh SMEs to progress along the pathway to commercialisation. The aims will be achieved by developing shared multi-use engineering tools, templates, standards, and models, which can be used across the sector in both Wales and Ireland. Irish Partners are MaREI-UCC, GDG ltd and DP Energy
- **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. This demonstration will show the potential for offshore renewable wave energy to make a significant contribution to the EU Green Deal target. Innovative actions taken in this programme aim to improve the efficiency, reliability, scalability and sustainability of wave energy technology, and reduce the Levelised Cost of Electricity of the technology by over 30%. This will help to de-risk investments in wave energy. This will be the steppingstone to large scale commercialisation of the technology. Ocean Energyand University Cork College are the Irish project partners.
- **HORIZON EUROPE SEETIP Ocean**: is a 3-year funded project running from 2022-2025 and will leverage from its predecessors, the ETIP Ocean and OceanSET projects. SEETIP will support 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. The aim of the project is to accelerate the deployment of the ocean energy sector by fostering collaboration amongst ocean energy sectoral stakeholders in all key SET Plan countries and to facilitate the greater integration of ocean energy into the wider energy system, industrial supply chains, infrastructure, local ecosystems, and European society. Current work to update the Strategic Research & Innovation Agenda

is ongoing as well as the publication on technology development and member countries policy development for ocean energy, market incentives and funding programmes. A guideline report on the community engagement and acceptance of ocean energy was published. SEAI are project partners of SEETIP.

- **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. The project will better inform decision-makers and managers on environmental risks, help reduce environmental and consenting uncertainty, develop country-specific licensing guidance and produce suitability maps for wave energy developments based on MSP decision support tools for most of the EU countries in the Atlantic Arc. MaREI UCC are the Irish project partners.
- **EMFAF SEA Wave: Strategic Environmental Assessment of Wave energy technologies** will address long term environmental concerns around the development of the marine renewable industry's emerging technology. A primary aim of SEA Wave is to undertake one of the first targeted multi-WEC ecological sampling campaigns adopting a rigorous experimental approach to address some of the remaining uncertainties that exist for WECs in offshore environments. The findings should provide the evidence-base required for regulatory bodies to adopt a risk-based consenting process and support developers secure future multi-device consents. New Wave Technologies Limited 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.

TECHNOLOGY DEMONSTRATION

## Existing Open Sea Test Sites

Ireland provides 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. Current 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 Smartbay Marine and Renewable Energy Test Site is located on the north side of Galway Bay, 2.4km southeast of Spiddal village, which is located 19km west of Galway city and approximately 1.5km offshore. The area of the site is 37 hectares, and it has water depths of 20-25 metres. The test site area is demarcated by four cardinal marks, one at each corner. The test site facilitates the open sea deployment of a quarter to half scaled prototypes of Wave Energy Converters (WEC's) with TRL ranging from 4 to 6. The Marine Institute (MI) with support from SEAI has been developing the Ocean Energy Test Site since 2006. Real-time oceanographic data, time-series data and full spectral data are available on the Galway Bay dashboard and the Marine Institute's Data Request service[9] and the Ocean Energy Ireland portal[10].

## Projects in the Water

No Ocean Energy technology has been deployed in the Irish water in 2023.

## Planned Deployments

There were no planned deployments of ocean energy projects in Ireland in 2023.

### 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. SEAI has expanded the scope of the test site to include floating offshore wind technology testing where the test site is currently consented to test wave energy converters. The geographical location with deep waters and a harsh metocean environment makes AMETS a suitable site to test floating offshore wind technologies. The following consents and planning permissions have been put in place for the site:

- A connection agreement is in place since 2011.
- The foreshore lease for the AMETS and deployment of the offshore cable; awarded in 2015 for wave energy devices.
- Planning permission, the electrical substation, awarded in April 2017 and extended until 2027.

The project includes: site development; onshore civil works for substation build; grid reinforcements; and offshore works for electricity export cable deployment. Currently the focus is on building of the onshore Substation, and obtaining consent to deploy floating offshore wind technologies in addition to WECs.

### Saoirse Project

Saoirse is a pre-commercial wave energy project that will demonstrate the CorPack, a pre-commercial wave energy array using CorPower Ocean WEC in a 5MW array off the west coast of Ireland. The project aims to prove the viability of wave energy in Irish seas subject to the necessary consents and a grid connection.

During 2023 funding of €39.475 million was announced for the Saoirse wave energy project through the European Commission's Innovation Fund programme. It was also announced that Simply Blue Energy would be joined by ESB Wind Development in a 50:50 joint venture between the two companies to develop the demonstration wave farm.

9 https://www.marine.ie/Home/site-area/infrastructure-facilities/ocean-energy/galway-bay-test-site-0
10 https://www.oceanenergyireland.com/data/observations/galway-bay/

## 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 (MRE) sets one specific goal; namely to promote carbon neutrality through MRE 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 2022 the second term of Pillar III commenced with Ireland appointed Pillar lead for Marine Renewable Energy, led by Kerrie Sheehan of the Sustainable Energy Authority of Ireland (SEAI).

The revised priorities for the coming term (2022-2024) will focus on four Task priority areas:

- Progressing the Pillar III Roadmap.
- Researching the changing policy landscape in the Member States.
- Assessing technological developments and progress of the rollout of MRE in the Member States.
- Fostering collaboration between Member States and Atlantic Stakeholders

## RELEVANT NATIONAL EVENTS

# Events in 2023

### SEAI National Energy Research and Policy Conference

This is an annual conference that aims to facilitate discussion on the role of energy research and policy in achieving Ireland's long term clean energy goals. In 2023, SEAI hosted the conference with a theme on Achieving Sustainable Energy Security. The conference featured speakers from a wide range of disciplines, outlining the focuses required to achieve a sustainable energy future. Policy makers, academic experts, energy industry and community representatives from Ireland, and internationally, shared their research findings, policy ambitions and insights, and engaged in lively discussions, in the field of energy security.

### Marine Renewables Industry Association

The MRIA represents and promotes development and implementation of policy for Marine Renewables Emerging Technologies. MRIA hosted the 14th Marine Renewables Emerging Technologies Industry Forum in 2023. Ireland's ORE policy developments, emerging technologies and innovations in ocean energy were presented at the forum.

### 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 such as creating models and simulations to optimise the energy output of these devices.

# Events Planned in 2024

SEAI will host an annual **National Energy Research and Policy Conference** where selected presenters from the energy industry will share their research findings, government targets and updates, policy development along with the challenges that lie ahead.

# ITALY

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**OVERVIEW**

In the wake of the past two years, 2023 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 2023 events.

**SUPPORTING POLICIES FOR OCEAN ENERGY**

## National Strategy

### NECP 2023 Draft

The 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, two specific investments (Green Islands and Innovative plants) 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.

### 2023 SEA PLAN

In 2023 a Sea Plan for the three-year period 2023-2025 was approved by the Interministerial Committee for Maritime Policies Resolution, then converted by law 204/2022. It is there stated that, in the context of Italy's new energy development strategy, the sea can make a decisive contribution to the production of energy from renewable sources, such as offshore wind farms and wave motion, which are increasingly important in the energy mix at European level and, despite a slower pace than Italy. It will therefore be essential to address the issue of energy "that comes from the sea" and "for the sea" - national clean energy which is fundamental to achieving the objectives of energy decarbonisation and energy independence - with specifically dedicated infrastructural, logistical and procedural interventions.

## Market Incentives

The Ministerial Decree 04/07/2019 is the latest issued support scheme, with the aim of promoting, through financial support, the diffusion of plants for the production of electricity from small, medium and large size renewable sources. In continuity with the D.M. 06/07/2012 and the D.M. 23/06/2016, registries and auctions are available to access incentives, which are dedicated to newly built photovoltaic plants, onshore wind turbines, hydroelectric plants and those with purification gas; according to NECP and Decree 199/2021, support for innovative technologies will be provided through following ad-hoc schemes, which will evaluate several kinds of promotion, depending on the maturity level of technologies. D.M. 23/06/2016 was the latest scheme providing support for ocean energy. The Decree identifies four different ways of access to incentives: direct access, bid auctions (Dutch Auctions), registries for new power plants, for fully reconstructed power plants, for reactivated, empowered and hybrid power plants and registries for rebuilding intervention. All the support schemes are managed by the Italian Energy Service Operator (Gestore Servizi Energetici - GSE). New, fully reconstructed, reactivated or empowered wave and tidal energy power plants can access directly to incentives if their capacity is not greater than 60 kW, otherwise they must apply for access to registries.

As mentioned above, in 2024 new specific decrees are expected, defining new incentive procedures and tariffs from innovative technologies, also including marine energies.

The Directive 2014/89/EU on Maritime 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 the D. Lgs 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.

In the National Recovery and Resilience Plan (NRRP), another investment (1.3 of Mission 2C2) is concerned with the promotion of innovative plants, including marine energy converters, to which 680 million euros are allocated. The project aims to support the construction of energy generation systems offshore renewable, which combine technologies with high development potential with multiple technologies experimental systems (such as systems that exploit wave motion), in innovative structures, also integrating storage. The intervention, therefore, aims to build plants with a total capacity of 200 MW from RES in the coming 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 (https://atlanteintegrato.rse-web.it/). 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, https://www.rse-web.it/progetti/energia-da-fonti-rinnovabili-e-integrazione-nel-territorio/) 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;
- WAVES: the wave prediction system that guarantees resolution up to 800 m in marine and coastal areas with high energy potential. Both models use the ENEA super computer "CRESCO6" with 1.4 million billion mathematical operations per second.

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.

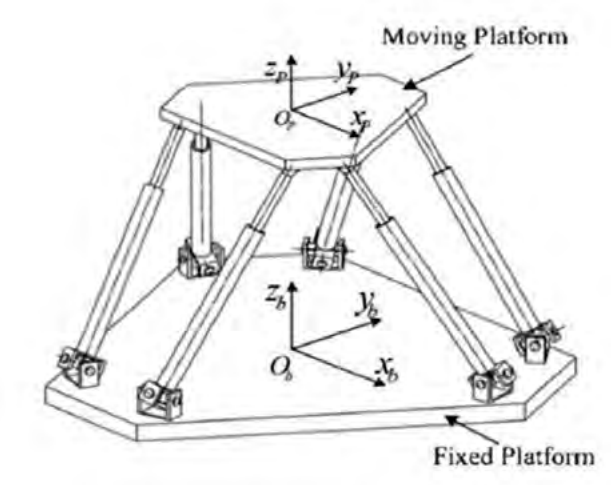
In Italy, attention is growing for the exploitation of energy from the sea, in particular from waves since the extraction of energy from the tides is limited to a single geographical area and WEC technology appears to be more promis-

ing 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. The investigation is taking place in parallel with that of the other 13 EU countries of the European marine energy task force. The task of the working group will be to lead the marine energy sector from the current phase of technological development of the devices to full commercial operation, through increasing the level of technological maturity of the individual experimental devices and of the entire industrial chain, the search for financial instruments and the development of environmental standards and certifications. Thanks to this survey it will be possible to know the technological progress of the projects, the financing and incentives available for the sector at European level. Furthermore, there will be a focus on all the crucial aspects concerning the launching phase of the devices, such as the availability of natural laboratories, the network infrastructure, the authorization procedures and the presence or absence of maritime space planning.

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 Politecnico di Torino, but triangulates with two important Eni structures: the Marine Virtual Lab and the offshore test area in Ravenna, where the pre-prototype phase of the ISWEC wave converter has been tested. In addition to Piedmont, Lombardy, Emilia Romagna also in Sicily, the laboratory collaborates with the Polytechnic site in Pantelleria, where other aspects of this technology are tested in an ecosystem, the insular one, which aims at energy autonomy and zeroing of the landscape impact. 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 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. Users are able to identify the best location for the wave energy assessment and obtain the time series of the main synthetic parameters in addition to several statistical analyses. (http://www.morenergylab.polito.it/more-est-platform/)

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.




Stewart platform in the hexapod configuration

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.

MOREnergy Lab played a significant role in the organization of the ENAEM-COER 2023 workshop, which took place in Buenos Aires, Argentina, from 6th to 8th November 2023. In addition to its involvement in the

ENAEM-COER 2023 workshop, MOREnergy Lab also served as a sponsor and was part of the organizing committee for the INORE European Symposium in Viana do Castelo, Portugal, held from 7th to 11th November 2023.

## TOWING TANKS

Small and medium scale prototypes are tested in wave flumes and wave tanks where a specific sea state can be artificially created, and power production and device survival assessed:

**CNR-INSEAN towing tank:** In particular, the CNR INSEAN offers the Umberto Pugliese towing tank, one of the largest worldwide. It is 470 m long, 13.5 m wide and has a depth of 6.5 m. It is equipped with a towing carriage that can achieve a maximum speed of 15 m/s. 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. The facilities are equipped with advanced measuring systems to provide the complete characterization of device performance and response to simulated operating conditions, including extreme events. Testing activity is supported by in-house laboratories for the design, manufacturing and maintenance of test models. A moving laboratory for field measurements is being developed to support on-site characterization and prototype operation activities.

**University of Naples Naval Tank:** The Naval Tank of the Department of Industrial Engineering – Section Naval of the University of Naples Federico II consists of the laboratory of electronic measurements and instruments, the workshops for wood and iron processing, the laboratory for photographic surveys and television shooting are also annexed to the naval tank. The actual tank, having an overall size of 140.20x13.16x5.55 m is all enclosed in a casing, statically independent of it, which at a lower level allows to complete inspection and, at an upper level, limits the working and running environment of the dynamometric wagon on rails arranged on the edges of the basin.

The Naval tank of University of Naples Federico II

### Waves4water project

In March 2020, an open procedure was published for the award of research services for the development of new technologies to improve the energy and water supply system within the Porto Conte Regional Natural Park. The "Waves4water" project involves the implementation of technology for producing electricity from sea waves and for desalination. The project will arrive at the prototyping, and the subsequent experimentation, of a system that will integrate a marine wave energy converter and a desalinator with which freshwater will be produced for self-consumption and agricultural uses within the Regional Park. The Waves4water project has the goal of producing renewable energy quantities per day on an annual average of at least 30 kWh/day, producing at least 2000 $m^3$ of desalinated water per year. At the end of 2021 the project has received a formal approval, with resources of about 0.5 mln€ financed by "Sardegna Ricerche" for the "Porto Conte Park", which will kick off the Waves4water project.

The Waves4water project started in June 2021 with Wave for Energy Srl awarded as winner of the public tender posted by "Azienda Speciale Parco di Porto Conte". The project started with the concept definition of the Water Energy Point Absorber (WEPA) and the development of a modelling tool used to optimize the WEPA configuration for the case study. The case study is located in the west coast of Sardinia Island, in the vicinity of the natural park "Porto Conte" and specifically offshore Capo Galera. The project continued with the design of the different components of the prototype, including the PTO, the hull,

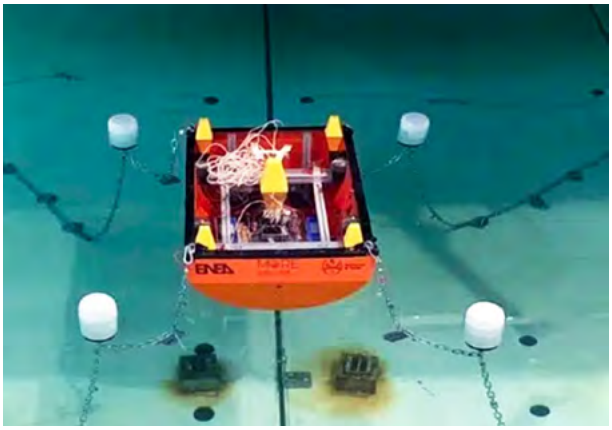
WEPA installation in Sardinian Sea near Alghero.

the electrical system, the control system, the mooring system and the communication system. Once the design was completed the procurement and construction followed, with the manufacture of the custom components such as the hull and most of the mechanical components. The assembly and dry testing of the prototype was completed by end of May 2022 and the installation took place on the end of June. The Waves4Water project ended with a 3 months testing and data collection period.

## Innovative Converters

### 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: a 1:25 scale prototype was tested at the Naval Tank of the Federico II University of Naples to study the response of the hull and moorings to extreme waves. The team's activity for the next three years will be to develop a 1-to-3 scale model to be installed at a test site.

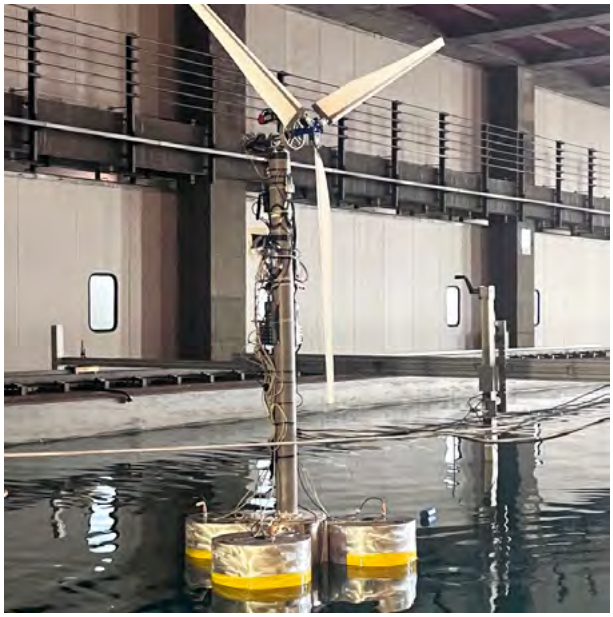


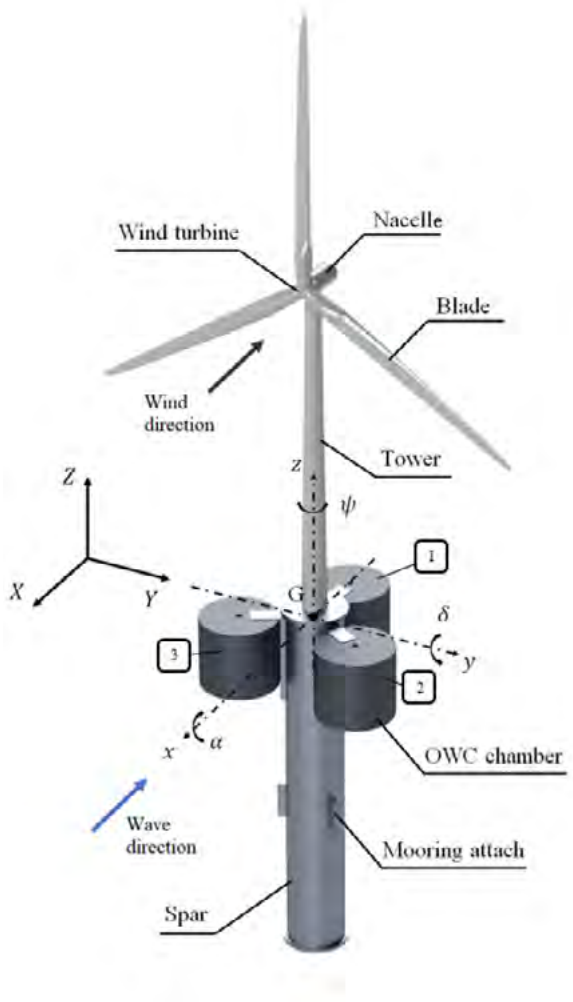
Testing phase of the 1:25 prototype at the University of Naples naval tank

## TEOREMA PROJECT

TEOREMA is a joint project performed by the National Research Council (CNR), the Italian National Agency for the New Technologies, Energy and Sustainable Economic Development (ENEA), the Politecnico di Torino, two of Italy's main national enterprises, ENEL Green Power and Fincantieri Oil & Gas, and one of the first university spin-off companies that project and test marine energy converters (Wave for Energy). TEOREMA project aims to define the design of novel

multi-energy platforms for marine renewable energy applications. The experimental investigation is based on a 1:42 scaled prototype composed by the floating substructure of spar buoy and OWCs air chambers and a three-blades wind turbine. The tests have been performed at the wave tank of CNR-INM, equipped with a wave maker and wind generator. Main emphasis is given to the assessment of the integration of the two technologies for the production of energy in terms of the response of the whole floating system to different sea states and wind conditions.






## WELLS TURBINE IN OWC

Air turbines meet the demands of a power transfer system by providing a straightforward method to convert the low velocities and high forces generated by compressed air from sea waves into the high speeds and low forces necessary for traditional electrical generators. The project involves the experimental representation in real time of a Wells turbine integrated into a fixed OWC. The prototype is scaled of 1:43 factor and equipped with a diaphragm on the top of the air chamber. The diaphragm opens and closes following the output from the real time model representing the Wells turbine. The experiments are performed to the Mechanical Department of Institute Superior Técnico of Lisbon to investigate the behaviour of the air turbine in regular and irregular waves.

## 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. Activated by the hull's motion, this mechanism propels an electric generator that is mechanically linked, generating electrical energy. To enhance stability and operational efficiency, the hull is secured by a catenary system, preventing damping on hull motion and ensuring 'station-keeping,' confining the WEC to a well-defined marine area. This addresses a prevalent issue in the WEC field where conventional devices directly couple a floater with a generator, exposing it to the harsh marine environment.

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. 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.

SWELL: an open-access experimental dataset for arrays of wave energy systems

In September 2022, MOREnergy Lab organised an experimental campaign at the wave tank facilities of Aalborg University, Denmark. This experimental campaign was conducted with the the sole objective of producing a complete and open-access dataset for the the validation of models of arrays of wave energy systems. The dataset is open-access[1], as well as the related paper[2].

## 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. The system consists of a fixed structure and a floating one. The buoy, hinged on the fixed structure, cap-


Pivot installation in Civitavecchia

1 Faedo, Nicolás; Peña-Sanchez, Yerai; Pasta, Edoardo; Papini, Guglielmo; Mosquera, Facundo; Ferri, Francesco (2023), "SWELL: An open-access experimental dataset for arrays of wave energy conversion systems", Mendeley Data, V2, doi: 10.17632/n34wcksmts.2

2 Faedo, N., Peña-Sanchez, Y., Pasta, E., Papini, G., Mosquera, F.D. and Ferri, F., 2023. SWELL: An open-access experimental dataset for arrays of wave energy conversion systems. Renewable Energy, 212, pp.699-716, doi: 10.1016/j.renene.2023.05.069.

tures the energy possessed by the waves and transforms it into usable energy through the PTO system. 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 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 created and tested in the port of Civitavecchia, which gave excellent results and a new development of the technology for offshore applications is being studied. A Pivot system measuring 5x3 m, with a draft of 1.5 m, installed on the coast of Sardinia, could generate 20,000 kWh, useful for powering around 10 homes.

## W.e.l.s.

The technology is called W.e.l.s. (Wave energy light system), and is the result of long studies that start from the first turbine created in order to exploit the wave energy. Two turbines were installed in Lipari island (150 Watt and 1.3 kW) to properly prove that these turbines can start to produce electricity with a minimum wave. These are particular turbines unique in the panorama of the reference market, able to produce electricity using very low waves and with application in port docks and breakwaters. Currently, 5 and 7 kW turbines are under construction and a project of 10 kW turbines will be tested in one of the large OWC rooms in the Civitavecchia harbour. The project was born from the collaboration between CNR, Fimeco ltd (Messina company that deals with mechanical processing and hydroelectric turbines) and Enermedesea ltd (an innovative start-up specialized in the renewable energy sector). In Lipari, the turbines have been placed for demonstration purposes and have already been dismantled. Enermedsea intends to submit to the Lipari municipality a partnership proposal for the construction of a 300 kW power plant.


The turbine developed by Fimeco and Enermedsea installed in Lipari island breakwater barrier

**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 most promising devices that have been developed and improved in the last few years are reported below.

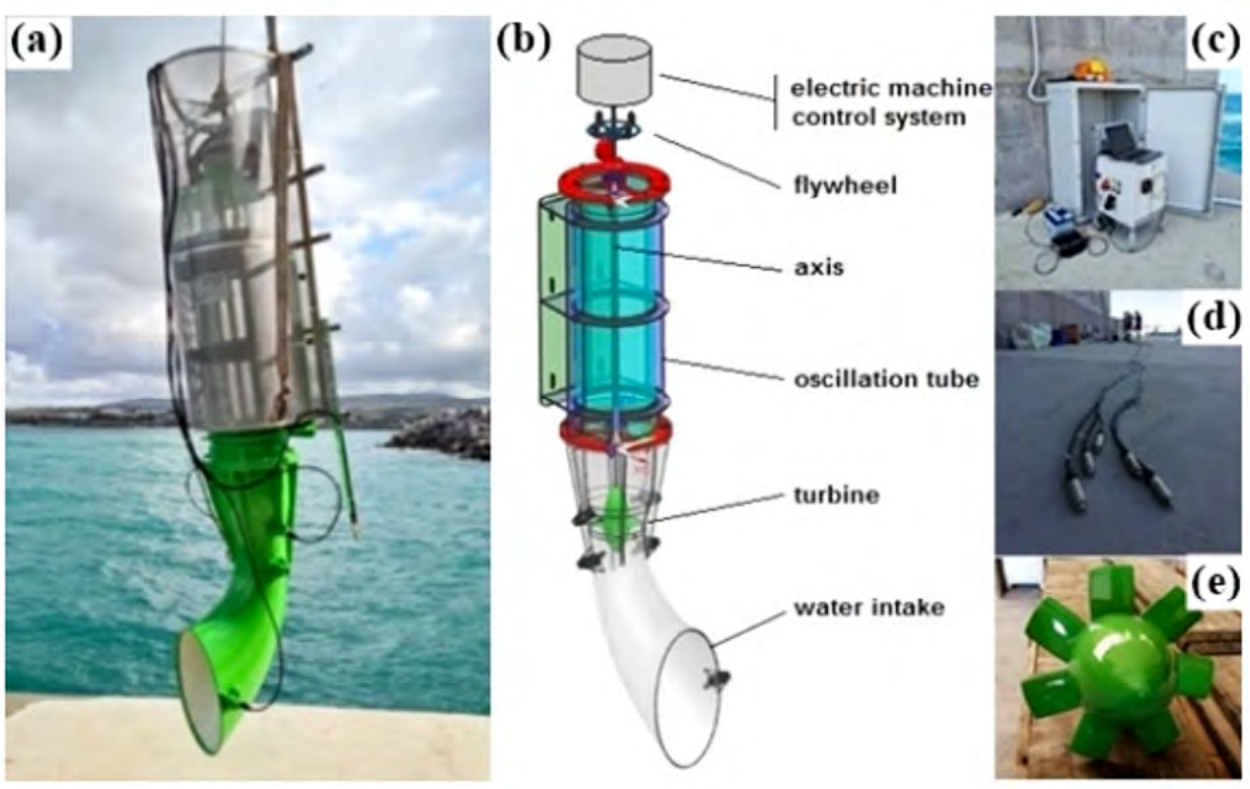
## Wave Converters

### WAVESAX

RSE S.P.A. (Ricerca sul Sistema Energetico – Research on the Energy System), in collaboration with Tuscia University, developed WAVESAX (TRL 5/6), an innovative wave converter within the OWC category, registered by the European Patent Office (Patent Document N. 2 848 802 B1, European Patent Bulletin 2016/23). This device has been conceived for its integration into coastal structures (e.g. harbours and ports). It consists of a vertical pipe in which water moves upward and downward, following the wave motion. Inside the pipe, a hydraulic turbine is positioned, which transforms the energy of the moving water into electricity. The turbine is of a bi-directional type (i.e. the rotor rotates in the same direction during both the ascending and the descending phase of water motion). The main advantages of the device are its low cost and its modularity, as it can be installed individually or in batteries of several elements. Following the protocol for the development of marine energy conversion devices (waves and currents) defined by the IEA-OES, various tests were carried out:

- Laboratory tests on a scale model (1:20) in the ocean wave basin of the HMRC - Hydraulic Marine Research Centre (Cork, Ireland) (2014);
- Laboratory tests on a second 1:5 scale prototype at the ECN Hydrodynamic and Ocean Engineering Tank (Nantes, France) without PTO (Power Take-Off) (2015);
- Laboratory tests on the 1:5 scale prototype at the CNR-INSEAN naval tank (Rome. Italy), aimed at evaluating the behaviour of the electrical control and generation system (2017).

In 2018, the 1:5 prototype was installed for the first time in a real environment (at the port of Civitavecchia). Afterwards, in December 2020, the second experiment was carried out with an improved prototype at a scale of 1:5 with a different configuration.




The WAVESAX 1:5 scale prototype and installation in the port of Civitavecchia

## 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. It consists of a vertical pneumatic chamber connected to the open wave field by a U-duct. A small-scale device has been installed at the Natural Laboratory of the University in 2005. 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.

## Overtopping Breakwater for Energy Conversion (OBREC)

The University of Campania Luigi Vanvitelli has developed a wave energy device denominated OBREC, embedded into a breakwater and based on the wave overtopping process. A 1:30 scale prototype was tested at Aalborg University (Denmark) during two complementary experimental test campaigns in 2012 and 2014. Tests have shown that the integration of an OBREC into a breakwater improves its overall performance. A full-scale, 6 m long prototype has been installed in the port of Naples in 2015, along the San Vincenzo rubble mound breakwater, where sea depth is about 25 m and available wave power is estimated to be around 2.5 kW/m. The overall performance of the device is being monitored.

Breakwater equipped with the OBREC prototype in the Naples harbour

## 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.

In August 2016, the first full-scale ISWEC prototype, with a nominal power of 100 kW, was moored 800 m from the coast of Pantelleria. In March 2019, another ISWEC pilot project has been put into operation, with a nominal capac-

ISWEC installation

ity of 50 kW, in the Adriatic Sea off the coast of Ravenna. The 50 kW prototype in Ravenna was removed in September 2022 after the conclusion of the test period. In the end of 2021 the revamping of unit installed by Wave for Energy and Politecnico di Torino in 2015 stated and lasted for the entire 2022. The unit has a rated power of 250 kW and was installed off Pantelleria in the early 2023. The project is currently ongoing.

### H-WEP 1

H-WEP 1 wave energy converter was first deployed off the coast of Marina di Pisa (Tuscany) by 40South Energy in September 2018 and it is operated and managed by Enel Green Power. The H24-50 kW is a sort of large mobile body that runs on a horizontal guide that collects the energy of the waves and puts it directly into the grid. H24 has the shape of a large table about 2 m high and 20 m long. It also has an electromechanical system which, by exploiting the wave movement, generates energy.

The installation in Marina di Pisa

## Tidal turbines

### GEMSTAR

SeaPower s.c.r.l. designed Gemstar, nicknamed the kite of the sea, which is 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 two marine turbines connected to a float that is tied to the seabed by a cable. In 2012 a first 20 kW prototype was built and installed for a short period in the Venetian Lagoon, thanks to a loan from the Veneto Region to a group of local businesses. Energy from the tides can be collected mainly in the Strait of Messina, where energy production could reach 125 GWh per year - a quantity sufficient to satisfy the energy needs of a city like Messina itself - thanks to the exploitation of the currents that they reach speeds exceeding 2.5 m/s. And it is in the Strait that Seapower aims to install the next full-scale 300 kW prototype. GEMSTAR has been selected among the 100 winning innovation solutions for the Planet of the European event The Arch, organized by THE ARCH 2022-2023 in partnership with the European innovation networks Atlanpole, IASP – International Association of Science Parks and Areas of Innovation and European Business Network (EBN).

Illustration of the deployed GEMSTAR system.

## SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

The Sea Plan, approved by Interministerial Committee for Maritime Policies Resolution in 31 July 2023, reports that in defining an effective marine energy policy, cross-border cooperation, the exchange of good practices and financing tools to support the sector are of particular importance.

**RELEVANT NATIONAL EVENTS**

## 2023

- **30 March-1 April 2023 Naples:** EnergyMed fourteenth edition.
- **3-5 May 2023 Naples:** The Arch 2022-2023, the European event with the aim of accelerating ecological transition.
- **30-31 May 2023 Salina Island:** Green Salina Energy Days: accelerating the energy transition in the Italian Minor Islands
- **1 June Salina Island:** Blue Island Day
- **30 June 2023 Siderno:** Polsi Ambiente 2023, Third edition, the challenge of energy sources: legal and ecological aspects, city of the sea – Siderno, Renewable energy from the sea
- **30 September Padova:** Energy from the sea - waves, tides and currents by IGI-CNR
- **10-12 October Rome:** ZeroEmission Mediterranean, Renewables energies for Southern Europe and the Mediterranean Coubntries
- **24-26 October 2023 Ravenna:** OMC - Med Energy Conference and Exhibition.
- **15 November 2023 Rome:** Energy: from the sea a possible futures; trying to produce energy from the sea, and how to do it.
- **15-18 november 2023 Florence:** Earth technology expo digital and ecological transition
- **30 November-1 December 2023 Rome:** Sea Festival - Rome at the center of the Mediterranean Sea.
- **20 December 2023 Rome:** National Energy Technology Cluster - Annual Event 2023 ENEA

## Planned for 2024

- **12-14 June 2024 Naples:** EnergyMed/Green Med Symposium

# MONACO

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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 gas 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's targets for combating climate change and recognizing the relevance of international cooperation.

Monaco is a coastal country with 2,08 $km^2$ 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 greenhouse gas emissions by 55% in 2030 compared to the reference date of 1990 and to achieve carbon neutrality in 2050. In 2021, the GHG emissions decreased by 28% 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 GHG emissions and energy efficiency, the development of renewable energies and 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 thalossothermal loops connected to seawater heat pumps have been put into service and the buildings are being connected. They should supply 3500 homes and eliminate 6 ktCO2eq of GHG emissions (approx. 8% of the total emissions of Monaco).

# NETHERLANDS

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## OVERVIEW

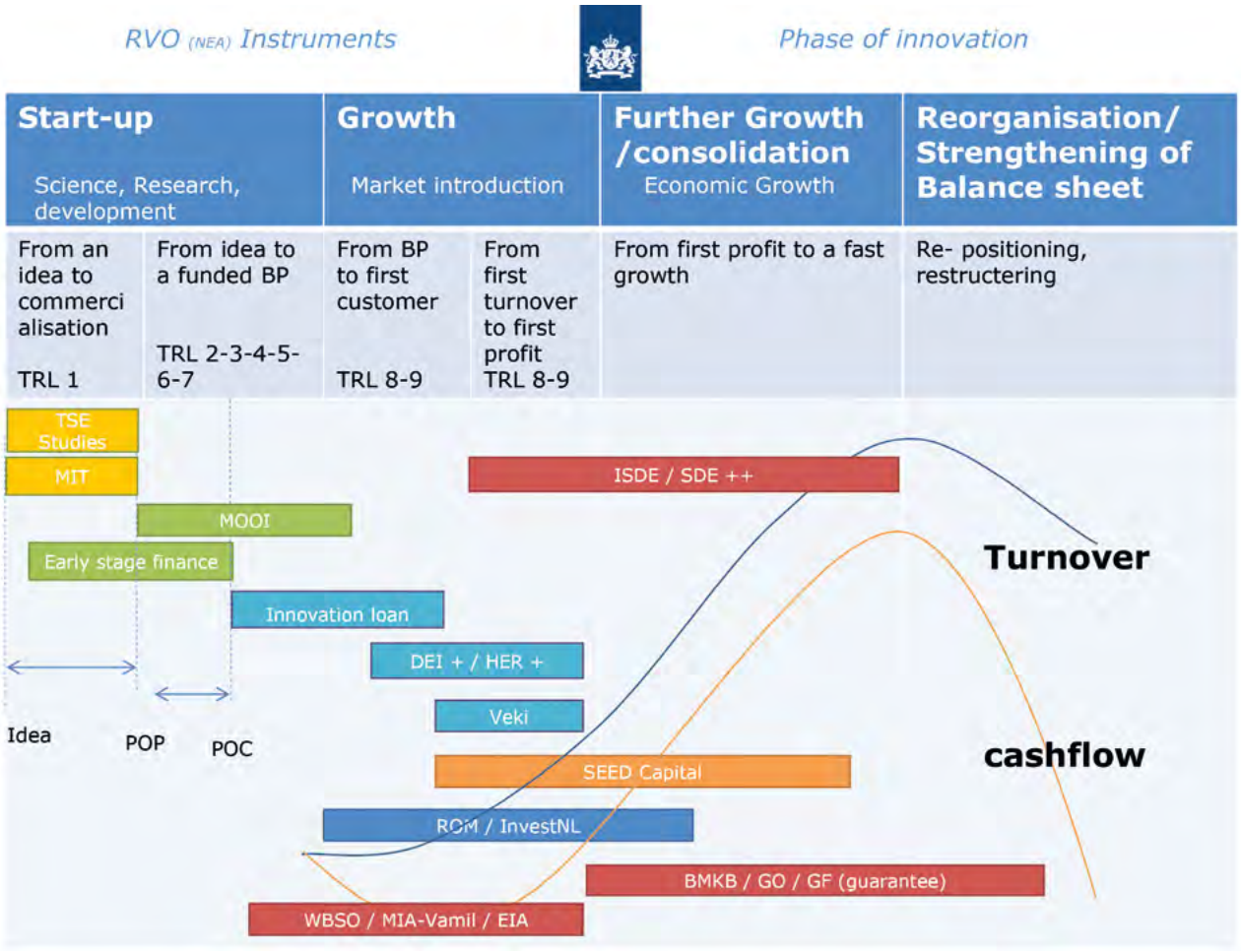
The Community of Practice (CoP) North Sea is an initiative by RVO (Netherlands Enterprise Agency) established five years ago to bring together various North Sea stakeholders. This collaborative platform includes representatives from offshore wind, offshore solar, wave and tidal energy, seaweed companies, fisheries, the oil and gas industry, NGOs, government bodies, and more. Its foundation aims to foster collaboration, share knowledge, and drive innovation across different sectors that operate in the North Sea region.

Additionally, a notable research study on "Wind and Wave resource complementarity at a Dutch offshore site" is available through TKI Offshore Energy. This study explores the synergies between wind and wave energy resources, highlighting the potential for integrated renewable energy systems at offshore locations in the Netherlands, contributing to a more comprehensive understanding of how diverse renewable energy sources can complement each other to enhance energy production and reliability.

## SUPPORTING POLICIES FOR OCEAN ENERGY

### National Strategy

The Netherlands has no specific policy on ocean energy 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, the Dutch government does support innovations in ocean energy through several innovation programs in different stages of development (Push and Pull mechanisms).




Above you will find an overview of the different subsidy schemes which are available for innovation, including ocean energy: For example, the DEI + (abbreviation for Demonstrating Energy Innovation, an investment subsidy (pilot and demonstrating, a push mechanism); the SDE++, abbreviation for Subsidy Sustainable Energy, an exploitation subsidy meant for supporting the implementation of new sustainable energy solutions which can be combined with DEI+ (feed-in tariff subsidy scheme).

Generic funding programmes are available for all relevant types of renewable energy. Most programmes have a tender system, suitable for high-level TRL-innovations. 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.

The Horizon Europe team at the Netherlands Enterprise Agency (NEA) provides support to entrepreneurs interested in applying for the Horizon Europe subsidy, specifically targeted at small and medium-sized enterprises (SMEs). While there are currently no specific processes or standards for licensing, the team collaborates with prominent research organizations such as TNO, Marin, and Deltares. These collaborations offer access to testing facilities and scientific modeling procedures to accurately assess the potential energy output of various energy converters. This support system is designed to enhance the development and deployment of innovative energy solutions by providing technical and financial assistance to entrepreneurs.

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 of identifying the most suitable zones for these technologies.

https://maritime-spatial-planning.ec.europa.eu/countries/netherlands

By 2050, all used energy in the Netherlands must come from renewable sources. The maritime spatial planning of the North Sea is focused on (growth of) offshore wind and increasing importance is given to system integration which is reflected in the tender scoring criteria. This promotes the concept of offshore multi-use where space within already designated areas for wind parks can be used also for other forms of energy generation. The Borssele wind farm zone, fully operational since 2021, includes the concept of "Area passports" which allow different technologies, including marine energy devices, to be deployed in the wind park. In addition, 3 other wind parks (Hollandse Kust Noord, Hollandse Kust West & IJmuiden Veer) will include other forms of offshore energy generation. The upcoming new energy law accommodates not only offshore wind but also other forms of offshore renewables.

## Market Incentives

The following market incentives are available for ocean energy:

- Market incentives include Feed-in-Tariffs: SDE++
- Green certificates: ***Regeling groenprojecten*** (interest rate discount on loan related to green renewable investments)
- Quota obligations: not yet, no target
- Auctions: not yet included in non-price criteria, but this has been an instrument to accelerate offshore solar
- Tax credit schemes: yes
- Private Public Cooperation: Yes

## Public Funding Programmes

Besides the above-mentioned subsidy programs supported by the Ministry of Economic Affairs, there exist different kinds of public funding (equity, loans, guarantees) by Regional development agencies:

- InvestNL, the national promotional bank
- Techleap
- Municipalities
- Export subsidies

**RESEARCH & DEVELOPMENT**

## Research Studies

- **Delta 21 (pending).** A research study on the storage of renewable energy (Fall Lake 20 s/km, Delta 21) is pending, funded by the Province of South Holland. This research study is expected to be published in March 2024.
- **Dynamic Tidal Power (DTP) (pending).** Commissioned by the Ministry of Economic Affairs and Climate and conducted by Deltares. This study is aimed to determine the potential of DTP. DTP is a long breakwater or dam (approximately 40 or 50 km) built offshore or nearshore (along the coastline) that houses tidal turbines to produce renewable electricity. This research study is expected to be ready in March 2024.

For 2024, further research is planned on various knowledge gaps of ocean energy. One of the most important knowledge gaps is a decent social cost-benefit analysis on ocean energy techniques (on a system level) in comparison with other techniques producing sustainable energy.

Currently, a project development team (part of CoP North Sea) is doing a research and feasibility study on the development of a maripark at the North Sea. A maripark can be described as an offshore Maritime Business Park with all kinds of activities and shared facilities. One can think of testing facilities for Marine Energy, port facilities for offshore wind farms and different kinds of sustainable food production (Seaweed, shellfish).

In 2023 two new projects started and seven projects continued their R&D activities:

- **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.
- **VALID** is a H2020 project aiming to develop and validate a novel test platform for wave energy. Technical University Delft is one of the academic partners contributing to the testing methodology offered by providing open-access models, testbeds and improved data management to lower the cost of future wave energy technologies. In 2022 the Technical University Delft launched the Marine Renewable Energies Lab (www.tudelft.nl/ceg/mrel) and joined as a founding member of the European Ocean Research and Education Alliance (EOREA).
- **OceanDEMO** is an Interreg Northwest Europe project concluded in 2023 targeting multi-device ocean energy installations to prove their technology at full commercial scale. In this project, Dutch developers SeaQurrent and Oceans of Energy have demonstrated their scaled systems at the Waddenzee area respectively the North Sea. Both demonstrations are supported by DMEC.
- **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.
- **ENCORE** is an Interreg 2Seas programme coordinated by Bluespring, which was successfully finalised in 2023. ENCORE advanced four offshore renewable energy technologies (with EEL-Energy, Water2Energy, Symphony Wave and Oceans of Energy) and developed a Route-to-market strategy to accelerate commercialization for islands, harbours, estuaries and offshore structures building.
- **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 a project partner, DMEC will pilot this tool across various developers, including SeaQurrent and Oceans of Energy.
- **InvestNL.** Research study; integration of dual renewable energy sources (combination offshore wind with offshore solar or wave energy, Common Future). Key challenges: wave power, tidal, osmose energy and offshore solar are not currently competitive compared to mature renewable power generation technologies, such as offshore wind, onshore wind and onshore solar. The generation costs are much higher than e.g. for offshore wind. Space for experimentation (at sea) and scaling up is key to the further development of the technologies current regulatory framework precludes stand-alone wave power or solar projects from acquiring a dedicated connection. Revision of law is in the making which is expected to enable direct connection to the national grid.
- **Sense hub** (pending); a research study on the integration of different reliable sustainable energy systems at the North Sea. Synergies between offshore wind, solar and H2. https://www.tno.nl/nl/newsroom/2023/02/sense-hub-offshore/
- **NS2OSP project** – Oceans of Energy (OOE) is developing the NS2 offshore solar pilot in cooperation with TKF, Primo-Marine, Wageningen Marine Research, NIOZ, TNO, Deltares and Utrecht University.
- **Waddenfonds research / partly funded by InvestNL:** Electricity production potential of osmose, tidal and wave energy in the Dutch Wadden region.

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 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 to 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.

Located 12 km off the coast of Scheveningen, the OTS is an innovation hub covering 6 km² of 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.

Test sites where prototypes can be tested but currently not in operation yet:

- Offshore wind Tender *Hollandse kust Noord site 5* (granted 2020), includes storage, solar, H2 a baseload power hub.
- Offshore wind Tender *Hollandse kust West Site 7* (granted 2022), includes storage and 5 MW solar.

# Projects in the Water

In 2023 eight developers have demonstrated or prepared demonstrations of their technologies at open sea locations in the Netherlands.

**Tocardo** has completed the array testing, demonstration program of the Tocardo T-2 turbine. As the world's longest operational tidal array, the 5 x T-2 turbines have provided 8-years of valuable insights for the development of their next-generation T-3 turbine series. The next generation Tocardo T-3 design will be used by UK firm HydroWing to deliver its 10 MW tidal stream energy project in Wales that secured a contract for difference (CfD) in the UK government's latest round.

**Water2Energy** has successfully demonstrated its grid-connected tidal turbine demonstration in a discharge sluice in the Port of Vlissingen. The ambition of W2E is to scale up the technology and install more devices in small and large sluices and discharge channels.

**SeaQurrent** is now working towards a demonstration of the fourth kite of its unique patented TidalKite system at Ameland. 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. Demonstration of the kite is planned for 2024. SeaQurrent has previously demonstrated a small scale version of the system in the Waddenzee.

SeaQurrent

**REDstack** is generating Blue Energy from the difference in salinity between river water and sea water at the Afsluitdijk. This is the first RED technology pilot-installation in the world which has been operating since its construction in 2014, with a production capacity of max 50 kW. The two main potential applications are where a river naturally discharges into the sea or within a desalination process.

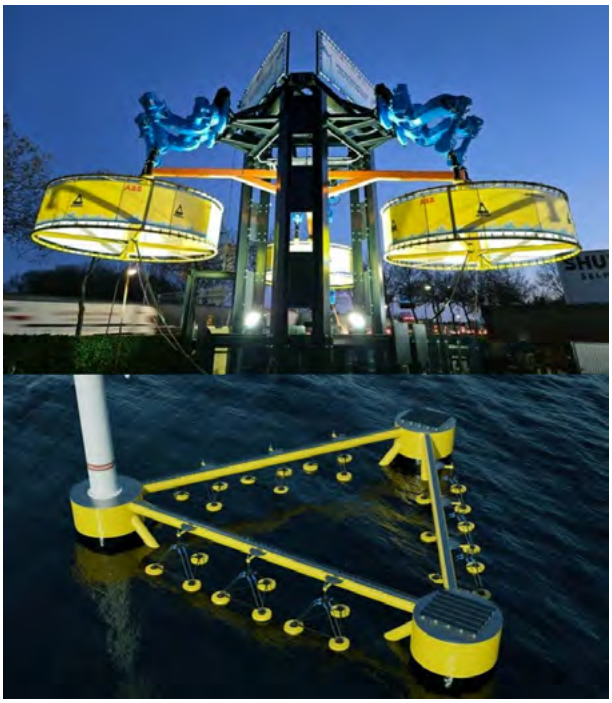
**WECO** has started a demonstration campaign at the North Sea Farmers' OTS in the North Sea. Tests in 2023 included scale tests and short-term deployments in preparation for a long deployment period to start in 2024. This will allow them to gain real-world operational experience and to collect long-term performance data. Multiple small units (~ 5 kWp) will be deployed in a WEC farm configuration.

## Projects Planned for Deployment

**Slow Mill** is preparing its next deployment of the Slowmill-40 to finalise validation tests. The company designed a novel wave energy device for moderate wave climates. A full-scale wave energy converter including grid connection is projected to harness 400 kW from North Sea waves and provide electricity for 100 households on the island of Texel. The engineering, constructing and dry test of this Slowmill-400 device is planned for 2024.

**Dutch Wave Power** is preparing to deploy a 20 kWp wave energy demonstrator in late 2024 or early 2025 and subject it to rigorous testing for a period of six to twelve months at the Offshore Test Site located at the North Sea 12 km off the coast of The Hague. This testing and validation campaign is part of the Interreg VI Flanders - Netherlands consortium project 'Offshore for Sure'. Dutch Wave Power previously tested prototypes successfully at MARIN and Deltares test basins.

AE WaveHexaPod completed the construction of an onshore testing facility in Dordrecht In October 2023. This innovative setup uses six robots at the base to simulate wave movements, while another six robots atop act as generators, converting simulated wave energy into electricity. A key feature of the WaveHexaPod is its use of repurposed robots from the automotive industry, incorporating standard parts into its design for efficiency and sustainability. AE WaveHexaPod is preparing for the next phase, planning to deploy two pods on a submersible in the North Sea farm, approximately 12km off the coast of The Hague by late 2024. This deployment aims to demonstrate the potential of the WaveHexaPod system with 2x500 kWp over a six to twelve-month period.



**Symphony Wave Power**, evolving from the Archimedes Wave project initially developed in Portugal and tested at full scale in 2004, showcases significant innovations in wave energy conversion. Its technology features a unique large rubber membrane that serves multiple functions: a linear bearing, seal, and internal pump, alongside a specially designed bi-directional turbine. These components have undergone extensive testing over the past three years, supported by both EU funding and private investments. The project is advancing with full-scale dry tests to thoroughly evaluate the core assembly under simulated operational conditions. Scheduled to continue through 2024 with water testing at EMAC Scotland planned for 2025, these tests aim to confirm the system's reliability before ocean deployment. Additionally, Symphony Wave Power is exploring applications of its technology in powering offshore oil production platforms, with a project delivery targeted for 2027.


Dry test setup under construction

## Relevant Investments

There has been a surge in investor interest in the Dutch marine energy sector, leading to significant investments in various developers:

- **RED STACK** has received an investment of € 4.9 million from the Wadden Fund for the construction of a new demonstrator facility at the Afsluitdijk in the North of the Netherlands (2023);
- **Symphony Wave Power** started the year by successfully bringing on board three new investors. Next to their ongoing partnership with Multimetaal another industry investor, Harsveld, has joined the company. In addition two VC's have provided additional funding. In total SWP secured close to € 500.000 in this latest investment round. In addition, SWP secured an investment of the Just Transition Fund (JTF) of more than € 800.000 (2023);
- **WECO** received multiple investments of in total €3 75.000 from UNIIQ investments as well as the Rabobank Impact fund;
- **InvestNL** (National promotional bank) made 2 investments in 2023;
- Offshore solar investment: **SolarDuck** – 15 million (2023);
- Tidal energy investment: **Seaqurrent** – 4.8 million (end 2022).

## Relevant National Events

In 2023 a number of international conferences showcased Marine Energy in the Netherlands:

### OEE

In October 2023 the Ocean Energy Europe conference took place in The Hague. The conference brings together ocean technology developers, decision-makers, supply chain actors and researchers from around the world to share the latest news from the world of ocean energy, and to define the future direction of the sector. The edition was attended by European Commissioner for Energy, Kadri Simson, and her colleague Virginijus Sinkevičius, EU Commissioner for Environment, Oceans and Fisheries, reinforcing their full support for offshore renewable (ocean) energy in the coming period. As part of the conference the Dutch Energy from Water Association (EWA) organised a visit to the facilities of prominent players in the Dutch ocean energy sector, including Symphony Wave Power, Slow Mill Wave Energy, RED-stack (Salinity Gradient), and Fishflow Innovations (tidal energy).

### OEEC

From November 28th to 29th, the offshore energy sector assembled at the Offshore Energy Exhibition & Conference (OEEC) in Amsterdam. Next to traditional offshore energy companies, innovative concepts were given the opportunity for knowledge exchange, collaboration and networking. Dutch and international marine energy companies showcased their developments to the offshore sector.

### Oceanovation

On June 21 and 22, the first edition of Oceanovation took place in The Hague. This event highlighted and showcased solutions for a sustainable and healthy ocean. Dutch innovators Weco, Slowmill and SeaQurrent were present and engaged in the exhibition, pitching and discussion sessions.

### Offshore Experience Den Helder

On the 12th of September, the second edition of the Offshore Experience was held in the harbour city of Den Helder. It was organised by the Port of Den Helder, North Sea Energy Gateway and ECHT. The event covered the opportunities and challenges faced by the offshore sector and the blue economy, specifically security issues. Slowmill and Wavehexapod were present to showcase how marine energy can contribute directly to the blue economy and sustainable future of the North Sea.

## Relevant Events Planned for 2024

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

# NEW ZEALAND

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## OVERVIEW

The key achievements in 2023 include:

- Holding the Offshore Future Energy Forum, 8-9 March 2023, organised by New Zealand's Future Energy Centre Ara Ake.
- Holding several workshops on marine energy organised by the NZ Marine Energy Association, the Aotearoa Wave and Tidal Energy Association (AWATEA), with participation from various stakeholders including New Zealand's Future Energy Centre Ara Ake.
- Azura Wave Power has completed provisional design and modelling work for a 50 kW and 100 kW WEC device with the capability to deliver 50 m3/100 m3 desalinated water.
- Deploying and testing short-term in the ocean at New Zealand's coastline two marine energy devices developed by the Waves and Dynamics Group at the University of Auckland.

## SUPPORTING POLICIES FOR OCEAN ENERGY

### National Strategy

Renewable energy strategy work programme, The Ministry of Business, Innovation and Employment.

### Market Incentives

There are no significant market incentives for ocean energy, except for the aquafarming industry that is growing fast in New Zealand, with increasing energy demand and interest in renewables.

## Public Funding Programmes

No Funding Agencies and national funding programmes specific to ocean energy.

New Zealand's Future Energy Centre Ara Ake manages a fund aimed at advancing New Zealand's future energy sector by accelerating the demonstration, commercialisation and deployment of critical innovations and emerging technologies into the market.

NZ Green Investment Fund and NZ Climate Fund could also support ocean energy activities potentially.

### RESEARCH & DEVELOPMENT

Azura Wave Power has completed provisional design and modelling work for a 50 kW and 100 kW WEC device with the capability to deliver 50 m3/100 m3 desalinated water.

Ruka Marine Turbine project will progress in 2024 to deploy a "proof of concept" surface floating turbine in Tai Tokerau, New Zealand.

The Waves and Dynamics Group at the University of Auckland, is currently developing and ocean testing short-term two marine energy devices, one harvesting wave energy, another tidal energy. Both devices target supplying electrical energy to aquafarms.

The University of Waikato is developing piezoelectric wave energy harvesters and tidal devices for integration into coastal protection structures.

### TECHNOLOGY DEMONSTRATION

## Projects Planned for Deployment

- Azura Wave Power is targeting Q1 2025 to deploy a 50 kW device in French Polynesia.
- Mana Wairua Energy 1999 Ltd (formally - Environment River Patrol-Aotearoa) is to deploy a proof of concept of Ruka Marine Turbine device in 2024.
- Aquantis has 20 MW ocean gyre current project in the US and a 30 MW tidal current project In Wales, both in development.
- Devices by the Waves and Dynamics Group at the University of Auckland are to be deployed at aquafarming sites in 2024.

### RELEVANT NATIONAL EVENTS

## 2023

- Offshore Future Energy Forum, 8-9 March 2023, organised by New Zealand's Future Energy Centre Ara Ake.
- Several workshops on marine energy organised by the NZ Marine Energy Association, the Aotearoa Wave and Tidal Energy Association (AWATEA) in 2023.

## 2024

- Offshore Renewable Energy Forum, 20-21 March 2024, New Zealand's Future Energy Centre Ara Ake.

# PORTUGAL

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## OVERVIEW

CorPower Ocean successfully installed their first device in the Atlantic coast and it was in the waters from September to November 2023. This is the first prototype of a wave energy farm of 1.2 MW under development.

In 2023, Portugal initiated its first auction for offshore wind projects. This move was part of a broader strategy to reach 10 GW of installed capacity by 2030. The preparatory process began by inviting companies to present non-binding declarations of interest, with a capacity of 2 GW. The significant interest and developments in Portugal's offshore wind sector in 2023, signal a robust commitment to renewable energy and a strategic shift towards leveraging the country's maritime resources. With the momentum gained from offshore wind energy projects, Portugal is likely to see an increased interest in exploring other forms of marine renewable energy. The country's extensive coastline and significant maritime expertise make it an ideal candidate for the development of wave energy projects.

## 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), housed within the Ministry for the Environment and Climate Action, has the main responsibility for developing and implementing Portugal's energy policy.

The Roadmap for Carbon Neutrality 2050 (RNC 2050) was approved in 2021. In conjunction with the objectives of the RNC 2050, the National Energy and Climate Plan 2030 (PNEC 2030) was developed, which is a key national instrument of national energy and climate policy for the next decade toward a carbon-neutral future. The PNEC (in conjunction with other instruments as the National Strategy for Hydrogen) is intended as well to put Portugal on a path to achieving the goals set in the Roadmap for Carbon Neutrality 2050 (RNC2050), which calls for GHG emissions reductions of 85-90% by 2050 versus 2005 levels, complete decarbonisation of electricity generation and transport, and carbon sequestration to reach carbon neutrality.

In January 2022, the government introduced Decree-Law No. 15/2022, outlining the organization and operational guidelines for the National Electric System (SEN). Additionally, this decree established a legal framework for Technological Free Zones (ZLT). These zones serve as dedicated spaces for testing and demonstrating new technologies in a real-world environment, subject to specific legislation and continuous oversight by regulatory bodies. This approach aims to expedite experimental and research activities through streamlined legal mechanisms. In 2023, the government, via Order No. 298/2023 on October 4, has approved the establishment of a Technological Free Zone for oceanic renewable energies offshore Viana do Castelo. 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.

## 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 was published in September 2021 containing over 180 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.

The ENM 2030 and the Action Plan can be assessed 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. In 2023, Portugal chaired the Atlantic Strategy Committee in accordance with the principle of rotation among the participating countries of the Atlantic Strategy.

More information:
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.

In 2022, the EMB activity was focused on preparing an update on status and recommendations related to marine renewable energy, highlighting the current knowledge and research gaps in marine science. This publication was released in 2023.

In 2023, 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 Wa-

vEC). 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.


## Maritime Spatial Planning Policy

### National Maritime Spatial Plan (PSOEM)

The Maritime Spatial Plan covers the entire national maritime space, from the baselines to the outer limit of the continental shelf, integrating inland maritime waters, the territorial sea, the exclusive economic zone and the continental shelf, including beyond 200 nautical miles.

The Maritime Spatial Plan (https://www.psoem.pt/) is an instrument for planning the national maritime space and constitutes an essential tool for the policy of the sea. The Plan 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.

In 2022, following the public announcement by the government of their intention to launch a 10 GW offshore wind auction, it was decided to review the PSOEM for the integration of potential areas for offshore renewable energies commercial projects. The definition of these areas also requires the identification of connection points to the electrical grid, as well as the development of grid and port infrastructures and the establishment of the procedures for the offshore renewable energy bids. In 2023 the Directorate-General of Natural Resources, Safety and Maritime Services held a public consultation on the Renewable Energy Allocation Plan aimed at identifying potential areas for the commercial exploitation of offshore wind energy in the national maritime area along the western coast of mainland Portugal.

### Permits for Private Use of the National Maritime Space (TUPEM)

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 the Directorate-General for Natural Resources, Safety and Maritime Services (DGRM), which shall ensure 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.

In 2023, 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.

### Directorate-General for Maritime Policy (DGPM)

DGPM is a public administration body of the Ministry of the Sea responsible to develop, evaluate and update the National Ocean Strategy, designing and proposing the national maritime policy, developing the maritime spatial planning strategy and management, monitoring and participating in the development of the Integrated Maritime Policy of the European Union and promote national and international cooperation on maritime affairs. DGPM is currently engaged in a variety of scientific marine and maritime research topics (including socio-economy sciences related to the Ocean, monitoring of the Blue Economy, and monitoring of the Portuguese contribution to the UN SDG 14 Goal), but also in Ocean Literacy and translational aspects between academia and industrial sectors.

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.

Portugal 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.

## Key R&D Projects

Most Key RD&D projects in Portugal are structured around international cooperation with European funding.

### Funded by the Horizon 2020 programme:

- **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.
- **LIFTWEC**, coordinated by the Queen's University of Belfast, focus on the development of a novel type of wave energy converter - LiftWEC - based on the exploitation of lift forces generated by wave-induced water velocities. **WavEC** has been contributing to the identification of promising configurations of the LiftWEC concept that may minimise environmental impacts and ensure social acceptance. It was initiated in 2019 and concluded in 2023.

### Funded by the European Maritime and Fisheries Fund (EMFF):

- **SAFEWAVE** addresses long-term environmental concerns around the deployment of wave and tidal energy converters in the marine environment. It is coordinated by EMEC, with a diverse range of project partners

across six European countries. **WavEC** is participating through the collection, processing, analysis and sharing of environmental data around devices operating at sea. The Portuguese company **Hidromod** is also partner of the project. The come to a close in 2023.

## Funded by the European programme INTERREG Atlantic Area:

- **PORTOS** – Ports Towards Energy Self-Sufficiency: aims to assess, develop and promote the integrated use of renewable energy resources in Atlantic Area ports and increase their energy efficiency, establishing a roadmap to a more competitive and sustainable sector. Additional objectives consist of disseminating the benefits of marine renewable energies and sustainability principles to the general public by organizing OpenPorts and OpenLabs events, supporting the development of novel technologies and promoting entrepreneurship. This project is coordinated by **UPORTO (FEUP)**, started in 2019 and its extension to 2023, with additional activities and partners (two additional case study ports and three technology developers) was recently granted.
- **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).

## Projects with funding from the European Regional Development Fund (ERDF):

- **ATLANTIDA** – *Platform for the monitoring of the North Atlantic Ocean and tools for the sustainable exploitation of the marine resources*: aims the development of a platform for the monitoring of the North Atlantic Ocean and tools for the sustainable exploitation of marine resources. ATLANTIDA creates a coastal observatory and monitoring, focusing on data collection and supply, including monitoring platforms and systems, sensors, data management and information technologies, which, among other objectives, also aim to promote the development of wave energy exploitation in the North Atlantic Ocean towards its promotion as a key driver for oceans sustainability and climate change resilience. Additionally, this project also focuses on important aspects related to the quantification and study of other potentially viable ocean energy sources such as marine biomass. The project is led by **CIIMAR - Interdisciplinary Centre for Marine and Environmental Research with other Portuguese partners: UPORTO, UTAD and UMINHO.**
- **Ocean3R** – *Reduce pressures, restore and regenerate the NW-Portuguese ocean and waters*: aims the development of solutions to reduce pressures on marine and freshwater ecosystems, and to restore and regenerate degraded habitats along the northwest coast of Portugal. Within the project, the supply of electricity from marine renewables to offshore facilities is being considered. The project is led by **CIIMAR**.

## Funded by the European ERA-NET - European Research Area networks:

- **WEC4PORTS** – aiming to develop a novel hybrid wave energy converter for ports. The key components (e.g., turbines) will be built and demonstrated in Mutriku testing site, after numerical and experimental testing. Furthermore, a new material will be tested in site to assess its strength and ability to withstand harsh marine conditions. This project led by the company IMDC - International Marine & Dredging Consultants, is conducted by 4 partners, involving from **Portugal FEUP** and **INEGI**, responsible for scaled physical and numerical modelling activities, performance improvement and optimisation to reduce the LCOE.
- **EVOLVE** aims to model future energy generation, taking in consideration supply and demand scenarios, from distribution to balancing and storage/back-up. This allows to evaluate whether, where and how ocean energy options can make a significantly positive and profitable contribution to future energy systems as secure, clean and efficient energy sources. This project will reinforce the development of marine energy while supporting emissions reduction, renewables targets and security supply requirements in a cost-effective way. **WavEC** has been leading the planning of energy mix scenarios, through metocean data, characterization of the different ocean energy resources and identi-

fication of demand and supply patterns. It was initiated in 2021 and was concluded in 2023.

### 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 experience 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 the 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.

TECHNOLOGY DEMONSTRATION

## Test Sites

Portugal has a **Pilot Zone at Viana do Castelo** set up by the government in 2018, with an area of 47 km$^2$, at 85-100 m water depth where Portugal's first floating offshore wind project, WindFloat Atlantic (25 MW) occupying an area of ca. 11 km$^2$, became fully operational in July 2020.

In 2022, through Decree-Law No. 15/2022 on January 14, the government established an offshore Technological Free Zone (ZLT) near Viana do Castelo. This zone serves as a dedicated space for testing and demonstrating emerging technologies in real-world conditions. Subsequently, the government, later in the same year, initiated a public consultation process to define the ZLT area within the bounds of the previous Pilot Zone, covering approximately 20 km$^2$. In 2023, the finalized area of the ZLT was determined to be 7.63 km$^2$, strategically located adjacent to the *Windfloat Atlantic* project site.

In Aguçadoura, a dedicated test site spanning 3.3 km$^2$ and situated at a water depth of 45 meters serves as a research and demonstration ground for innovative projects. The Swedish developer CorPower has been actively progressing with their flagship wave energy project, Hi-Wave-5, within this designated area. This site is managed by a private entity, *Companhia de Energia Oceânica*.

## CorPower Ocean

In 2023, 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 tothe 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**

**WavEC Annual Seminar in 2023** was organized on November 10th in collaboration with the Dutch Embassy in Portugal, aiming to provide its participants with a unique opportunity to explore new collaboration opportunities in business and research in marine renewable energies and other blue economy sectors. This online event had over 250 participants - developers, researchers and other professionals – from the public and private sectors.

Presentations are available at: https://www.wavec.org/en/seminar

# REPUBLIC OF KOREA

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## 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 demonstrated the performance of a 30 kW-class wave energy converter (WEC) of the oscillating water column (OWC) type, combined with a breakwater and an energy storage system (ESS), to provide electricity to remote off-grid islands, and will extend the similar WEC system for another site with three 30 kW WECs in total 90 kW installed capacity. Korea Institute of Ocean Science and Technology (KIOST) developed dual Darrieus-Savonius tidal energy converters combined with ESS to supply energy to remote off-grid islands and verified its power performance at the existing Uldomok tidal power plant. KIOST also installed a 1 MW class commercially available tidal energy converter in the Uldolmok tidal energy test site. The three ocean energy technical standards, harmonized from IEC TS 62600-100, 200, and 201, were submitted to the Korea Agency for Technology and Standards, an official governmental organization, and will be registered in 2024 as the new Korean Industrial Standards.

A second stage of the bilateral cooperation project (2021-2023) between South Korea and China, led by KIOST and the First Institute of Oceanography (FIO), China, was carried out to exchange the technology development and the utilization of ocean energy systems and the 7th joint workshop was held in July 2023 as a face-to-face meeting in Weihai, China.

## 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 for 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 million USD in 2021 and 7.8 million USD in 2022 were invested in developing ocean clean energy technologies and tidal energy systems in 2021. In 2023, 9.4 million USD was invested for developing green hydrogen production technology using ocean energy, for developing OWC wave power plant, and for establishing the open sea test bed for tidal energy converters.

## RESEARCH & DEVELOPMENT

In 2022, a new R&D project was initiated to develop the green energy production system using wave energy, and in 2023, a new R&D project was also started to develop a multi-module breakwater-combined wave energy converter with a target installed capacity of 90 kW, employing three 30 kW class devices.

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. 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, an official governmental organization, and will be registered in 2024 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.

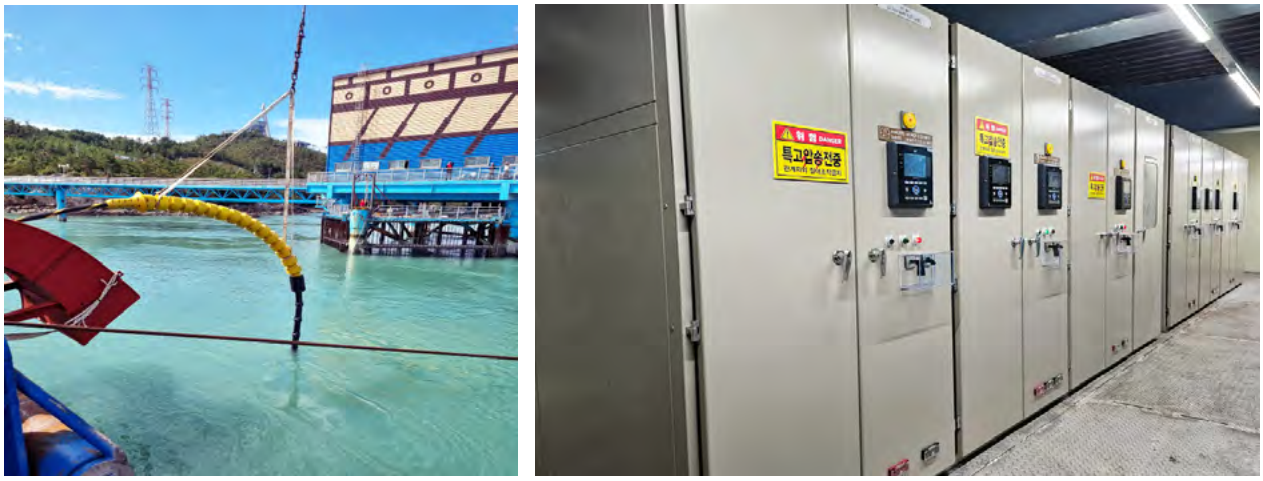
TECHNOLOGY DEMONSTRATION

## 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 has 5 test berths, including the Yongsoo OWC pilot plant, two in 15 m, one in 40 m, and one in 60 m water depth. Each berth has a 4.5 MW maximum output capacity and 5 MW capacity in total, and it is considered to increase the capacity to meet the requests from floating offshore wind developers. 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, this test site will be used for testing floating offshore wind and green hydrogen production projects. Unmanned underwater vehicles, radars, and floating lidars are being tested using this facility. By conducting more test projects, it will come closer to operating this facility without additional financial support from the Korean government.


Projects at the KRISO-WETS (Courtesy: KRISO)

The second open-sea testbed is the Korea Tidal Energy Center (KTEC) operated by KIOST. This center consists of two parts: (1) a tidal energy converter component experimental building at KIOST Busan headquarter (completed in March 2021), and (2) an open sea testbed in Uldolmok strait. Among them, the open sea testbed has five berths with a total installed capacity of 4.5MW. The submarine cables with 6.6 kV power voltage and dry-mate connectors are equipped to provide them to the developers. The submarine cables were manufactured and installed in 2023 in Uldolmok Strait. The details of the open sea test bed for tidal energy converters are as follows: it is located in the southwestern sea of Korea, Jindo Island, and 5 test berths are prepared. Of the five berths, four submarine cables have a capacity of 1MW, respectively, and the other has a capacity of 0.5MW. In particular, the existing Uldolmok tidal power plant is being used as a 0.5MW test berth. Regarding the tidal energy resource, the water depth is between 20 and 45 m, the annual maximum tidal current velocity is over 3.5 m/s with bi-directional flow, the seabed condition is almost rock, and the waterway width is about 500 m. The site is not a fishing area, but




A picture of the submarine cable laying and offshore substation facilities (Courtesy: KIOST)

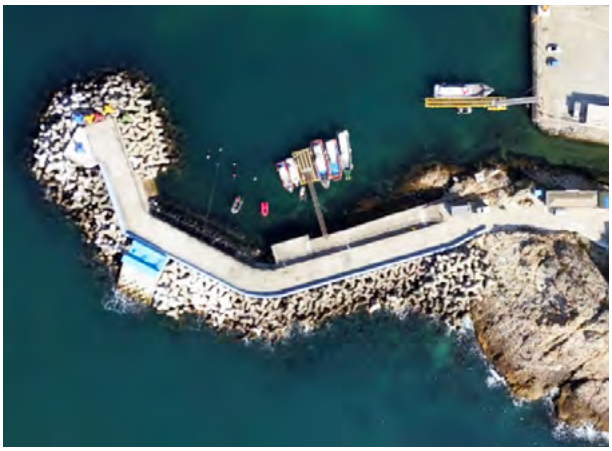
vessel traffic is available. The top clearance between a tidal energy converter's blade tip and the water surface is 5 m for vessel traffic. The four submarine cables were laid in December 2023, and a 1 MW tidal energy converter developed by KIOST will be installed and operated for performance testing. In addition, the SCADA system with maritime vessel activity management and monitoring system was built. Furthermore, KIOST is preparing to get accreditation as a testing laboratory for power performance and mechanical loads.

## Projects in the Water

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). The Pilot Plant passed the electrical safety inspection in 2022 and is conducting performance evaluation and technology verification through long-term operation. This project was selected as one of the 2022 National R&D Excellent Accomplishment 100 by the Ministry of Science and ICT.

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 way to utilize ocean energy in islands with narrow land and relatively large marine space and is expected to be widely applied.

The Mook-ri OWC plant will be operated by KRISO and private enterprises to study various topics such as (1) the correlation of wave condition with power output, (2) output variability of OWC WEC system according to tidal level in the real sea, (3) optimization of control strategy to maximize power output under fluctuating wave conditions, (4) the effective ESS charging and discharging method, (5) continuous measurement and analysis of field noises by operation of WEC, (6) the safety and durability of caisson structures for WEC.



Overview of Mook-ri OWC Plant (Courtesy: KRISO)

The development and installation of the vertical axis tidal current energy converter (TEC) system linked to the ESS system was completed in June 2023 and is currently operating at the Uldolmok Tidal Power Pilot Plant, one of the open-sea test sites. This system, which has a two-stage dual vertical axis turbine, has an output of 100 kW at a rated flow speed of 3.6 m/s, and is generating power in conjunction with a 500 kWh ESS. It generates power through PMSGs and operates by monitoring and recording the power generation status and controlling the generator through a SCADA. Through one month of operation, 11,684 kWh of eco-friendly electricity was produced, and it was confirmed that this system can be sufficiently applied to various island areas.

Tidal turbine deployed at Uldolmok tidal power plant (Courtesy: KIOST)

## SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

A second-term bilateral cooperation project (2021-2023) between South Korea and China, led by KIOST and the First Institute of Oceanography (FIO), was conducted to exchange the technology development and the utilization of ocean energy systems. The 7th joint workshop was held in July 2023 as a face-to-face meeting after the COVID-19 pandemic. Twelve presentations were made in tidal, wave, and ocean thermal energy converters and technical standardization activities.

Photos at the 7th Ocean Energy Joint Workshop (Courtesy: KIOST)

## RELEVANT NATIONAL EVENTS

The 2024 IEC TC 114 plenary meeting will be held on Jeju island from April 15 to 19 for working group meetings, a two-day plenary meeting, and a technical tour to KRISO-WETS. AWTEC (Asia Offshore Wind, Wave and Tidal Energy Conference) 2024 will be held in Busan from October 22 to 25.

# SINGAPORE

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**SUPPORTING POLICIES FOR OCEAN ENERGY**

## National Strategy

Singapore is an islandic nation located in the heart of Southeast Asia with a total land area of about 734 $km^2$ and with a population of about 5.9 million as per data provided by Department of Statistics Singapore in 2023. In 2015, Singapore pledged to reduce its Emissions Intensity (EI, or GHG emissions per unit of GDP) by 36% from 2005 levels by 2030 and stabilise emissions with the aim of peaking around 2030. 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. Singapore's low-carbon transition have three thrusts:

- To transform our industry, economy, and society,
- Harness emerging technologies as they mature.
- Pursue and leverage international collaborations.

## Market Incentives

In Singapore, several governmental bodies provide schemes and incentives to help promote the adoption of renewables. They are the Energy Market Authority (EMA), Building and Construction Authority (BCA) and Economic Development Board (EDB). The Green-e Renewable Energy Standard for Singapore allows Green-e Energy certification of renewable energy products throughout Sin-

gapore, in order to accelerate the development of renewable generation and renewable electricity markets, and to provide consumers a meaningful mechanism through which they can express demand for renewable electricity (Green-e, 2017). Instead of subsidies, Singapore has taken proactive steps to introduce regulatory enhancements to facilitate the entry of renewable energy when such technologies become commercially viable (EMA, 2017). The Government's support for renewables mainly comes in the form of funding for Research & Development to develop capabilities within the industry. Singapore Power Group (SP) has been authorised as a local issuer of International Renewable Energy Certificates (I-RECs) or tradable certificates of energy from renewables in Singapore, the first in Asia Pacific. Each megawatt-hour of renewable energy produced is recorded as one REC and uniquely numbered and tracked. It would be used for achieving renewable energy targets and for reporting consumed energy as coming from renewable sources (SP Group, 2019). Enterprise Singapore has also formed a working committee TC114 on Marine energy which actively involves in adoption of international standards to support clean marine energy initiatives of the Singapore government towards new industries such as aquaculture, desalination, electrification of marine operations, fisheries, and tidal energy powered data centre systems, etc.

## Public Funding Programs

Ocean renewable energy has been identified as one of the prominent alternative energies by ERI@N specifically towards remote coastal and islandic region as part of its strategic research interests. The government also welcomes clean technology companies to use Singapore as a 'Living Lab' to testbed and demonstrate innovative solutions before scaling up for the rest of the world.

More than S$800 million public funding has been set aside by the Singapore Government for research in energy, water, green buildings and addressing land scarcity. The Singapore Government awarded $55 million to support 12 research, development and demonstration projects on low-carbon energy technology solutions. Government is also prepared to spend more than the estimated S$1 billion in carbon tax revenues collected in the first five years, to help companies invest in energy- and carbon-efficient technologies. The Maritime and Port Authority of Singapore (MPA) has partnered up with several major industry players with a $300m decarbonisation fund to boost decarbonisation efforts in the maritime industry.

### RESEARCH & DEVELOPMENT

ERI@N, supported mainly by the EMA & EDB, focuses on the areas of sustainable energy, energy efficiency infrastructure and socio-economic aspects of energy research. Its mission is to be a centre of excellence for conducting advanced research, development, and demonstration of innovative solutions, which have both regional and global impact. The Institute has considerable expertise and strength in areas of offshore energy, which includes wind, wave, floating solar and tidal energy, and complementary technologies, such as energy storage, micro grids, and smart energy systems, and collectively provide an integrated set of expertise from materials design & synthesis, device fabrication and modelling, and systems integration and optimization.

ERI@N's Wind and Marine (W&M) research programme is aimed at improving the performance, lowering costs, and accelerating deployment of offshore renewable technologies specific to the tropics, where unique technology challenges exist. It advances the technology development and commercialization through early collaboration with industry. It works closely with government agencies to understand regional needs, and with local and global renewable energy firms to identify technology gaps. ERI@N is also actively contributing towards marine energy standards adoption and development as part IEC TS 62600.


TCOMS – Ocean basin Facility

TECHNOLOGY DEMONSTRATION

# Test Sites

## Ocean Basin Facility – TCOMS

The Technology Centre for Offshore and Marine, Singapore (TCOMS) is a national R&D centre dedicated to the Marine & Offshore and Maritime sectors. TCOMS is a joint venture between the Agency for Science, Technology and Research (A*STAR) and the National University of Singapore (NUS). TCOMS integrate research and industry expertise to co-create innovative concepts and solutions to address real world challenges. A core feature of TCOMS is the next-generation Deepwater Ocean Basin research facility which is equipped with advanced wave and current generation systems to simulate challenging ocean environments that marine platforms and ships operate in. TCOMS is also supported by the petascale supercomputing capabilities of the National Supercomputing Centre (NSCC) Singapore. These allow researchers to evolve coupled numerical-physical modelling and simulation capabilities that can recreate complex operating scenarios, so as to help companies enhance the design and performance of their solutions.

Key Research Thrust areas of TCOMS are:

- To enhance the predictability of the operating environment and the behaviour and response of ocean systems in challenging and complex sea states.
- To advance research and technological innovation in maritime autonomous surface ships.
- a digital twin of the met ocean environment for the waters around Singapore and for locations of offshore assets of interest.

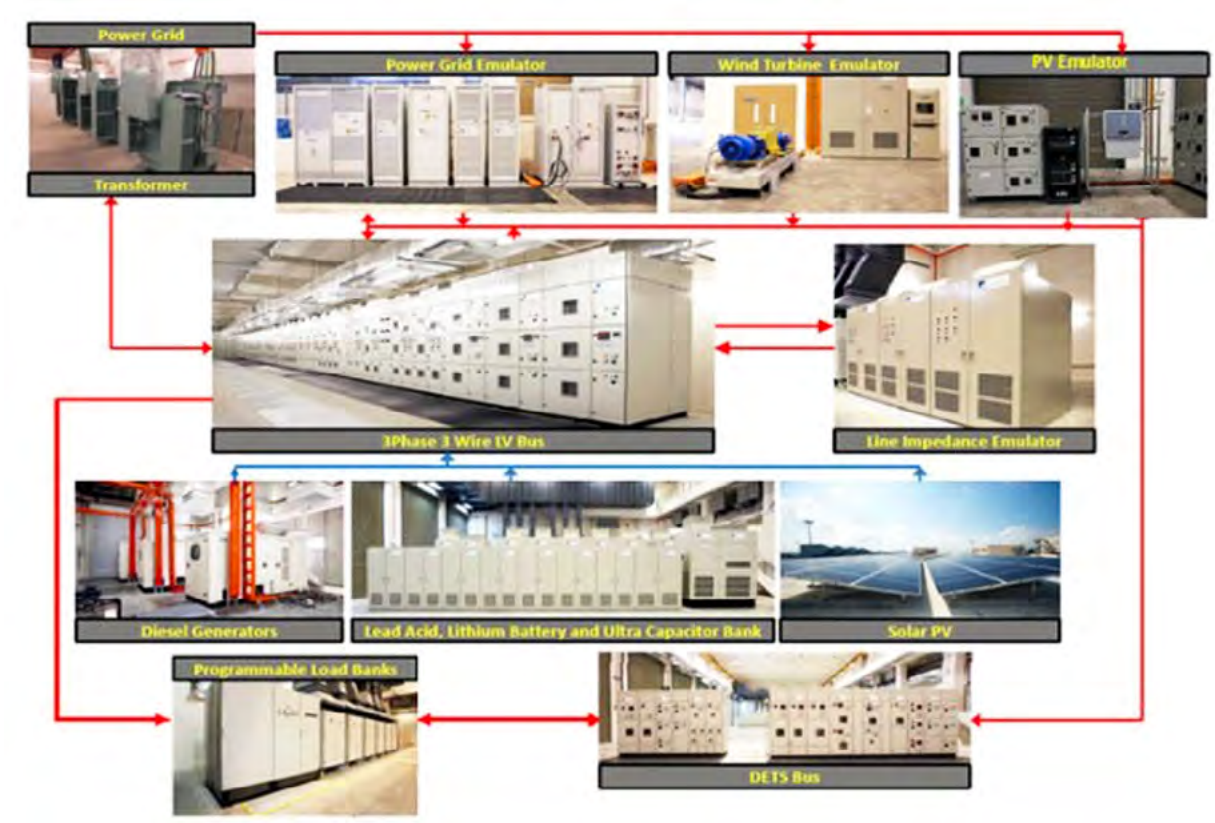
### Experimental Power Grid Centre – EPGC

ERI@N has a megawatt-scale grid facility that is one of the largest in this region. 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.

The facility offers the following testing platforms that have been built up throughout the years:

- 200kW ESS testing platform
- 500kW motor testing platform
- Real-time power system simulation and HIL testing platform
- 100kW PV inverter testing platform
- Intelligent Building Energy and Environmental Monitoring and Control System (iBEEMS) testing platform
- Multi-functional test facility
- Micro-grid design and diagnosis
- Electricity market and business models analysis
- Multi-energy system optimisation
- Power electronics design and prototype

EPGC's facilities can be used for testing a wide range of equipment such as electrical drives, inverters, power converters, machines, transformers, micro-grid controllers and energy storage systems.




MW testing facility at EPGC

## Planned Deployments

### Renewable Energy Integration Demonstrator-Singapore (REIDS)

The Renewable Energy Integration Demonstrator - Singapore (REIDS) is a Singapore-based R3D (Research, Development, Demonstration and Deployment) platform dedicated to designing, demonstrating and testing solutions for sustainable and affordable energy access-for-all in Southeast Asia as well as the future of urban electrici-

Renewable Energy Integration Demonstrator Singapore

ty distribution. REIDS is the largest hybrid microgrid test and research platform in the tropics. REIDS is supported by (EDB) and (NEA). REIDS and its partners are testing and demonstrating the integration of solar, wind, tidal, diesel, storage as well as waste-to-energy and power-to-gas technologies & end-use technologies and solutions suitable for deployment in Southeast Asia. ERI@N(REIDS) team promotes research/ tech capabilities in flexible reconfiguration capabilities of grids, the LVMGC platform developed enables comprehensive multi-microgrid test scenarios, dynamic system optimization, energy exchange and interoperability, which are instrumental to explore pre-competitive R&D opportunities in energy sector for future micro grids.

## REIDS Offshore

The offshore renewable energy integration and demonstration (Offshore REIDS) project, also termed as Tropical Marine Energy Centre (TMEC), has been initiated by ERI@N and financially funded by the ClassNK firm (a Japanese classification society) and seeks to pave the way for establishing the world's first scaled marine renewable energy testing facility for tropical needs. In March 2015, the feasibility study for the test sites was officially launched and completed in December 2017. During this project, the resource mapping methodologies were well utilized to identify the ocean energy potential of the southern islands of Singapore that have been identified from the Maritime port Authority of Singapore (MPA). Environmental impact assessment (EIA) for the test sites was done to understand the impact of ocean energy system deployment on marine life and environment. The EIA included investigating the baseline conditions, possible effects of the test sites in the surroundings, and other associated research, such as underwater acoustics, water purity, sea level changes, tidal flow effects, etc. Geotechnical and geophysical surveys are also being planned. The outcome of this project will be extended towards Singapore's guidelines and standards development by working with Spring Singapore to support local supply chain's marine energy resource mapping guidelines of new regions, such as our neighbouring region of Southeast Asia and other tropical islands and remote coastal regions. Overall, the present project aims to develop technologies and deployment methodology for meeting energy needs towards the remote island region.

## Deployment of Clean Energy Powered water generation system in Southern Islands of Singapore

Southern islands of Singapore act as spots for tourist attraction. The energy and water demand in the island are mainly due to tourism and other governmental facilities in the islands. The islands consist of bungalows /campsites for tourists, temples, beaches, fishing, and picnic spots in addition to the governmental facilities. Currently, the islands use diesel power generation and water transported by mainland. Energy Research Institute @ Nanyang Technological University (ERI@N) with support from Singapore Land Authority (SLA) has deployed clean energy powered water generation system and renewable systems in southern islands of Singapore in order to support the water and energy needs of southern islands which attracts large

number of tourists every year. Presently, deployment and demonstration of renewable powered water generation system completed in Kusu Island, Singapore and further discussion towards deployment in other islands is in progress.

## Singapore Decarbonization efforts

Jurong Island is planned to serve as a "living" test bed for sustainable solutions, as the industrial estate transforms into a sustainable energy and chemicals park. Jurong Town Corporation, a Singapore government agency has launched two innovation calls aimed at coming up with solutions to boost the circular economy and reduce carbon footprint. The first - Jurong Island Innovation Challenge - crowdsources innovative ideas from start-ups and small- and medium-size enterprises (SMEs) to enhance the sustainability and circularity of resources. Industry players such as Chevron Oronite, Shell and Singapore LNG Corporation has participated in the call, and have come together to submit 10 challenge statements. The challenge statements cover four key themes that will boost resource efficiency efforts: Energy efficiency, emissions reduction, water management and chemical waste management. SMEs that put forth proposals will gain opportunities to work with large corporates and will also receive funding support for the development of their solutions. Under the enterprise track, qualifying start-ups and SMEs can tap on ESG's Enterprise Development Grant, which can provide support for up to 80 per cent of the qualifying solution development costs. For selected challenge statements, awarded solution providers will receive up to S$2 million in grant support under the National Innovation Challenge, for solution development and industry adoption. The second innovation call is a request for proposals for energy solutions that can reduce the island's carbon footprint. This call focused on test-bedding renewable energy and energy storage systems such as high-efficiency solar panels and solar deployment on pipe racks and storage tanks. The Energy Market Authority (EMA) and JTC, with support from Enterprise Singapore (Enterprise SG), have awarded three projects under the $6 million grant to test-bed floating renewables on Jurong Island.

Renewable powered water generation system deployed in Kusu Island, Singapore

Singapore also announced plans to import up to 4 GW of low-carbon electricity by 2035, with the first Request for Proposal to import up to 1.2 GW beginning by 2027. Singapore is now on track to achieving its target of 4 GW of electricity imports by 2035 with these Conditional Approvals:

- 1 GW from Cambodia
- 2 GW from Indonesia
- 1.2 GW from Vietnam

Jurong Island, Singapore

Floating Solar System in Reservoir

## Floating Solar Deployment

- Singapore has switched on a 45-hectare solar photovoltaic (PV) farm that floats in the island's Tengeh Reservoir. This offsets 7% of PUB's annual energy needs.
- G8 subsea deployed first offshore floating solar substation platform of 5 MW capacity near the coast at north of Woodlands Waterfront Park, along the Straits of Johor.
- BBR Greentech, one of Singapore's leading EPCs, was appointed by PUB, Singapore's national water agency, to commission the Island's two most recent floating solar PV systems of 1.5 MW each at Bedok & Seletar Reservoirs.
- Keppel Infrastructure's subsidiary Keppel Energy Nexus was awarded 6 million grant to test bed offshore floating solar in Jurong island coast of Singapore.
- Keppel Infrastructure, through its applied technology innovation arm, KepInfra Energy Transition Centre (KETC), National University of Singapore, through its Solar Energy Research Institute of Singapore (SERIS), and Nanyang Technological University (NTU), through its Energy Research Institute @ NTU (ERI@N) have signed a Memorandum of Understanding (MOU) for a joint-study on the technological and economic feasibility of developing a first-of-its-kind floating hybrid renewable energy system (RES) for operations in Singapore.

## Electrification of Ships & Electricity Imports from other ASEAN countries

- MPA announced in 2022 a $300 million, 2050 maritime decarbonisation blueprint. One of its aims is the electrification of Singapore's harbour craft, with the whole fleet to run on electricity and/or net zero fuels by 2050.
- Keppel O&M working with DNV, the Energy Research Institute @ NTU, Eng Hup Shipping, Envision Digital, Surbana Jurong, and the Technology Centre for Offshore and Marine, Singapore undertake efforts to test, trial, and operationalize end-to-end solutions for the electric harbor craft.
- As COP26 approaches, Singapore has made several announcements regarding plans to decarbonise its energy sector. Chief among them is its plan to import 30 per cent of its electricity from low-carbon or renewable sources such as from neighbouring ASEAN countries.

## Workshops on Tidal Current Extractable Energy: Modelling, Verification and Validation

The main goal of this workshop is to prepare a **Tidal Energy Resource Modelling Guideline report** through the study of the various factors affecting the result of the

simulations. This is likely to be a joint exercise effort concentrating on the accurate modelling and reporting of tidal energy resources.

As great multitude of tools and techniques are used to determine the amount of tidal resources and to quantify the resources available in different parts of the world, establishing a standard in extractable resource modelling can pave the way in promoting the adoption of tidal energy among the various stakeholders, as it can provide confidence in the amount of available resources. **International Tidal Energy Working Group** is thus consequently formed and various research teams can conduct extractable resource studies to share their results and methodology, and work towards creating a standard report for modelling in harnessing tidal energy.

This workshop was organised and hosted by Energy Research Institute @ NTU (ERI@N), Singapore through teleconferencing. There were attendees from various international tidal energy working teams from all over the world such as France, Sweden, USA, UK, Germany, India, Australia, Indonesia, China, Philippines and Singapore.

## 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 16th Singapore International Energy Week (SIEW) is Asia's leading platform for the discussion of key energy issues that impact the region. Themed "Energy Transition Towards a Net Zero World", SIEW 2023 was organised by the Energy Market Authority of Singapore and took place from 23 to 27 October 2023 at the Sands Expo and Convention Centre, Marina Bay Sands, Singapore.

Singapore and IRENA co-hosted a High-Level Forum at SIEW, with the theme "**Regional Interconnectivity for Net Zero**". The third edition of the Singapore-IRENA High-Level Forum focused on regional energy integration and cross border infrastructure to stimulate energy trade in the region, as well as investments in the energy transition for a net zero future.

SIEW 2023 also had Roundtable sessions focused on the following:

- Accelerating Progress on the ASEAN Power Grid 2.0: Lessons from the LTMS-PIP and Beyond
- Energy Transition in Lead up to COP28
- Low Carbon Technology in Decarbonising the Energy Sector
- New Type of Power System Enabling a highly Efficient, Safe and Low-Carbon Energy Future - Insights from China and ASEAN
- Net Zero Buildings in Singapore, Is It Achievable
- Financing ASEAN Decarbonisation Roadmap Towards Carbon Neutrality


SIEW 2022

# SPAIN

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## OVERVIEW

From an administrative point of view, the biggest breakthrough in 2023 in Spain was the approval of maritime spatial planning, while work continues to develop a new legal framework for the deployment of marine renewable energies. The commitment of the Spanish government is evident from the publication of the REN-MARINAS DEMOS aid programme to support investments in pilot projects and testing infrastructures in marine renewable energies.

From the technology development point of view, several R & D projects are under development, testing infrastructures continue to improve to enable prototype tests, systems and subsystems; and different projects advance to ensure prototype deployment by 2025. Noteworthy is the work done by WAVEPISTON at PLOCAN to begin its trial in 2024 and the new milestone reached by the Mutriku Wave Plant, which in its 12 years of continuous operation has exceeded the 3GWh of electricity injected into the network.

## SUPPORTING POLICIES FOR OCEAN ENERGY

### National Strategy

In the field of spatial maritime planning, Royal Decree 150/2023 was adopted on 28 February 2023 approving the maritime spatial planning plans of the five Spanish marine demarcations (POEM). The plan does not declare any area for the priority use of ocean energies, nor does it indicate any area as a high-potential area for ocean energies because technologies are still far from the commercial phase. For prototype testing or pilot project development the plan proposes the use of existing test areas (BiMEP and PLOCAN) and reserves several sea areas for priority use of R&D projects.

Additionally, during 2023 the Spanish government has been developing a new legal framework for the licensing of renewable marine energy plants. This legal framework that has not yet been approved.

## 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 20MW every two years focused on "Other Technologies", where ocean energy is included, reaching 60 MW for 2025

## Public Funding Programmes

At the end of 2022, the first call for the RENMARINAS DEMOS Program was published. It is an initiative of the Ministry for Ecological Transition and the Demographic Challenge, 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 call and the evaluation of the proposals submitted, a total of 21 projects were deserving of support. Of these, 4 projects in the field of wave energy, with a cumulative power of 1.7MW and a joint support of €4.5 million; and one project of a hybrid prototype of wind and wave energy, with 5MW of total power and aid of €7.5 million.

These projects are expected to be completed by early 2026.

The Basque Energy Agency (EVE) launched a new call of its "Demonstration and validation of emerging marine renewable energy technologies" programme in 2023. As previous calls, the programme has a total budget of 2,5 M€ for 3-year maximum duration projects. However, this year the call has incorporated significant changes:

- The call has moved to a competitive scheme, with fixed opening and closing deadlines, in which proposals get ranked based on the technical merit and get funds allocated accordingly.
- Maximum grant amount per project has been raised to 2.5M€.
- Prototype fabrication cost now eligible for the demonstration actions.
- Updated aid intensity to match latest wording of Commission Regulation (EU) No 651/2014

**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.

EuropeWave project's main activities during 2023 have been:

- Successful delivery of contract scope of the 5 Phase 2 projects
  - Mocean Energy Ltd: Blue Horizon 250
  - IDOM Consulting, Engineering, Architecture SAU: MARMOK Atlantic
  - CETO Wave Energy Ireland Ltd: ACHIEVE
  - Arrecife Energy Systems SL: Trimaran
  - AMOG Consulting Limited: Sea-Saw WEC
- Completion of Phase-Gate (down-select) process with Phase 2 Contractors
- Selection of the 3 successful Phase 3 proposals
  - Mocean Energy Ltd: Blue Horizon 250
  - IDOM Consulting, Engineering, Architecture SAU: MARMOK Atlantic
  - CETO Wave Energy Ireland Ltd: ACHIEVE
- Commencement of contract execution of Phase 3 projects
- Communication and Dissemination activities (EuropeWave 2nd Annual Event - Brussels, Side-Event at OEE 2023…)

## TURBOWAVE

The Basque Energy Agency (EVE) launched in December 2022 the **Call for Tenders** for the **TurboWave** project. This **Pre-Commercial Procurement** initiative aims to accelerate the development of cost-efficiente, safe and reliable air turbine technologies that are tailored to the needs of the wave power industry in general and the specific technical requirements of the Mutriku Wave Power Plant.

The **TurboWave** project is expected to progress through 3 phases, currently identified as:

- Phase 1: Concept development.
- Phase 2: Design refinement and laboratory testing.
- Phase 3: Detailed design, manufacturing and on-site tests at Mutriku wave power plant.

The project has made significant steps during 2023:

- Call for Tenders (Dec'22- Feb'23), including dissemination webinars and technical visits to Mutriku Wave Power Plant
- Evaluation and Award of Framework Agreements and Phase 1 Call-Off contracts to 5 successful tenderers:
- 4D Engineering
- Advanced Simulation Technologies – New Wave Technologies (Consortium)
- Arrecife Energy Systems SL
- IDOM Consulting, Engineering, Architecture SAU
- Kymaner – IDMEC (Consortium)
- Commencement of contract execution of Phase 1 projects

## 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 second annual co-funded call was published on 20 September 2023 (expecting pre-proposals) and will close on 22 November. Full proposal submission is expected to open in January 2024.

## VALID

The **VALID** project, funded under the H2020 programme, is developing a new methodology for accelerated testing of critical wave energy components. It combines numerical and experimental modelling approaches in an integrated and open hybrid testing platform, which will reduce the product developing time, cost and uncertainties. In 2023, three critical components have been tested, and results documented, following the novel hybrid testing methodology . In Spain, TECNALIA, IDOM and BiMEP work together in the analysis of 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). TECNALIA is leading, in collaboration with Ocean Energy Europe and the University of Edinburgh, the Work Package on Research, Technology, Development and Innovation. So far, three technical webinars have been organised to enable knowledge sharing, a gap analysis has been conducted to assess the sector progress, and several discussions with sector representatives have led to identify the technical priorities for the new Strategic Research and Innovation Agenda.

### 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 2023, TECNALIA has been involved in the blade research, testing and design activities of the project. Working hand in hand with the technology developer, Orbital Marine Power, they have put together a comprehensive programme to test a series of coating samples under relevant environmental conditions.

### 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 2023, among other projects, the JRL-ORE has coordinated KONFLOT, a project funded by the Basque Government in the field of Control co-design of floating renewable energies. The objectives are to stablish a design methodology that considers, from the first phases of the design, the different subsystems, their dynamics and interactions and the performance of the controls available in the floating renewable generation devices, as well as to develop ultra-fast and reliable mathematical models to simulate a large number of design & control alternatives. More information: https://jrl-ore.com/

### SAFEWAVE

**SafeWAVE** project (https://www.safewave-project.eu/). The project started on October 2021 and was extended until June 2024. During 2023 environmental monitoring activities continued, and several documents on public education and engagement strategy, consenting, and maritime spatial planning were produced as project deliverables.

Co-funded by the European Climate, Infrastructure and Environment Executive Agency (CINEA) and launched in November 2020, the Safe WAVE - Streamlining the Assessment of Environmental Effects of Wave Energy share common objectives and builds on the results of the WESE project representing the second effort of the EU in the objective of overcoming the non-technological barriers that could hinder the development of ocean wave energy projects in EU

## Research from Companies

### Arrecife Systems

Arrecife Energy Systems has conducted multiple studies throughout the year 2023, both in laboratory and in open-sea, as part of the Europewave program, to continue studying their Trimaran system. Regarding laboratory studies, the company has carried out numerous tests to examine the behaviour of its turbines in response to both waves and currents, investigating the shoaling effect and the wave-breaking impact on the turbines. As for open-sea studies, a fixed system with two turbines has been installed in Harslab, the offshore laboratory located in the BiMEP area, to explore different materials and coatings aimed at preventing corrosion and fouling, thereby extending the lifespan of the equipment in the marine environment.

### IDOM

Regarding EuropeWave, IDOM has been one of the awarded developers of Phase 3 of the EuropeWave project. In this project, IDOM will deploy the MARMOK-A-5 at BiMEP in the summer of 2025, for a one-year test campaign.

The innovations are mainly focused on improving the efficiency and reliability of the power take-off, in three subsystems.The rotor, with a novel design that increases conversion efficiency through a variable pitch mechanism and performance-enhancing features. The electric generator, with ad hoc design with good efficiency and power peak endurance. And a machine learning based control strategy coupled with a reinforcement learning algorithm.

Regarding TurboWave, based on experience gained in the development of OWC technology, IDOM is proposing for the TurboWave challenge an innovative power take-off system with outstanding efficiency and reliability, optimised for the Mutriku wave power plant.

Three main pillars support this design. A variable geometry turbine will maximise the extracted power and allow the system to operate in optimal and safe conditions. A novel, fully integrated electrical generator will be responsible for minimising conversion losses while being fully prepared for the harsh offshore environment. Finally, an advanced control strategy will be responsible for ensuring optimum operation of the system, maximising both power capture and conversion.

As a result of this project, it is expected that a new generation of adaptive turbines will be developed, which will be compatible with other OWC systems both onshore and offshore.

**TECHNOLOGY DEMONSTRATION**

## Existing Open Sea Test Sites

### HARSHLAB

**HarshLab** testing laboratory was installed in BiMEP in June 2022. During 2023 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), a novel corrosion monitoring system (Vicinay) or an echo sounder for measuring biomass under floating structures (Fundación Azti, at SAFEWAVE project), among others. All of them concluded offering valuable results on the viability of the different technologies tested, and demonstrating once again that the possibility of carrying out tests in a real offshore environment is a competitive advantage for our clients.

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. Thus, it is of vital importance to control the behaviour of the mooring lines that anchor the laboratory to the seabed, 65 metres underwater. To this end, we have monitored the state of the mooring lines with a small ROV that allows us to descend safely to the seabed, as well as the design and execution of tests on mooring line components and umbilical cables.

HarshLab installed at BiMEP

More info at: https://harshlab.eu/

## PLOCAN

PLOCAN offers a 23km$^2$ test site for marine energy converters among other uses. It includes an offshore multipurpose platform providing workshops, laboratories, classrooms, training rooms and open working areas.

## 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.

Additionally, water parameters such as temperature, salinity, dissolved oxygen, among others parameters, can be measured thanks to an oceanographic station located at the Harshlab 0.5, offering the possibility to monitor water parameters that may have an influence on the material behaviour in real marine conditions.

During 2023, PLOCAN provided access to Harshlab 0.5 to several companies and organisations, technically supporting them to develop their tests. Some examples of the access during 2023 are:

- Test of passive samplers of heavy metals and hydrocarbons for environmental monitoring.
- Test of novel concrete-based materials for artificial reefs.
- Test of offshore wind components such as electrical cables, mooring ropes and metallic tendons.
- Performance tests of coatings and paintings developed for offshore wind.

More information about how to access Harshlab 0.5 facility can be found here: https://plocan.eu/en/installations/onshore-headquarters

### Marine Corrosion Test Site "El Bocal"

The main objective of this facility is to test, study and analyze, in realistic conditions, coatings and materials used in the marine industry, such as renewable energy devices (wind, tidal, wave, etc.), ships, oil & gas structures, etc., with improved corrosion, degradation, and erosion properties and marine growth. In order to achieve this objective, the Marine Corrosion Test Site (MCTS) "*El Bocal*", an unique place for testing new coatings and components under realistic marine conditions, has been developed by CTC.

The MCTS "*El Bocal*" is located at the shoreline of the Cantabria coast, few kilometers away from Santander city, in an idoneous site with an easy access for testing and monitoring activities. This facility is placed in open water so that specimens to be tested are subjected to real offshore environment. By this reason the corrosion and biofouling conditions are similar to the ones a typical offshore structure faces along its life cycle. In the MCTS "*El Bocal*" the effects on specimens of the following four corrosion marine environments can be studied: atmospheric, splash, tidal and submerged. The designed setup allows to cover a wide range of corrosion and biofouling environments.

### 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.

During 2023 BiMEP deserved support from the above-mentioned RENMARINAS DEMOS program (€2.6M, OLAGARRO Project) to improve its infrastructure. Improvements are being made focusing on the network connection of devices and the O&M of own equipment and installed devices.

On the Mutriku Wave Power Plant side, 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, by 2023 the cumulative production reached the milestone of 3 GWh produced and injected into the grid. The energy production during 2023 was 266 MWh.

## Projects in the Water

### WAVEPISTON

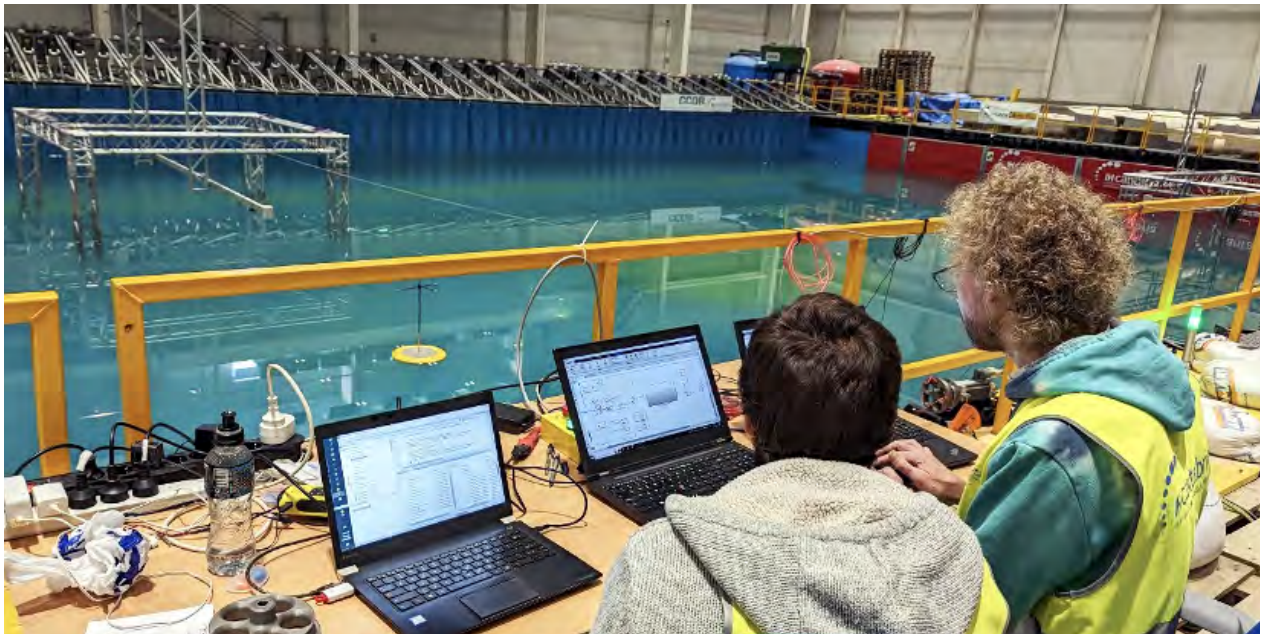
WavePiston has been developing its system in PLOCAN's test site. On one hand, the power plant and desalination systems have been commissioned. On the other hand, the collectors installation started at the end of the year, and the full installation is expected to happen in early 2024. At that moment, the collectors will pump water to the power plant to generate electricity and to the desalination system.

Installation of Wavepiston

### Rotary Wave

During 2023, Rotary Wave completed the installation of its low power full scale WEC (20 kW) at La Marina in Valencia. Tested from March to November it reached a production of 30000 kWh. During the test it was possible to define improvements that will be implemented in the next generation of the device, which with a power of 270 kW will be installed outside the Port of Valencia. For this new project Rotary Wave is supported by the RENMARINAS DEMOS Program.

## Projects Planned for Deployment



CETO tank testing at IH Cantabria testing facility

### CETO-CARNEGIE

In 2023, Carnegie Clean Energy (CCE) made significant strides in the commercialisation pathway of CETO through the ACHIEVE Programme with a subsequent planned deployment at the Biscay Marine Energy Platform (BiMEP), a milestone achievement.

The ACHIEVE programme has incorporated significant testing through various projects to de-risk CETO including participation in the IMPACT Project where belt testing was undertaken. Carnegie Clean Energy, through its wholly owned subsidiary CETO Wave Energy Ireland was selected for Phase 3 of the EuropeWave Programme, which involves deploying a scaled CETO device at the BiMEP test site. The tender was successfully awarded in September 2023, securing Carnegie's participation in the final design, manufacturing, deployment, and operation of the CETO device. The company received funding support from the IDAE through the RENMARINAS-DEMOS funding call to enhance and expand the EuropeWave ACHIEVE project, with the aim of improving the CETO wave energy technology and contributing to the marine energy sector in Spain.

Looking ahead to 2024 and beyond, CCE plans to establish its activities at BiMEP, leveraging the extended operational window and collaboration opportunities offered by the site

to further enhance CETO technology and contribute to the clean energy transition. Carnegie Clean Energy's activities in Spain in the successful activities of 2023 demonstrated progress in technology development, partnerships, and recognition of the value of CETO as a wave energy solution, reinforcing our commitment to the advancement of the marine energy sector in Spain and globally.

### PLOCAN Testbed Optimised Floating Ocean Thermal Energy Conversion Platform (PLOTEC)

PLOTEC is a pan-European consortium (2022 - 2025) that will design and validate an ocean thermal energy conversion (OTEC) platform capable of converting solar heat energy stored in the oceans into reliable, baseload power with an economical cost model. The overall objective of the project is to design and simulate an OTEC platform capable of withstanding the extreme weather effects of tropical oceans, with a viable cost model, validated by a scaled demonstration of a structure. By doing so, key technical and economic barriers to mass OTEC deployment can be overcome. These developments in offshore design, improved materials and computational modelling may also be transferable to other offshore industries where affordable, reliable power is required, such as green ammonia production or aquaculture. The consortium will undertake a series of computer simulations concluding with a physical deployment at the PLOCAN test facility in Gran Canaria in 2024.

PLOTEC is funded by the EU's key funding programme for research and innovation, Horizon Europe, and UK Research and Innovation (UKRI) in the amount of € 3.5 million. The project will demonstrate pan-European leadership in sustainable, and competitive energy solutions, through the novel utilisation of materials, new designs for OTEC, and advanced modelling technologies demonstrating efficiency gains through a drop in Levelised Cost of Energy (LCOE). The project will also engage with SIDS leaders and policy-makers to set foundations for future capacity-building.

## 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 a "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". 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

Spain, and particularly the CIEMAT (Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas), a public research body assigned to the Ministry of Science, Innovation and Universities, is currently coordinating an international network named REMAR, Opportunities of Integration in Ibero American Electric Grids of Marine Energies". The network, started in 2021 and finishing in 2024 is promoted and funded by the Ibero American Programme of Science and Technology for the Development (CYTED), and comprises currently 13 countries of the Ibero American Region (list) and 141 researchers, being increased every year (https://www.cyted.org/REMAR).

The main objectives of the REMAR network are: improving the professional skills of the professionals and students in the area of marine energies integration; fostering the research activities, with special interest in the experimental ones, related to ocean energy and grid integration; the collaboration in scientific publications and training programmes; and fostering the policies to support the development and grid integration of marine energies in Ibero-American countries.

The main activities carried out by the network are: the funding of several stays for research activities and the development of projects and technologies; the elaboration of a map of experimental facilities; monthly sem-


inars related to marine energies, already compiled in a YouTube channel (https://www.youtube.com/@ReddeEnergiasdelMarREMAR); several publications in journals and conferences, training courses and seminars for the dissemination of ocean energy knowledge among the scientific and general public; and finally, a review of the roadmaps related to marine and ocean energies within the participant countries, with the perspective of grid integration.

## TECNALIA

TECNALIA has contributed to the ***Study on the offshore energy potential in the Atlantic Ocean*** under the coordination of France Energies Marines and the collaboration of University College Cork (Ireland) and EDP NEW (Portugal). This study has been carried out in response to a contract issued by Directorate-General for Energy of the European Commission. TECNALIA has contributed to the OES Task 12 "Performance Metrics International Framework for Ocean Energy" supporting the publication of a second edition of the report "AN INTERNATIONAL EVALUATION AND GUIDANCE FRAMEWORK FOR OCEAN ENERGY TECHNOLOGY". In this document, the IEA-OES demonstrates its commitment to advancing the ocean energy sector globally while harmonising and strengthening the technical and evaluation processes in the industry.

# RELEVANT NATIONAL EVENTS

## EWTEC 2023

The city of Bilbao hosted European Wave and Tidal Energy Conference in 2023 (3-7 September) organised by the University of the Basque Country (https://ewtec.org/ewtec-2023/)

## PLOCAN event together with the Canary Maritime Cluster and the Cabildo of Gran Canaria

The event called "***Ocean energy: the journey to 2050. Recipes not to lose the wave***" was held on the 4th of December 2023. The "***Progress of the IEA's new Ocean Energy Roadmap***" was presented. A preview of the next IEA-OES roadmap for ocean energy to be launched at COP28 was given. The UK example of Ocean Energy Policy was also explained: An overview of the potential of ocean energy, specifically wave energy and marine currents, to contribute to the UK's net zero emissions target for 2050.

# SWEDEN

**AUTHOR(S)**
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## OVERVIEW

In 2023, Swedish ocean energy developers continued to develop, test and demonstrate their ocean energy systems, thereby moving closer to commercialization. For example, CorPower Ocean successfully installed its first commercial scale wave energy converter (WEC), C4, in Aguçadoura, Portugal where survivability was later demonstrated when the device endured multiple storms. Minesto continued testing of the two Dragon 4 (100 kW) tidal power plants in Vestmannasund, Faroe Islands, while in parallel preparing for deployment of the Dragon 12 system (1.2 MW), which is now ready to be installed. Novige has tested a slightly modified 1/6 scale WEC prototype, NoviOcean, at Coast Laboratory in Plymouth, UK, where the tests confirmed the calculated power output. The prototype has then been deployed in the Stockholm archipelago for long-time endurance testing. In addition, Ocean Harvesting Technologies, OE Systems and Waves4Power have made various R&D progress.

As previous year, over 20 R&D projects were running, covering topics such as reliability & survivability, anchoring systems, cable solutions, material improvements, array optimizations, multi-source parks, control algorithms and environmental effects.

## SUPPORTING POLICIES FOR OCEAN ENERGY

### National Strategy

Swedish energy policy aims to combine ecological sustainability with competitiveness and security of supply. It is based on the legislation established within the EU. 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 maritime 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. In 2018, the second phase of the Swedish Energy Agency´s national ocean energy programme was started. The programme ends in 2024 and has a total budget of around 10,2 MEuro. Since 2018 three calls have been held, resulting in a total number of 21 funded projects. No additional calls are planned within the ocean energy programme but ocean energy projects can apply for funding within other existing programmes such as, for example, Framtidens elsystem[1], Pilot- och demonstrationsprojekt[2], Verifiering av innovation med kund[3] and Utveckla en affärsidé[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 2023, see examples below. In addition to this, several new research and development projects, which were awarded within the first call of the EU Clean Energy Transition Partnership (CETP), started up in December 2023: ***MORE Next Generation Marine Materials for Resilient Offshore Renewable Energy Devices, SEASNAKE+ Industrial upscale of surface protection system & fibre optic-based condition monitoring for the SEASNAKE MVC (Medium Voltage Cables), Smart mooring for safe and efficient ocean energy production (SMARTMOORING), and Sustainable Concrete Material Leading to Improved Substructures for Offshore Renewable Energy Technologies (WECHULL+)***.

1 https://www.energimyndigheten.se/forskning-och-innovation/forskning/elsystem/framtidens-elsystem/
2 https://www.energimyndigheten.se/forskning-och-innovation/stod-till-affarsideer-test-och-lansering/pilot-och-demonstrationsprojekt/
3 https://www.energimyndigheten.se/forskning-och-innovation/stod-till-affarsideer-test-och-lansering/verifiering-med-kund/
4 https://www.energimyndigheten.se/forskning-och-innovation/stod-till-affarsideer-test-och-lansering/utveckla-en-affarside/
5 https://cetpartnership.eu/

## Analysis of array systems of wave energy converters with regard to interaction effects in the LCOE and fatigue analyses (INTERACT)

The project develops new design methods and simulation models that can be used to design wave parks where interaction effects are considered for optimal system performance. It is achieved through systems engineering, risk analyses, and fully coupled hydrodynamic-structural analyses. LCoE calculations are used to show how the LCoE is affected by WEC interaction effects in wave farms including the structural integrity of moorings and cables. Several showcases of different WEC technologies, sites of operation and array systems are simulated, analysed and optimised. Project partners are Chalmers University of Technology, NKT Cables AB, RISE Research Institutes of Sweden, CorPower Ocean AB, Waves4Power AB, Novige AB and Seaflex AB.

## Collaborative learning of wave energy converters

The project aims to develop a new type of control algorithm for wave energy conversion by using a machine learning approach where the wave energy converters collaborate and teach each other how to move in order to increase the energy capture. With enough training the wave energy converters should be able to learn how to maximize energy absorption based on the recent history but still use a simple mechanical construction. The algorithm will be trained on data from small scale experiments in wave tank and full-scale experiments from offshore experiments. The project is carried out by Uppsala University.

## Control of wave energy converters based on wave measurements, for optimal energy absorption (WAVEMEASURE)

The project is primarily a theoretical study of wave propagation around a point absorbing buoy, with the intent to build numerical models to better understand and calculate a point absorber's production of electricity in different wave climates. The project has carried out a comparison of model fidelity, for three different models, in the simulation of WEC performance. Project partners are Waves4Power AB, Chalmers University of Technology and Lund University.

## Deep Green Tether

In this project, Minesto will develop a new tether for their powerplant and demonstrate it in real operating conditions. The tether includes the power cable for electricity distribution, counterforce to the lift force of the wing, communication, connectors, and hydrodynamic fairings. The project has developed and delivered two tethers for Dragon 4 powerplants in different materials. Both were used in real operating conditions. The project also developed improved fairings and designed a tether for the Dragon 12 powerplant.

## De-Risk PTO by control of marine biofouling and corrosion (DERISK)

The project aims to study the effects of marine growth, corrosion and wear and validate solutions for the piston rod and sealing system within wave energy devices. Tests were carried out in accelerated forms in lab environments as well as in field environments. The project's final aim is to establish methodology for multi-degradation testing. Project partners are RISE Research Institutes of Sweden and CorPower Ocean.

## Dynamic Sealing Systems for Wave Energy (DynSSWE)

The project will develop, test, verify and evaluate cost-effective and durable dynamic sealing systems for point absorbing wave energy converters operating with linear reciprocal motion. Selected surface treatments will be studied in detail, a test rig for accelerated tests on scale models developed, and long-term tests under simulated sea conditions conducted while measuring wear and leakage. Evaluation will be carried out by microscopy and various analytical methods. The project is carried out by Uppsala University.

## European Scalable Offshore Renewable Energy Source (EU-SCORES)

The EU-financed project EU-SCORES will demonstrate the combination of offshore wind with wave and offshore floating PV parks. 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. Among the project partners are CorPower Ocean and Uppsala University. The project will include ocean demonstration of two 2nd generation full-scale CorPower WECs and collection hub. Uppsala University leads the task on grid infrastructure planning, electrical power management, and power quality from the multi-source parks.

## Harvesting of Blue energy using Swedish natural and artificial resources

The main goal of this project is to evaluate the potential of salinity gradient power (SGP) as a sustainable energy source in Sweden based on the existing natural and artificial resources. In 2023, a salinity gradient map for Sweden based on both natural resources and anthropogenic sources was created and results were published. This project is a collaboration between Umeå University and Lund University.

## Hull-Material for Wave Energy Converters (WECHULL)

The main objective of the WECHULL project is to develop and validate two types of innovative materials, composite (CorPower Ocean) and concrete (Ocean Harvesting Technologies), to be applied to hulls for wave energy converter (WEC) devices. The overall concept of the WECHULL project is based on accelerated hybrid testing of the materials through establishing loads though slamming analysis, material screening process, testing of critical sections of the hull and integrating the results in a full-scale simulation. Project partners are RISE Research Institutes of Sweden, RISE SICOMP, CorPower Ocean, Ocean Harvesting technologies, KTH Royal Institute of Technology and I-Tech AB.

## Kite array: Optimization of tidal power arrays

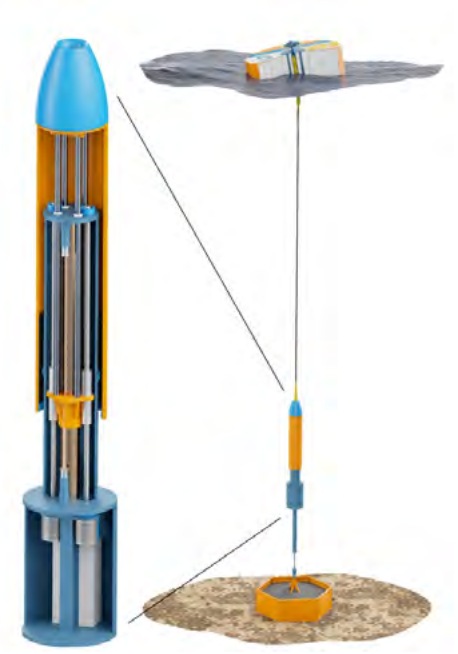
The aim of the project is to develop general simulation tools to study how the power plants in an array affect each other and enable the optimization of tidal power arrays. The work is based on state-of-the-art numerical models for natural turbulence in tidal water, and an implementation of the forces for the Minesto Deep Green device in the code OpenFOAM. The generated knowledge and tools are general and useful for other types of plants as well. In 2023, a study where the numerical model for the Deep Green was validated using observations from an Acoustic Doppler Current Profiler (ADCP) was published in a peer-reviewed journal. The project is a collaboration between University of Gothenburg and Minesto.

## Multi-criteria optimisation for offgrid marine renewable electrical production (OPTILE)

OPTILE is funded by France Energies Marines. The main objectives of the project are to develop and validate a method to optimize the design and integration of the electrical system in isolated islands and microgrids by considering reliability, machine position, electrical grid, carbon dioxide estimation, consumption control, cybersecurity and electrical stability. Project partners are Corpower Ocean, France Energies Marines, Total Energies, Entech SE, Saumon de France, Nantes Univesité, Ens Rennes and Université de la Réunion.

## Ocean Harvesting Technologies / InfinityWEC

Ocean Harvesting Technologies AB develops a wave energy converter called InfinityWEC. During 2023, the 500 kW InfinityWEC wave energy converter has been refined and improved. A novel hydrostatic pre-tension spring solution doubles the force capacity of the ball screw actuators, providing instant force control capability at low cost and high efficiency. The end stop functionality has been improved with a new damping solution in the buoy, ensuring power production in the toughest conditions while limiting the extreme loads, reducing the use of material and enhancing the lifetime and reliability of the system. The InfinityWEC power take-off is designed to host advanced model-based predictive control strategies, to optimize energy output one wave at a time. The result is 25-50% higher annual energy production compared to non-predictive reactive control strategies, reducing the LCOE and improving the material efficiency.



Visualization of an InfinityWEC unit deployed in the sea, including zooming in on the InfinityWEC Power Take-Off. (Copyright: Ocean Harvesting Technologies)

## Predicting failure of dynamic subsea cables by insulation breakdown (WATERTREE)

This project develops simulation models and a methodology that enable growth analysis of water trees in dynamic subsea cables due to mechanical and electrical loadings. It allows for prediction of the time it takes for a water tree to grow to a size which causes cable failure. Project partners are Chalmers University of Technology, NKT Cables AB and RISE Research Institutes of Sweden.

## Product verification of WaveMove in scale 1:25

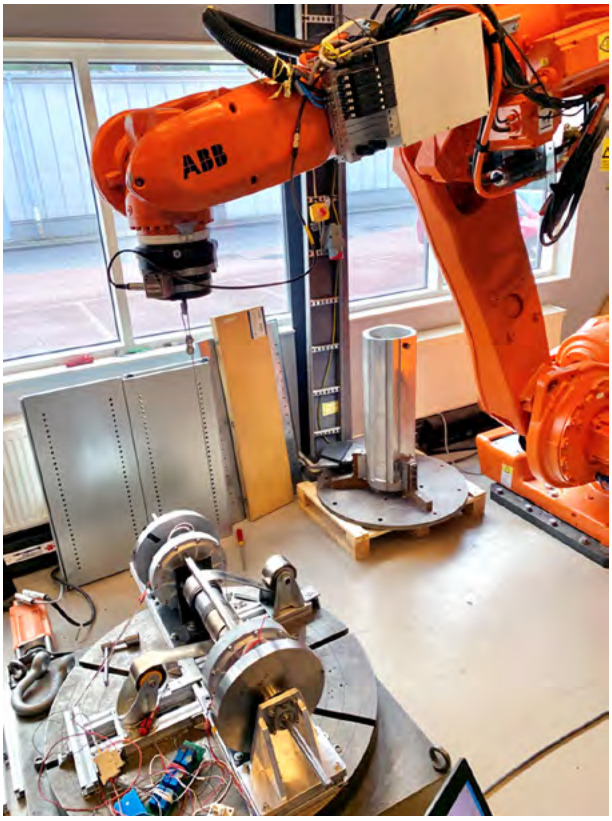
OE systems develops a wave energy converter called WaveMove, which is a terminator wave energy solution that works in water depths from 30m - 200m. The purpose of the project is to test WaveMove 1MW on a scale of 1:25 in a wave tank and in the sea to assess its stability, efficiency, and durability under realistic operating conditions. During 2023, the WaveMove prototype was built and in December wave tank tests started at SSPA Maritime Center, Sweden.

## Robotized dry testing of wave energy converters

A robotized dry test rig for wave power is under development at Uppsala University. The concept idea is to utilize a commercial industrial robot manipulator to emulate the motion of a point-absorber buoy in ocean waves. This enables realistic and cost-effective in-house testing of scaled wave energy converter systems with different emulated wave climates and with different load control strategies. During 2023, recorded wave climates and buoy motions have been implemented and emulated in up to full 6-DOF motion freedom with high accuracy in the full-scale robot test rig demonstrator. In addition, a hydrodynamic force model to the robot controller, connected to a force control and measurement system mounted on the robot manipulator, has been developed and integrated. Hereby it has been possible to achieve and demonstrate real-time hydrodynamic motion control for realistic emulation of buoy heave motions in regular (sinusoidal) ocean waves with a prototype wave energy converter power-takeoff system connected to the robot.

## SEASNAKE

The main goal of the project is to provide a step change in the overall performance of a medium voltage cable system, while ensuring that it is highly reliable. To date, the project has for example completed characterization of mechanical properties of three marine cables by four different experiments. In addition, the development of numerical simulation models of the three cables is almost completed. The knowledge can be applied to various WEC technologies and transferred also to offshore wind power cables. Project partners are Chalmers University of Technology, CorPower Ocean AB, i-tech, MWA Coatings, NKT Cables AB, Ocean Harvesting Technologies, RISE Research Institutes of Sweden, Université Gustave Eiffel, WavEC, Waves4Power AB and WaveVenture.




Project Robotized dry testing of wave energy converters. (Copyright: Uppsala University)

## Streamlining the Assessment of environmental effects of Wave Energy (Safewave)

The main objectives of the EU-funded project are to develop an Environmental Research Demonstration Strategy, a Consenting and Planning Strategy and a Public Education and Engagement Strategy. During 2023, environmental monitoring campaigns on field measuring WEC underwater noise and seabed integrity have been carried out. Project partners are Corpower Ocean, AZTI, WavEC, BIMEP, CTN, HYDROMOD, University College Cork, Ecole Centrale de Nantes, RTSYS and GEPS Techno.

## 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. The university has developed the generator, turbine and electrical system design. A 7.5 kW marine current converter, with a 5-bladed vertical axis turbine, is installed in a river in Söderfors, Sweden. The system is connected to the local utility grid.

## Verification through Accelerated testing Leading to Improved wave energy Designs (VALID)

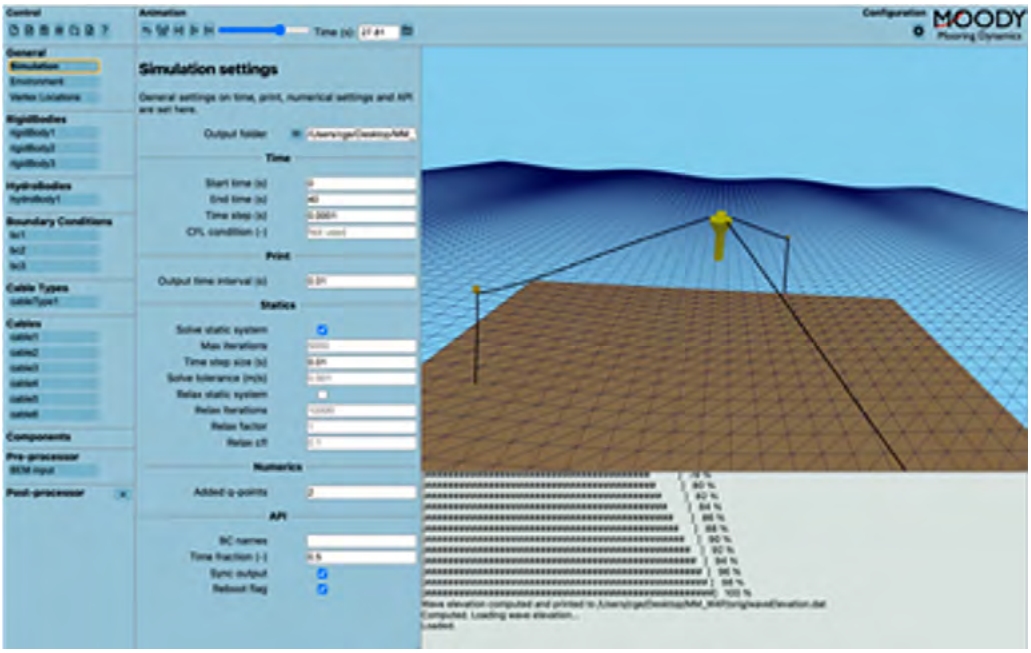
The EU-financed project is developing and validating a new test platform and procedures for accelerated hybrid testing that can be used across the wave energy sector to improve the reliability and survivability of the components and subsystems that form wave energy converters (WECs). The new test rig platform and methodology will be validated for a variety of WECs, critical components and subsystems through three different user cases. Project partners are RISE Research Institutes of Sweden, Corpower Ocean, AVL, Aquatera, IDOM, Wavepiston, Julia F Chosaz Consult Engineering, RINA-C, Tecnalia, Bimep, Aalborg University, TUDelft and DTU.

## Wave Energy Converters – integration of tribological design principles

The main goal of this project is to enhance the development and implementation of wave energy converter (WEC) technology by integrating tribological principles into the WEC design work. During 2023, work has been carried through regarding analysis of the operational conditions of wave energy converters, development of a scaling method for accelerated bearing testing and adapting in-house test rigs for operational conditions in wave energy converters. A large part of the activities was to generalize experimental studies of components from participating wave energy converter companies. The project is being carried out by KTH Royal Institute of Technology in collaboration with Axel Christiernsson International AB, Corpower Ocean AB, Novige AB and Nynas AB.

## WECs in Survival Conditions: augmenting linear models using machine learning

The computational efficiency of weakly nonlinear potential flow (WNPF) models makes them the tool of choice for optimization and design of wave energy converters. In this project, RISE Research Institutes of Sweden and Sigma Energy & Marine have worked on enhancing the performance of WNPF models by replacing existing non-




Screenshot of graphical user interface of MoodyMarine.
(Copyright: RISE Research Institutes of Sweden and Sigma Energy & Marine)

linear approximations (Morison drag, wave stretching, etc.) with improved approximations based on machine learning. The results are encouraging. The developed underlying linear potential flow (LPF) model MoodyMarine has been equipped with a graphical user interface and is freely available from www.moodymarine.se.

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 and grid connected.

### Testbed for Marine Materials – Fiskebäckskil, Sweden

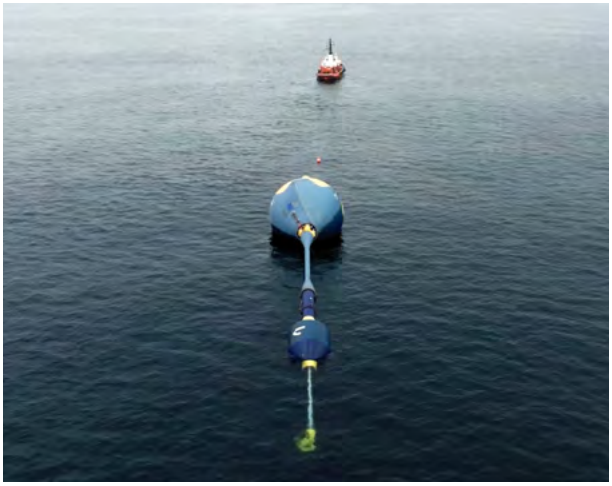
The testbed for materials in marine environment was inaugurated in 2021 and offers development, testing and verification of antifouling systems, corrosion protection and environmental assessment. The testbed for materials in marine environment is located at the Kristineberg Marine Research and Innovation Center in Fiskebäckskil (Skaftö), Sweden. The facility gathers expertise, laboratory resources and field infrastructure.

Kristineberg Marine Research and Innovation Center in Fiskebäckskil, Sweden. (Copyright: RISE)

## Projects in the Water

### 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 4km 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. After the successful deployment and retrieval in 2023 the C4 WEC will be redeployed in 2024 to further verify power-performance, survivability, and maintenance strategies.



C4 WEC in Aguçadoura, Portugal. (Copyright: Corpower Ocean)

Dragon 4 in Vestmanna waters, Faroe Islands. (Copyright: Minesto)

## Minesto - Vestmannasund, Faroe Islands

During 2023, Minesto continued its operations in Vestmannasund, Faroe Islands. Two Dragon 4 (100 kW) tidal power plants were commissioned during 2022 with continued testing during 2023, generating electricity.

## Novige – Stockholm archipelago, Sweden

Novige has been developing the NoviOcean wave energy converter (WEC), which is a point absorber. During 2023, Novige has tested a slightly modified 1/6 scale unit at Coast Laboratory in Plymouth, UK. The tests at Coast Laboratory confirmed the calculated power output, as well as the wire connection to sea floor with a shorter cylinder than earlier. The prototype has then been deployed in the Stockholm archipelago for long-time endurance testing. It has now been deployed there for six months, with full remote control. Including tests from previous years, the NoviOcean WEC concept has now in total been tested in open sea for 12 months.


Novige's NoviOcean deployed in the Stockholm archipelago. (Copyright: Novige)

# Projects Planned for Deployment

## 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 in 2025.

## Minesto – Vestmannasund, Faroe Islands

The subsea infrastructure for a Dragon 12 (1.2 MW) tidal power plant was being prepared during 2023. The export cable was installed, and the seabed anchor solution was drilled and grouted. The Dragon 12 kite has been assembled. The Dragon 12 system (1.2 MW) is now on the quayside in Vestmanna, Faroe Islands and is ready for installation and electricity production.

The Dragon 12 kite assembled on quayside in Vestmanna. (Copyright: Minesto)

## Novige

In 2021, Novige 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. Novige is currently working on the full-scale design of their device. The plan is for it to be a hybrid with 650 kW of wave, 300 kW of wind, and 50 kW of solar, totalling 1 MW. The capacity factor in a medium location is estimated to be 40%. As the total height would be 12 meters, it is expected that the hybrid can collocate with traditional wind power arrays without disturbing their output. The wave energy portion of the device, including the PTO, float, and moorings, are partly funded by CINEA-LIFE. The additional hybrid components are planned to


Visualization of Novige´s hybrid system deployed in the sea. (Copyright: Novige)

be added to the same structure when funding has been secured. Novige is planning construction in 2024/2025 and deployment in 2025/2026 at a Spanish test site.

### Ocean Harvesting Technologies (OHT) – off west coast of Sweden

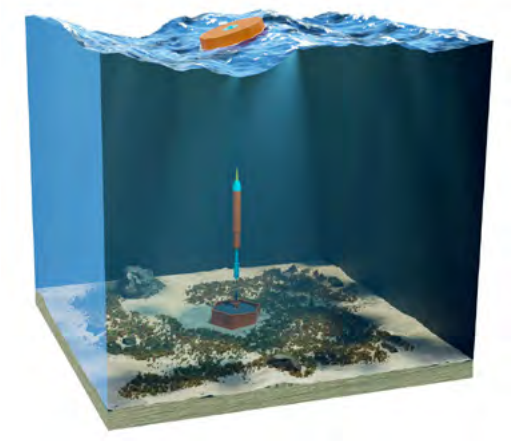
Ocean Harvesting is preparing for sea trials of InfinityWEC at scale 1:3 to be performed off the west coast of Sweden, to validate the technology and performance in real sea environment.

### OE Systems

During 2024, OE Systems plan to take the next step to TRL6 by constructing a 1:5 scale WaveMove prototype that will be deployed offshore for testing. The offshore trials will provide OE Systems with valuable data on the WaveMove system's performance in real-world conditions, including its durability in the marine environment.

### Uppsala University – Lysekil test site, Sweden

A new type of measurement system integrated in a 1 m buoy has been developed during 2022. The measurement system consists of an inertial measurement unit (IMU) and a force load cell. All measurements are synchronized in time, which allows to measure both 6 degrees of freedom motion of the buoy and the force in connection line simultaneously, which is essential, for example, for active control in offshore conditions. The buoy will be installed for long term offshore testing at the Lysekil test site.



Visualization of an InfinityWEC unit deployed in the sea. (Copyright: Ocean Harvesting Technologies)

## SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

### Viable Seas – A Swedish collaboration platform for a sustainable blue economy

Viable Seas is an open Swedish partnership founded in December 2022 to accelerate the transition to a sustainable blue economy. https://www.viableseas.se/

### International collaboration within marine tribology

KTH Royal Institute of Technology, Sweden, and Ghent University, Belgium, have initiated a collaboration within marine tribology. The aim of the collaboration is to develop an international platform within this area and to include wave energy developers. In 2023, the collaboration has resulted in joint application for EU funding.

## RELEVANT NATIONAL EVENTS

### International Conference on Marine Structures, April 3-5, 2023, Gothenburg

The conference was organized by Chalmers University of Technology

### International Antifouling Conference, September 12-13, 2023, Gothenburg

The conference was organized by I-Tech AB and RISE Research Institutes of Sweden.

### Workshop on Engineering Design of Wave and Wind Energy Harvesting, October 18, 2023, Stockholm

The workshop was organized by KTH Royal Institute of Technology. Participants came from academia and industry, both national and international. A second workshop is planned to be organized during autumn 2024.

# UK

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## OVERVIEW

At an international level, the demand for a diverse, resilient and, most importantly, net zero energy system has never been clearer. As a result, the future role of the UK ocean energy sector, and the policy programmes that will be required to underpin its continued development, are enjoying increasing prominence within the national policy-making landscape. Across the UK, both industry and academia continue to highlight the benefits that a commercially successful ocean energy sector brings and the role that this sector has in helping to address our net zero, energy security and just transition commitments. This collaborative approach, combined with the UK's flagship Contracts for Difference (CfD) market support mechanism, has helped to drive the development of one of the world's most successful and mature ocean energy sectors.

Over the course of 2023, the UK has provided continued support to its ocean energy sector by setting a ringfence for the second consecutive time within the CfD mechanism. Contracts have been awarded for nearly 100MW of tidal stream projects to date, the largest such allocation in the world. Coupled with the sustained support offered to wave energy technology developers via world-leading innovation programmes, ocean energy in the UK is poised to play a substantial role in the national energy mix over the coming decades.

However, at such a critical point, there is a need for increased awareness of the challenges posed by current economic conditions and supply chain insecurities, both of which pose a threat to the continued development of the sector. In addition, despite a growing understanding of the non-price factor benefits that a commercial wave and tidal stream sector can bring to the UK economy, such as regional socio-economic growth and energy system cost savings, there is still a requirement for the sector to continue to innovate as it chases the cost-reductions enjoyed by other sectors.

With the largest pipeline of tidal stream energy projects in the world now on the immediate horizon, the UK has been presented with an opportunity to provide the support and guidance required to en-

sure that the progress made by the sector over the preceding years is capitalised upon. By combining this support with a collaborative and coordinated policy programme there is an opportunity, in this critical decade for climate action, for the UK to cement its position as the leading nation in both ocean energy development and deployment.

### Tidal Stream Energy Highlights

2023 has proven to be a pivotal year for the UK tidal stream sector, with many developers launching ambitious projects designed to accelerate commercial array-scale deployments:

- The UK government awarded a record number of Contracts for Difference to the tidal sector, with 11 contracts granted across the UK at a Strike Price of £198/MWh;
- Orbital Marine Power have been selected by the European Commission's Horizon Europe Programme to deliver a 9.6MW tidal stream turbine array project, EURO-TIDES;
- Nova Innovation has also won Horizon Europe funding for a 4 MW tidal stream farm off the coast of Orkney, with the SEASTAR project set to deploy the largest number of turbines in an array anywhere in the world;
- A recent report by the London School of Economics, 'Seizing sustainable growth opportunities from tidal stream energy in the UK', emphasises how tidal stream can deliver sustainable economic growth, enhance net zero efforts, improve energy security and generate jobs across the UK;
- The Scottish government's draft energy strategy released in early 2023, outlines the vast potential of tidal stream technology and plans to consult across government on ambitions for realising its potential.

### Wave Energy Highlights

The UK wave energy sector continues to lead on the international stage as multiple technology developers and academic institutions strive to develop the next generation of wave energy converters (WECs):

- Now in its third and final phase of pre-commercial procurement, the innovative R&D programme EuropeWave has progressed CETO Wave Energy Ireland, IDOM Consulting, and Mocean Energy to final design and prototyping, in anticipation of real sea testing;
- Under their Direct Generation Concept Creation Competition, Wave Energy Scotland has awarded five developers funding to develop their design concepts. These are 4c Engineering, AWS Ocean Energy, Southampton and UTC, WaveX, and TTI Renewables;
- Mocean Energy and energy management specialists Verlume, with funding from Wave Energy Scotland, have engaged in a collaborative project to deliver low-carbon power to critical sea-based infrastructure;
- The Scottish Government's draft energy strategy, released in early 2023, recommends continued support for Wave Energy Scotland and will provide £18.25 million of investment to support the long-term development of the sector.

**SUPPORTING POLICIES FOR OCEAN ENERGY**

## National Strategy

The design and implementation of energy policy within the UK is made more complex by the presence of the devolved administrations in Wales, Scotland, and Northern Ireland, all of whom have differing levels of autonomy and policy decision-making. This is further complicated by the different net zero timelines that each ruling party, at devolved and national levels, has adopted.

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. Historically, wider UK energy policy has aimed to unite the different administrations in a shared ambition to resolve the energy trilemma to decarbonise electricity generation, ensure energy security and minimise the cost of electricity to consumers. However, as low-carbon energy becomes increasingly synonymous with low-cost energy, due to the cost reductions experienced by renewables, this strategy is beginning to evolve.

Within the UK, energy policy is largely devolved to the Northern Ireland Executive, yet it is only partially devolved to the Scottish and Welsh governments, restricting

their ability to make decisions and policy independently of UK government. However, the ability to enact policy that is designed to tackle climate change, through policy levers such as the promotion of renewable energy, energy efficiency and electricity generation and transmission development are partially devolved matters, allowing the devolved governments some powers in governing their overall domestic energy mixes.

## United Kingdom

For British society 2023 was a pivotal year for the perception of climate change, as the UK recorded the highest national summer temperature extremes since records began. As the challenges and dangers of a rapidly warming climate become clearer, both nationally and internationally, the UK has a growing role as a world leader in the effort to mitigate the worst extremes of the climate emergency. In response to this challenge, the UK has undertaken a comprehensive effort to rapidly increase the amount of renewable energy sources in its domestic energy mix and has committed to an ambitious and legislatively bound target of achieving Net Zero by 2050. While a national transition to a Net Zero economy will provide the obvious benefit of low-carbon emissions, it also proves the opportunity for jobs, socio-economic growth and the development of new sustainable industries. However, these benefits are attractive to nations across the globe and the UK currently faces growing competition from the USA and EU, both 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 over a decade remaining for the UK to meets its ambition of a decarbonised electricity system by 2035, 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 clearly defined, with long-term targets set and policy support fixed. However, ensuring that the UK delivers a sustainable, diverse and resilient energy mix, that harnesses all our national resources, will be key to achieving Net Zero in a cost-effective manner. To this end, there is now a growing understanding of the role that our abundant wave and tidal stream resources could play in helping to underpin and strengthen our national energy mix. This growing consensus can be better understood through the high-level policy guidance reports published by the UK government and other organisations over the previous years:

- In 2023, the UK government responded to the Environmental Audit Committee's report 'Accelerating the Transition from Fossil Fuels and Securing Energy Supplies' by underlining their commitment to exploring the potential of tidal power to contribute to our Net Zero ambitions. In the same response they committed to reviewing the merits of setting a potential target for tidal stream deployment;
- The British Energy Security Strategy (BESS), published in 2022, remains the most recent national energy policy report published by the UK government. This report explicitly links a Net Zero energy system, achieved through the increased provision of renewable energy resources, to enhanced levels of energy security. The BESS also highlights the need to 'aggressively explore' tidal energy as a future source of clean energy and the potential importance of funded collaboration with international partners;
- To enable the delivery of the commitments in the BESS, DESNZ has strengthened the National Policy Statement for Renewable Energy Infrastructure, including for the first time a framework for assessing planning applications for tidal stream projects of above 100 MW capacity. The draft planning guidance contains provisions for assessing and mitigating impacts of tidal stream infrastructure on seabed habitats and on distributions or movements of marine species;
- The "Net Zero Strategy: Build Back Greener", published in 2021 and updated in April 2022, is the governments primary climate change policy document and aims to keep the UK on track for meeting the UK carbon budgets, the 2030 Nationally Determined Contribution, and net zero by 2050. This report also acknowledges that the UK possesses some of the best ocean energy resources in the world and highlights the ongoing efforts to explore their role in meeting net zero targets.

## 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. Scotland's transition to net zero is supported by the Scottish Government's vision for the future of the energy sector and includes a target for the equivalent of 50% of the energy for Scotland's heat,

transport and electricity to come from renewable sources by 2030. However, meeting these ambitious targets will not be easy and the Scottish Government will need to continue to proactively shape policy and support rapid renewable energy deployments, wherever possible.

Scotland's geographical location on the western fringes 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 deployed. 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. It suggests a potential ambition to deliver at least 20 GW of additional low-cost renewable electricity capacity by 2030, which could help to generate the equivalent of around 50% of Scotland's current 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 over 250 responses relating to the need for an ocean energy deployment target and identifying priority actions to sustain the achievements of the sector to date. Scotland has also benefited from the formation of the Offshore Wind Directorate, a government body responsible for the development of policy work related to offshore renewables, marine energy and sectoral marine planning. The Offshore Wind Directorate supports 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 continue the journey towards commercial-scale deployment. The 2023 CfD AR5 was an unparalleled success for the Scottish tidal stream sector, with a record 7 new contracts shared amongst three developers, who are now set to deploy in Scottish waters. Combined with the successful auctions from AR4, there is now over 65 MW of tidal stream energy set for deployment by the end of 2028. This represents a significant proportion of the global allocated capacity for tidal stream and reaffirms Scotland's position as one of the leading nations with regards to development and deployment. The Scottish Government, together with industry itself, continues to advocate for long-term certainty for the ocean energy sector through the CfD and will closely monitor developments relating to the sixth allocation round, due to take place in 2024. 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 the Wave Energy Scotland (WES) programme, the Scottish wave energy sector has continued to benefit from sustained support and guidance. This has resulted in the completion of the demonstration of the AWS Waveswing device in Scottish waters, support to the re-deployment of Mocean's Blue-X device, demonstration of three mechanical and electrical quick connectors and conclusion of the control system development projects. WES also continues to support technologies emerging from the programme towards commercialisation and is delivering the EuropeWave device development programme in partnership with the European Commission, Ente Vasco de la Energía (EVE) and Ocean Energy Europe.

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. During 2023, Crown Estate Scotland commissioned Offshore Renewable Energy Catapult to conduct an in-depth market engagement survey of wave and tidal energy sectors to provide an insight into current market conditions and the future project pipeline to inform a review of leasing activities going forward.

## Wales

2023 has proven to be a historic 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 essential to 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 official opening of Wales' first tidal stream energy site, Morlais, to successful awarding of over 22 MW of tidal stream capacity between four companies via the CfD scheme. 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.

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 2023 State of the Sector report clearly highlights how the development of significant infrastructure projects has helped the ocean energy sector to produce record contributions of £103 million to the Welsh economy during the 22/23 financial year. Of this total, £45.1 million was contributed by the tidal stream sector and a further £44.7 million was contributed by the continued expansion of the domestic supply chain. Spending and investment in both these areas was fuelled by the contributions of two key projects – Morlais Tidal Demonstration Zone, the world's largest pre-consented demonstration zone based in North Wales, and the Pembroke Dock Marine project, a development project that has established a world-class centre for marine energy and engineering with easy access to the Celtic Sea. Overall, this represents a sharp increase from the levels of financial investment made during 2022 and brings the total cumulative spending and investment in the Welsh ocean energy sector to £263 million. The MEW report also estimates that the ocean energy sector provides employment to approximately 440 full time employees across areas such as technology development, supply chain and academia.

## 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. To date, there have been five allocation rounds (AR) which have seen a range of renewable energy technologies bid into competitive auctions for contracts. In both AR4 and AR5, 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. This has resulted in a record number of contracts being awarded, with six developers across 11 different contracts delivering 53 MW of tidal stream capacity:

- MeyGen was awarded 4 contracts totalling 22 MW to further develop their tidal array of the North coast of Scotland;
- Orbital Marine Power was awarded 2 contracts totalling 7.2 MW at EMEC's Fall of Warness site;
- Magallanes Renovables was awarded a further 3 MW at Morlais in Wales, and 1.5 MW at EMEC's Fall of Warness test site;
- Hydrowing was awarded a contract for 10 MW at Morlais, Wales;
- Verdant Isles awarded a contract for 4.9 MW at Morlais, Wales;
- Môr Energy awarded a contract for 4.5 MW at Morlais, Wales.

Building on the 41 MW of tidal stream capacity that was awarded in AR4, there is now a pipeline for 94 MW of tidal stream projects in the UK, all of which are expected to be commissioned by 2028. While wave energy is yet to benefit from the CfD program, developers are increasingly confident that the technology is on the cusp of the levels of technological maturity required to bid for multi-MW contracts.

In November 2023, the parameters for AR6 were announced, with significantly increased administrative strike prices for all technologies to address the issues of rising supply chain costs. For tidal stream this is now set at £261/ MWh. Throughout 2023 the UK government also held consultations on the creation of a Sustainable Industry Reward, as a new mechanism to secure broader benefits for UK households and communities from the roll-out of renewable energy technologies.

## Public Funding Programmes

### UK Research and Innovation (UKRI)

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 7 Research Councils, Innovate UK and Research England.
https://www.ukri.org/

### The Engineering and Physical Sciences Research Council (EPSRC)

The EPSRC is the main funding body for engineering and physical sciences research in the UK, investing in various fields such as chemistry, energy, engineering, materials and physics. 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. In 2023, EPSRC invested £7 million into the CoTide project, a collaborative undertaking between Oxford, Edinburgh and Strathclyde universities to deliver the next generation of cheap, scalable and reliable tidal stream turbines.
https://www.ukri.org/councils/epsrc/

### Innovate UK

Part of UK Research and Innovation, Innovate UK is the UK's national innovation agency, providing funding and support to businesses, helping to spur growth via the development and commercialisation of new products, processes, and services. Innovate UK delivers programmes for UK-based companies in all sectors and industries, from pre-start-up to large multinationals. These programmes seek to foster a dynamic, agile, and inclusive innovation ecosystem, with the aim of helping businesses develop and exploit their innovation, both domestically and on the global stage. Innovate UK is a key delivery body for the Government's Innovation Strategy for the UK to be a global hub for innovation by 2035.
https://www.ukri.org/councils/innovate-uk/

### UK Marine Energy Council (MEC)

Launched in 2018, the UK MEC acts as the voice of the UK's tidal stream and wave energy industries. In 2023 the UK MEC signed Memorandums of Understanding with Marine Renewables Canada to better facilitate information sharing and identifying areas where the associations could work together. The MEC holds the joint-secretariat of the Marine Energy All-Party Parliamentary Group in Parliament and is frequently invited to give evidence to select committees, and brief MPs ahead of key debates on renewables. The MEC organised responses to key governmental consultations including on the Sustainable Industry Reward, changes to Allocation Round 6 and key devolved administration consultations including the Scottish Government's Draft Energy Strategy and Just Transition Plan, and the Welsh Government's Just Transition strategy consultation.
https://www.marineenergycouncil.co.uk/

### Wave Energy Scotland (WES)

Since 2014 Wave Energy Scotland has been applying Scottish Government funding to the technical challenges facing the wave energy sector, driving innovative technology projects towards commercialisation through a competitive stage gate process. Within the WES programme, separate funding streams have supported the development of novel wave energy devices, power take-off systems, control systems, quick connection systems and materials. The headline achievements of 2023 were:

- Completion of the demonstration of the AWS Waveswing device in Scottish waters;
- Support to the re-deployment of Mocean's Blue-X device;

- Demonstration of three mechanical and electrical quick connectors, by Apollo Offshore Engineering, Blackfish Engineering Design and Quoceant;
- Conclusion of the control system development projects.

WES continues to support technologies emerging from the programme towards commercialisation and is delivering the EuropeWave device development programme in partnership with the European Commission, Ente Vasco de la Energía (EVE) and Ocean Energy Europe.

WES is analysing wave energy commercialisation pathways, in particular the opportunity for co-location and asset-sharing with the growing floating wind sector. A WES-commissioned study showed that such partnerships could offer up to 7% cost of energy reduction for wind projects and up to 40% saving for wave. In support of more radical cost-reduction opportunities, WES launched the Direct Generation programme, which is beginning to design concepts for flexible wave energy devices based on electrostatic power conversion technologies.
https://www.waveenergyscotland.co.uk/

### Scottish Enterprise

Scottish Enterprise helps ambitious companies across Scotland grow by supporting businesses with innovation, investment and increasing their international competitiveness. In 2023, Scottish Enterprise led on delivery of the European Clean Energy Transition (CET) Partnership, a Horizon Europe partnership comprising of 30+ funding agencies from Europe and beyond, providing funding for trans-national collaborative R,D&I projects. The Scottish budget for the Joint Call 2023, which closed for pre-proposals in November 2023, is €5 million. The call includes opportunities for ocean energy under the call module "advances renewable energy technologies for power production". Results of the call will be published in June 2024. Scottish Enterprise has also been supporting companies to speed-up the transition to a low carbon economy in manufacturing, through the Low Carbon Manufacturing Challenge Fund (LCMCF). This has resulted in several grant awards, including £499,500 for Mocean Energy and the detailed design, build and testing of key subsystems for their small-scale Blue Star wave energy machine.
https://www.scottish-enterprise.com/

RESEARCH & DEVELOPMENT

## Key R&D Institutions

### Supergen Offshore Renewable (ORE) Hub

The Supergen ORE Hub was established in July 2018 with £5 million of funding from the Engineering and Physical Sciences Research Council (EPSRC). It was subsequently awarded a further £4 million in June 2019, and recently secured a further £7.5 million in July 2023 for the second phase of its program. Some key updates as announced by the organisation in 2023 are as follows:

- The Supergen ORE Hub Sixth Annual Assembly took place between 11 – 12 July 2023 at the University of Southampton, bringing together over 250 delegates from across the offshore wind, wave and tidal stream communities. Alongside the Annual Assembly, the annual early career researcher (ECR) Forum was held, bringing together 60 ECRs to discuss their latest research;
- The Supergen ORE Hub has awarded £799,000 to 10 research projects at UK institutions through its Flexible Funding scheme in 2023. The Flexible Funds are designed to support ambitious research in offshore renewable energy across offshore wind (fixed and floating), wave and tidal stream sectors. These recent awards bring the total investment into ORE research between 2018 and 2023 to £3.8 million across 40 projects, a total that has been matched by £4.4 million of industry support over the same period;
- The Supergen ORE Hub has awarded an additional £38,000 to 9 ECR projects at UK institutions through its Early Career Researcher fund. These recent awards bring the total investment into ECRs between 2018 and 2023 to £204,000 across 46 projects;
- The Supergen ORE Hub and the Policy and Innovation Group at The University of Edinburgh published two new studies titled "Research and Innovation for Wave and Tidal Stream in the UK and EU - A 2023 Summary" and "UK power system benefits through deployment of marine energy technologies" which quantified the potential economic and power system benefits that the

UK stands to gain through the deployment of innovative offshore technologies;
- The Supergen ORE Hub attended COP28, where it launched a new briefing paper on the role of offshore renewable energy in supporting the delivery of net zero.

https://supergen-ore.net

### ORE 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. In 2023 ORE Catapult celebrated its 10-year anniversary and its achievements since 2013 include supporting over 1350 Small Medium Enterprises (SMEs) with the development, demonstration and commercialisation of their technologies, as well as being at the heart of over £677 million of innovation projects by total value.

In 2023, as part of the Interreg funded TIGER project, the ORE Catapult produced a "Tidal Stream Technology Roadmap" detailing tidal stream cost reduction via 10 key technology innovations and predicting that tidal stream costs could reduce to £50/MWh by 2035.

Crown Estate Scotland commissioned ORE Catapult to conduct an in-depth survey of wave and tidal technology developers, project developers and key stakeholders and gather feedback on ways to finesse the present leasing arrangement for projects between 3 and 30 MW to maximise potential for commercialisation. In 2024, ORE Catapult plans to launch the Marine Energy Partnership (MEP), a collaborative joint industry programme that aims to address sector-wide challenges to reduce marine energy costs, accelerate development and create opportunities for local supply chains.

https://ore.catapult.org.uk

## Key R&D Projects

In addition to many smaller studies, there were several significant ocean energy R&D projects funded by UKRI through EPSRC:

### Bionic Adaptive Stretchable Materials for Wave Energy Converters (BASM-WEC)

Launched in November 2021 and running for three years, BASM-WEC is a £1 million project, led by Strathclyde University, with the aim of developing and testing new cutting-edge wave energy technologies that will help the UK achieve its Net Zero goal. BASM-WEC seeks to take inspiration from the flexible bodies and fins of aquatic animals to develop an analysis and laboratory testing toolbox to reliably design, analyse, and process a new range of adaptive and stretchable materials and structures applicable to WECs. In early 2023, the University of Strathclyde held the 1st BASM-WEC workshop, with the aim of establishing a network in the field of flexible Wave Energy Converters (WECs).

https://basm-wec.org/

### Co-design to deliver Scalable Tidal Stream Energy (CoTide )

CoTide is an ambitious 5-year programme (2023-28) with £7.4 million EPSRC funding to develop and demonstrate holistic integrated tools and design processes for tidal stream energy, helping to reduce costs and accelerate innovation. CoTide will integrate advanced hydrodynamics simulation and testing, corrosion and resilience modelling, novel composite materials, structural design and fatigue testing, leading to large scale demonstrations of advanced integrated systems using world-leading facilities FloWave and FastBlade. CoTide brings together a team of around 35 researchers and academics from the world-leading centres at the Universities of Oxford, Edinburgh, Strathclyde and Sheffield to develop holistic integrated models covering all aspects of tidal stream turbine design from hydrodynamics, through structures and fatigue, to reliability. CoTide is supported by 25 project partners including 10 OEMs, utilities, standards agencies, and government agencies.

https://cotide.ac.uk/

### Holistic Advanced Prototyping & Interfacing for Wave Energy Control (HAPiWEC)

HAPiWEC is a wave energy research project, run in partnership by the University of Strathclyde and the University of Edinburgh, supported by industrial partners West Atlantic Marine Energy Community (WEAMEC), the National Renewable Energy Laboratory (NREL), Wave Energy Scotland (WES) and Renewable Dynamics. HAPiWEC aims to tackle the urgent issue of lowering the LCOE of wave energy to a level comparable with other commercialised renewable energy technologies by formulating more efficient control mechanisms that dramatically improve energy capture and device lifetime.

https://www.hapiwec.net/

### FlexWave

FlexWave, led by the University of Plymouth and the recipient of funding from EPSRC, seeks to improve the design, manufacture and survivability of flexible WECs. FlexWave will investigate intelligent design concepts to explore whether different types of rubber, composites and polymers can be effective in improving performance, reliability and reduce costs compared to currently available materials.
https://www.plymouth.ac.uk/research/offshore-renewable-energy/flexwave

### Mooring analysis and design for offshore WEC survivability and fatigue (MoorWEC)

Led by University of Manchester in collaboration with Universities of Plymouth, Strathclyde, London City, and Exeter, MoorWEC will model the impact of waves on various mooring options to generate key information and efficient modelling methods to aid the design of future WECs. The project concentrates on the multi-float system M4 capable of MW capacity at full scale with some idealised analysis for a single float relevant to point absorbers.

### Morphing-Blades

Funded by the EPSRC, "Morphing Blades: New-Concept Tidal (and Wind) Turbine Blades for Unsteady Load Mitigation" aims to demonstrate, at model-scale, a novel technology to reduce unsteady-loading for tidal and wind turbines, improving resilience and reliability and decreasing the levelised cost of energy. Led by the University of Edinburgh and involving University of Bath and several UK based ocean energy developers, the project has been conducting tests at FloWave in Edinburgh in late 2023.
https://voilab.eng.ed.ac.uk/morphing-blades

### MU-EDRIVE

Led by Newcastle University in collaboration with the University of Edinburgh and Mocean energy, MU-EDRIVE aims to establish the advantages of using electric power technologies in wave energy converters. Compared to electrical machines in other industrial sectors, wave energy converters are slow which has led to a range of novel generators being developed, yet comparatively few have been demonstrated at full scale with developers instead preferring to use conventional generators connected via device specific mechanical linkages. Pure electric drive train concepts are known to be efficient and mechanically simple but must now be proved feasible and advantageous at a meaningful device scale. If the electrical generator is allowed to run flooded with sea water, there will be no requirement for sealing and therefore a much-reduced requirement for maintenance. The project will design and demonstrate direct drive power take off for subsea communication networks and also powering subsea equipment for the oil and gas industry.

### WavE-Suite

Led by City, University of London in collaboration with the Universities of Bath, Edinburgh and Cardiff, WavE-Suite aims to provide robust modelling tools that can assess the survivability of WECs under the types of extreme marine environments that cause extreme loads and large responses. This project will develop a novel numerical modelling suite by combining different models and by proposing new numerical approaches and machine learning techniques, which will be more accurate and require less computational effort.

**The UK was also well represented in collaborative European projects, primarily funded through Horizon 2020 and Horizon Europe:**

### Element

ELEMENT, running from 2019 to 2023, was a €5 million EU H2020 project led by Nova Innovation alongside an international consortium of 10 partners. The ELEMENT team developed an advanced control system for tidal energy turbines that, by extending tidal turbine lifetime, improving efficiency and increasing availability, delivered a 17% reduction in the levelised cost of tidal energy. In 2023, the control system was trialled first on a 50 kW Nova Innovation demonstrator turbine deployed in the Étel estuary, Brittany, before being rolled out in Nova's Innovation's Shetland Tidal Array.
https://element-project.eu

### Enabling Future Arrays in Tidal (EnFAIT)

EnFAIT was a flagship €20 million EU H2020 project led by Nova Innovation and supported by six international partners, which ran from 2017 to 2023. It demonstrated development, operation and decommissioning at the world's first offshore grid-connected tidal array of up to six 100 kW turbines, delivering a 40% reduction in the levelised cost of energy for tidal power. Following successful demonstration in 2020 of Nova's first direct drive turbine (Eunice), activity in 2023 started with deployment of two

additional direct drive turbines, turbines 5 (Grace) and 6 (Hali Hope) in January, making this the largest tidal array ever in terms of deployed devices. Turbines 5 and 6 are connected to shore via a subsea electrical hub – the first time this has ever been successfully achieved for multiple tidal devices. After a period of operating the full six turbine array, the initial three turbines were decommissioned in 2023, successfully completing the demonstration of the full lifecycle of a tidal energy project. The Shetland Tidal Array continues to set new benchmarks that showcase the growing maturity of the tidal energy sector. By December 2023 the array had extended its own world-record performance, achieving 72 months of continuous monthly power output to the grid. No negative effects on marine life have been recorded in over 12 years of environmental monitoring at the site.
https://www.enfait.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. EuropeWave is a 3-phase programme co-funded by the European Commission which will lead to the deployment of three large-scale wave energy converters in 2025. In 2023, three Phase-3 projects were selected: 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.
https://www.europewave.eu

## EVOLVE

Results from the three main studies of the EVOLVE project were published in January 2023, highlighting the practical deployment potential, plus the system benefits both at a country and island level. GIS based modelling highlighted locations most suitable for wave and tidal energy technologies, in the three regions studied: Great Britain, Ireland, and Portugal. Power systems modelling for these three regions, using supply and demand profiles for credible future energy supply scenarios, quantified the benefits of ocean energy. The key result is that including a higher proportion of ocean energy within our future electricity mixes consistently results in higher renewable dispatch, for the same total renewable energy availability, due to the offsetting of wave and tidal with wind and solar generation. The ability to dispatch more renewables results in lower fossil fuel and peaking plant dispatch, and thus lower total dispatch costs and carbon emissions. Similar results were shown at a micro-grid level, using the Orkney Islands as a case study. The EVOLVE project received support under the framework of the OCEANERA-NET COFUND project, with funding provided by Scottish Enterprise, Swedish Energy Agency and Fundação para a Ciência e a Tecnologia, with partners in the UK, Sweden, and Portugal.
https://evolveenergy.eu

## FORWARD 2030

In 2022, Orbital Marine Power and partners completed the design phase of the €26.7 million FORWARD-2030 project set up to deliver the accelerated commercial deployment of floating tidal energy. The FORWARD-2030 project consortium received €20.5 million grant support from H2020 to develop a system that will combine predictable floating tidal energy, wind generation, grid export, battery storage and green hydrogen production. As project coordinator and lead technology developer, Orbital Marine Power will oversee the installation of the next iteration of the company's turbine. This will feature a range of cost reduction innovations and be coupled with a hydrogen production and battery storage facility at EMEC. The project also will develop and assess large scale integration of tidal energy to the European energy system, 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 maritime spatial planning issues for wide scale uptake of tidal energy.
https://forward2030.tech

## LiftWEC

Concluding in March 2023, LiftWEC was a €3.4 million H2020 project led by Queen's University Belfast – Marine Research Group (QUB-MRG). The LiftWEC concept uses a unidirectional crossflow rotor to exploit hydrodynamic lift forces, extracting energy from the passing wave energy. The LiftWEC consortium aims to apply these concepts to the design of a 2 MW device, with the current study taking the design up to TRL4, including scaled tank demonstration and validation of numerical models. The successful completion of the H2020 LiftWEC project is the latest milestone in the technology's development, proving the viability of the concept and identifying key research

themes for further R&D to bring this technology closer to marine trials and commercialisation.
https://liftwec.com

## 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 decommission, embedding a circular economy element in their design. Working with tidal technology company Orbital Marine Power, the project will implement longer blade designs, increasing the swept area and reducing the overall cost of tidal energy. Innovations from MAXBlade will be integrated with findings from its sister project, FORWARD2030, to enable large-scale production of Orbital's O2 turbine technology. 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

## Marine Energy Engineering Centre of Excellence (MEECE)

MEECE was an ERDF funded project between the Offshore Renewable Energy (ORE) Catapult and the Universities of Swansea, Cardiff, Bangor, and Cardiff Metropolitan. At the point of its conclusion in 2023, MEECE had supported over 100 Welsh companies in the development of new products and services for the marine energy sector.
https://www.meece.org.uk

## 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). These facilitate widespread knowledge-sharing within the ocean energy sector and support the execution of the SET Plan Implementation Plan. In 2023, the project investigated best practice guidelines on community engagement and the future infrastructure requirements for ocean energy.
https://www.etipocean.eu and https://www.oceanset.eu

## SELKIE

After four years, the SELKIE project concluded its collaborative mission to advance marine renewable energy in Wales and Ireland. A key achievement is the creation of open-source decision support tools, addressing challenges faced by early-stage developers and facilitating cost-effective development. Dedicated to sustainability and innovation, SELKIE produced a comprehensive economic report on the offshore renewable energy sector, identifying strengths and challenges. The project also established a network of 100 SMEs in Ireland and Wales, fostering collaboration through events and workshops, marking a significant milestone in advancing marine renewable energy technologies and moving closer to commercialisation.
https://www.selkie-project.eu

## Tidal Stream Industry Energiser (TIGER)

Led by ORE Catapult, TIGER was an ambitious €48.4 million project that concluded in 2023. TIGER has proved highly successful in influencing policy and driving the development of the Tidal Stream Energy sector on both sides of the Channel Manche. At the time of writing the UK has allocated £450m to support Tidal Stream Energy under AR4 & AR5, while in France the FloWatt tidal project has received €65 million and revenue support to assist the continued development of la Raz Blanchard. Throughout the project, consent for six turbine installations was achieved, with a further three planning applications submitted. TIGER partners have also manufactured & tested eight different tidal devices or components, with four of these being deployed at TIGER sites, including the QED Naval Subhub Community Demonstrator in The Solent. In addition, a cross-channel supply chain database, with over 5,000 registered companies, has been created, along with five Low Carbon Technology networks.
https://interregtiger.com

QED Naval Subhub being towed to Langstone as part of TIGER Project. Photo: © QED Naval.

TECHNOLOGY DEMONSTRATION

# Existing Open Sea Test Sites

## European Marine Energy Centre (EMEC)

2023 marked the 20th anniversary of 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.

As well as operating its wave and tidal test sites, EMEC has also established an R&D hydrogen ecosystem, and in 2023 set out the needs case for a National Floating Wind Test Centre in the UK. In 2023 EMEC's grid-connected Billia Croo wave test site was awarded a site-wide section 36 consent, further streamlining the consenting process for EMEC's clients, reducing the time and cost associated with offshore demonstration. The site has also been expanded by an area of 2.6 $km^2$ to the north-west enabling access to deeper water. Maximum installed generating capacity has been increased to 20 MW and a wider 'envelope' of device types and operations has been approved. Technologies over 1 MW can now demonstrate at the Billia Croo test site without having to apply for individual section 36 consents.

Mooring in Tidal Flow at EMEC Fall of Warness test site (Source: EMEC)

2023 also marked the 10th anniversary of the International WaTERS (Wave and Tidal Energy Research Sites) network, established by EMEC to encourage collaboration, knowledge sharing and cross-border project development with ocean energy test centres around the world. Supported by IEA-OES, a new website was launched which includes

a database of all operational and planned test sites. EMEC also hosted the latest International WaTERS workshop, with 30 delegates, representing 18 test centres and 5 observer organisations, from 10 countries, travelling to Orkney for site tours, workshops and discussions.
https://www.emec.org.uk
and https://www.internationalwaters.info

### Morlais

The Morlais project, encapsulates 35 km² of seabed around the promontory of Holy Island being developed by Mentor 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, with Welsh First Minister Mark Drakeford opening the onshore substation in October. Four developers have secured subsidy support under the Contracts for Difference (CfD) scheme in AR4 and AR5, namely Hydrowing, Magallanes Renovables, Môr Energy, and Verdant Isles.
https://www.morlaisenergy.com

### Marine Energy Test Area (META)

The Marine Energy Test Area, situated in the Milford Haven Waterway, is managed by Marine Energy Wales. It 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. In June 2023 after over a year of deployment the MEECE buoy was successfully decommissioned from the META Dale Roads site. There are now three projects in the water at META which include: A low carbon concrete experiment being conducted by Cardiff University looking at the suitability of this material for tidal range schemes; A project investigating scour protection infrastructure habitat enhancements lead by Exo-Engineering; And an experiment exploring seaweed cultivation with consideration of colocation with ocean energy systems. Currently booked in to deploy in 2024 are Dolphyn Hydrogen with a floating hydrogen production system designed to be coupled with renewable energy, and Swansea University with a multi-use tidal energy barge which can support different turbine designs.
https://www.meta.wales

## Projects in the Water

## Tidal Energy

### Magallenes Renovables

During 2023, Magallanes Renovables experienced a transformative year in the realm of tidal energy. Their groundbreaking efforts included the continuous testing of the ATIR, their 1.5 MW tidal energy device at the European Marine Energy Centre, marking a significant leap forward in harnessing tidal power. Furthering their technological prowess, the completion of the engineering phase for the second-generation ATIR 2.0 showcased their commitment to advancing tidal energy solutions towards commercialization, as it will be installed in the new sites. They secured tariffs in the UK CfD auctions for two pivotal projects: a 3 MW expansion in Wales and a 1.5 MW contract in Scotland.
https://www.magallanesrenovables.com

### 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 current array has been in operation since 2018, with four 1.5 MW turbines. As of December 2023, MeyGen has delivered over 60 GWh of clean, predictable electricity to homes and businesses. Phase 1 incorporated two different turbine technologies, SAE's AR1500 and Andritz Hydro Hammerfest AH1000 MK1. The current turbines are consistently delivering availability >95% and have maintained continued production at 1.5 MW for >5 years without the need for recovery. The next phase of MeyGen will deliver an additional 50 MW of capacity with a target commissioning

A MeyGen turbine is lowered beneath the waves (Credit: SAE Renewables)

date by 2028. Phase 2 successfully secured a CfD in AR4 for 28 MW at a strike price of £2012178.54/MWh and the other 22 MW at AR5 at a strike price of £2012198/MWh. The success at securing the consents and funding required to deliver this world leading project is a transformational moment for both the project and the industry. MeyGen is expected to deliver the world's first commercial scale tidal array and be a showcase for the whole sector.
https://saerenewables.com/tidal-stream/meygen/

## Nova Innovation

In 2016, Nova Innovation installed the world's first offshore tidal energy array, the Shetland Tidal Array, with three 0.1 MW turbines installed at Bluemull Sound in Shetland. The array was doubled in size under the EnFAIT project, and in 2023 the fifth and sixth turbines were installed, bringing the overall installed capacity to 0.6 MW and making this the largest ever tidal stream array in terms of installed devices. The three initial turbines deployed in 2016/17 were later decommissioned in 2023, completing the successful demonstration of all stages in the lifecycle of a tidal array. Nova is currently advancing the design for their next-generation tidal turbine under the UpTEMPO project. In 2023 Nova Innovation was awarded the SEASTAR project that will see an array of 16 Nova Innovation turbines deployed at the European Marine Energy Centre in Orkney. They deployed a 50 kW demonstrator tidal turbine at the Étel estuary in France under the ELEMENT project. Nova have also initiated the GHOST project in Shetland to explore the supply of Green Hydrogen and Oxygen from Sustainable Tidal energy, including the potential to generate energy and fuel for the Saxavord Spaceport. Finally, Nova has been actively collaborating with the Department for Energy Security and Net Zero as

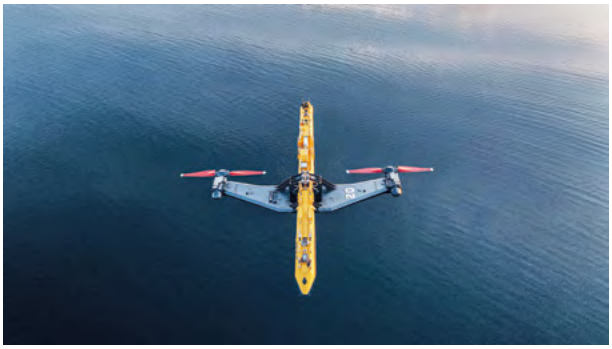
Nova Innovation Tidal Turbine installed as part of the EnFAIT project (Source: Nova Innovation)

part of the CREATE project, with the aim of developing tools and techniques to reduce the cost of tidal turbine deployment and recovery.
https://novainnovation.com

### Orbital Marine Power

In March, Orbital announced that it had secured an option agreement from Crown Estate Scotland for a 30 MW project at the Westray Firth, Orkney. The project is currently under development with bird and marine mammal surveys ongoing and a grid connection agreement secured.

Orbital was awarded a further 2 CfDs totalling 7.2 MW in AR5, building on the 7.2 MW from the previous year's AR4. These projects will be deployed alongside the current O2 tidal turbine at the European Marine Energy Centre, Orkney and come on the back of the formal approval by Ofgem of a new transmission link to Orkney, which will unlock 220 MW of new renewables capacity



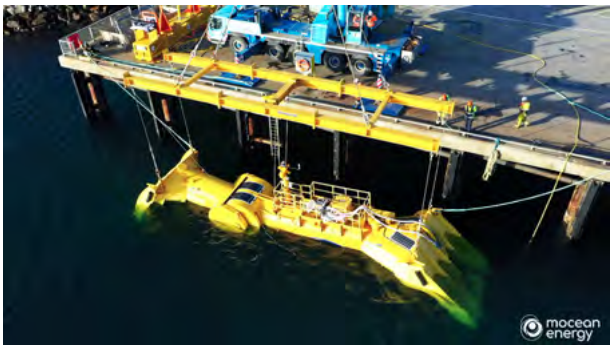
Orbital O2 at EMEC's Fall of Warness test site
(Source: Orbital Marine Power)

in the islands. In December, Orbital was announced as the technology partner for Euclaire Tidal's project at the Fundy Ocean Research Centre for Energy (FORCE), Nova Scotia, Canada. This project would initially involve a single 2.4 MW installation.
https://www.orbitalmarine.com

## Wave Energy

### Mocean Energy

In 2023, Mocean Energy moved closer towards the commercial roll-out of its Blue Star technology (tens of kW) and prepared to scale up via its Blue Horizon technology (hundreds of kW), as it continues to learn by doing to implement its roadmap across different near- to longer-term markets. In 2023, Mocean's prototype wave energy converter (WEC), BlueX, completed 10 months of operational time as part of the pioneering Renewables for Subsea Power (RSP) project. Under the remit of the Net Zero Technology Centre, RSP is demonstrating local, reliable, renewable power and communications provision from a WEC to a subsea micro-grid off the east coast of Orkney. Mocean has successfully demonstrated hybridisation of its hinged raft technology via the inclusion of solar panels on Blue X's topside hulls, leading to an ocean energy product with boosted continuous power provision capabilities, essential to the off-grid use-cases. It is also a stand-alone example of the diversification advantages that a more diverse renewable grid holds in store at larger scale. As well as robust wave and solar yields, and reliable remote control and communications, BlueX successfully survived and exported power during Storm Babet, with significant wave heights exceeding 7 m. Mocean Energy continues to advance step-change innovations, such as the novel




Mocean Energy's Blue X being lifted into the water at Hatston Pier
(Colin Keldie - EMEC)

Vernier Hybrid Machine technology, well suited to high-torque low-speed applications and bringing direct-drive electrical generators to the sector. Finally, Mocean continues to strengthen its commercial and industrial links, with memorandums of understanding signed with Tier I Aker Solutions and Dundee-based fabricator TEXO, both important steps in bringing the Blue Start technology closer to commercial deployment. 2023 also saw Mocean awarded £3.2 million to develop its Blue Horizon 250 kW WEC via EuropeWave.
https://www.mocean.energy

### AWS Ocean Energy

By the start of 2023, AWS Ocean Energy had successfully completed at-sea testing of a 16 kW prototype of their Archimedes Waveswing wave energy converter at the EMEC Scapa Flow scale test site in Orkney, UK. The Waveswing is a modular, fully submergible, pressure differential absorber and this testing has proven the key technology sub-systems necessary to give confidence that the concept will work at full scale. Since completing device testing, AWS has continued to progress the design and feasibility of large-scale multi-absorber wave energy platforms that makes use of the Waveswing technology. Finding a solution that addresses the fundamental challenge of scale, and the practicality of offshore maintenance, is essential to the delivery of affordable utility scale power. AWS is seeking partners to participate in the development and demonstration of a 2 MW multi-absorber pre-commercial prototype, whilst also pursuing other opportunities for deployment of smaller systems in bespoke applications.

AWS Waveswing testing at EMEC Scapa Flow test site (Source: EMEC)

https://awsocean.com

## Projects Planned for Deployment

### 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 two winter periods from 2024 at EMEC's 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.

### Tidal CfD projects

With the 41 MW CfD previously awarded in AR4, and the further 53 MW in AR5 announced in 2023, there is now a pipeline for 94 MW of tidal projects in the UK, expected to be commissioned by 2028 at Morlais, MeyGen and EMEC.

**RELEVANT NATIONAL EVENTS**

Relevant events for the ocean energy sector that took place in the UK in 2023 include:

- **21-22 March** – Marine Energy Wales Annual Conference, Swansea
- **10-11 May** – All-Energy, Glasgow
- **25 May** – Scottish Renewables Marine Conference, Edinburgh
- **11-12 July** – Supergen ORE Hub Annual Assembly, Southampton
- **16 November** – Wave Energy Scotland Annual Conference, Edinburgh

The UK will also be hosting a series of important events in 2024, including:

- **13-14 March** – Marine Energy Wales Annual Conference, Swansea
- **15-19 April** – Environmental Interactions of Marine Renewables Congress, Orkney
- **24 April** – Supergen ORE Hub Annual Assembly, Plymouth
- **15-16 May** – All-Energy, Glasgow

# USA

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## OVERVIEW

The United States continues to advance marine energy through device deployments scaled for coastal communities and at-sea activities in the near term, and through design and development for the U.S. electric grid in the long term. Federal government funding and technical support opportunities, lessons learned through testing, and landmark state legislation advanced the U.S. marine energy sector in 2023.

At least four wave, three tidal, and three river current energy projects conducted open water testing across the country in 2023. Notable U.S.-based research and development (R&D) efforts included wave and tidal energy converter (WEC and TEC) designs, power take off and mooring/anchoring subsystems, technologies for powering at-sea activities, approaches for protecting devices from biofouling and corrosion, and community engagement projects.

The U.S. Department of Energy's (DOE) Water Power Technologies Office's (WPTO) Marine Energy Program is the United States' primary public funder of research, development, demonstration, and deployment activities supporting technologies that harvest energy from waves, tides, ocean, and river currents; free-flowing waters; and differentials in salinity, pressure gradients, and water temperature, including ocean thermal energy conversion. In fiscal year 2023 (which spanned October 2022-September 2023) the U.S. federal government provided $120 million, a record amount, to WPTO's Marine Energy Program. WPTO also continues to execute funding allocated from the 2021 Bipartisan Infrastructure Law; for example, these funds were used to release a $45 million opportunity for tidal and current energy, representing DOE's largest funding opportunity for marine energy to date. In addition to WPTO, other U.S. government organizations continue to support marine energy R&D such as DOE's Advanced Research Projects Agency – Energy (ARPA-E), the Department of Defense, the National Science Foundation, the National Oceanic and Atmospheric Administration (NOAA), and others. At the U.S. state level, in 2023 California became the first state to pass legislation specifically designed to support marine energy development off its coast.

SUPPORTING POLICIES FOR OCEAN ENERGY

# National Strategy

### National Ocean Energy Policy

In 2023 the U.S. interagency Ocean Policy Committee officially released the Ocean Climate Action Plan (OCAP). The OCAP is intended to guide and coordinate near-term actions of the U.S. federal government and society to create a carbon-neutral future, accelerate nature-based solutions, and enhance community resilience to ocean change. The OCAP recommends several actions related to both offshore wind and marine energy such as expanding R&D, monitoring environmental and social impacts to inform design and deployment, fostering partnerships focused on workforce training, and investigating the potential to power applications in the sustainable ocean economy.

Also published in 2023, a Technological Innovation System Analysis report assessed the U.S. marine energy innovation ecosystem using surveys and interviews with the marine energy community as well as publication and funding data. The University Marine Energy Research Community, a program coordinated by the Pacific Ocean Energy Trust, led the analysis. The report recommended four actions to strengthen U.S. marine energy innovation: develop technology-specific, cohesive roadmaps; provide predictable funding and support for entrepreneurial activities; leverage the knowledge, support, and workforce of other relevant fields; and continue supporting research, development, and knowledge exchange.

State policies in the United States could play a major role in advancing marine renewable energy development and deployment. In 2023, California became the first U.S. state to enact a marine energy law, which requires the California Energy Commission to work with state agencies and stakeholders to assess the feasibility and potential impacts of wave and tidal energy and to identify suitable locations in state and federal waters. New Jersey also introduced a bill in 2022 that would support marine energy development in the state, though it has not yet been enacted into law.

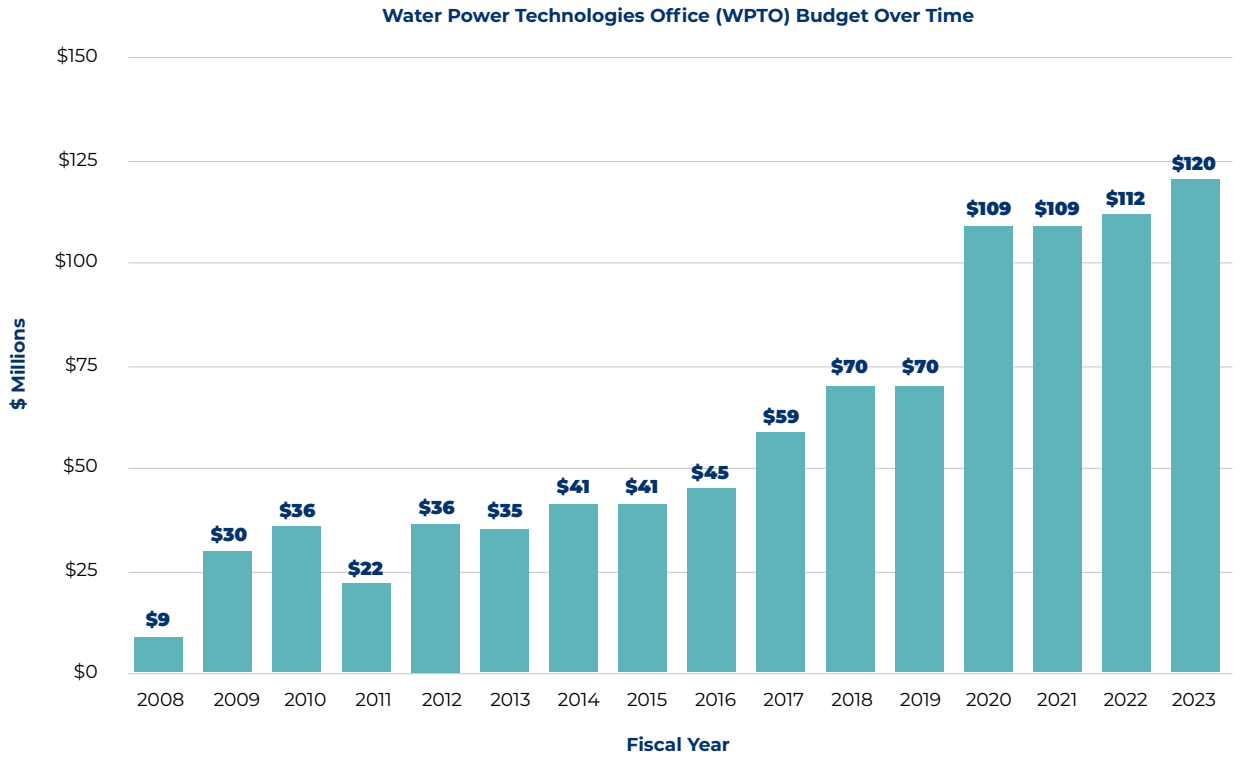
# Market Incentives

The DOE Grid Deployment Office is continuing to implement a 2021 Bipartisan Infrastructure Law provision that updated and provided additional funding to the Hydroelectric Production Incentive Program. The program provides payments based on the statutory rate of $0.018/kWh (to be adjusted for inflation), up to $1,000,000, for projects involving a water-powered turbine in an existing conduit or in an area of inadequate electric service. WPTO aims to encourage hydrokinetic developers to take advantage of these credits if they have eligible projects.

The Inflation Reduction Act of 2022 (IRA) provisions included clean energy production tax credits for electricity produced from certain renewable resources, as well as clean energy investment tax credits for marine and hydrokinetic energy technologies. The U.S. Treasury Department is regularly updating IRA tax credit guidance. For example, in December 2023, the Treasury published updates on hydrogen production tax credits, which could be relevant for marine energy in applications such as producing hydrogen for energy storage or shipping fuel in remote communities. As new information is made available, WPTO will update its webpage summarizing tax incentives for water power technologies.

# Public Funding Programs

The DOE WPTO Marine Energy Program's 2023 annual appropriations were $120 million, the highest annual budget for the program since its origin. At the time of this writing, Congress has not passed a final budget for fiscal year 2024 (which spans October 2023-September 2024) and U.S. government agencies are currently funded by a temporary funding bill called a continuing resolution. In addition to annual appropriations, the 2021 Bipartisan Infrastructure Law provided $110.4 million to WPTO for marine energy activities. WPTO implements funds via technical assistance programs and funding opportunities for researchers, developers, small businesses, National Marine Energy Centers, students, and others in the marine energy sector.




Note: This graph shows annual appropriations and enacted funding only. This graph does not reflect the $110.4 million of funding WPTO received in 2021 from the Bipartisan Infrastructure Law for WPTO-led marine energy activities.

WPTO year-on-year marine energy budget

In 2023 WPTO announced DOE's largest investment to date for marine energy, a $45 million opportunity using Bipartisan Infrastructure Law funding to develop a pilot tidal and/or current energy technology research, development, and demonstration site in the United States. In addition, the opportunity will support a community-led tidal and/or current energy planning and development project that will balance community energy priorities with technology innovation. WPTO expects to announce selected projects in February 2024. In 2023 WPTO also released a $6.4 million joint funding opportunity with DOE's Wind Energy Technologies Office to focus on mooring system design solutions for marine energy and offshore wind.

In early 2024, WPTO announced a $14.5 million funding opportunity for marine energy research conducted by U.S. universities, spanning a range of different topics. WPTO is also continuing to support marine energy research at universities through funding to the four National Marine Energy Centers, which received $40 million from the 2021 Bipartisan Infrastructure Law.

Notable WPTO funding selections in 2023 include the Marine Systems Innovation at Sea opportunity, which awarded $9.8 million to seven projects led by developers and universities. Six projects will advance research on wave-powered technology for seawater desalination, and one will assess the feasibility of an ocean current test facility off the coast of Florida.

Small businesses can apply for marine energy funding through the federal Small Business Innovation Research (SBIR) and Small Business Technology Transfer (STTR) programs. Through this program, WPTO invested $8.4 million in small businesses working to advance marine energy in fiscal year 2023 and plans to invest at least $12 million in 2024 for Phase 1 marine energy projects.

WPTO continues to support the Testing Expertise and Access for Marine Energy Research (TEAMER) program, which provides developers with access to ocean energy testing facilities and capabilities across the United States in collaboration with universities and national laboratories. In 2023 TEAMER funded its 100th project. Both U.S.

and non-U.S. developers are eligible to apply for technical support through TEAMER.

WPTO funds marine energy R&D at six DOE national laboratories and in 2023 awarded about $3 million to national laboratory researchers through its Seedling and Sapling program, which funds discovery research across all areas of marine energy. In 2023 WPTO extended funding for this Seedling program to universities for the first time, through the National Science Foundation's Engineering Research Initiation program as well as DOE's Minority-Serving Institution STEM Research and Development Consortium.

WPTO-sponsored prizes and competitions are open to the public and often have entry stages that solicit concept-level ideas. In 2023, the Innovating Distributed Embedded Energy Prize (InDEEP) ($2.3 million) and the Power at Sea Prize ($1.7 million) both launched. InDEEP challenges competitors to develop distributed embedded energy converter technologies (DEEC-Tec) and encourages collaboration among interdisciplinary innovators. The Power at Sea Prize seeks conceptual solutions for using marine energy to power off-the-grid ocean activities, such as oceanographic research and aquaculture. Additionally, the annual Marine Energy Collegiate Competition (MECC) engages undergraduate and graduate students in marine energy projects. The 2023 competition selected 19 student teams to compete and the ongoing 2024 competition includes 20 teams.

In addition to WPTO funding, other federal agencies and DOE offices include marine energy in their clean energy opportunities. For example, DOE's Office of Clean Energy Demonstrations funds demonstration-scale projects and can serve as a subsequent opportunity after R&D-stage projects or after technical assistance for community energy planning. The DOE Loan Program Office implements loan guarantees for projects supporting clean energy deployment through the Title 17 Clean Energy Financing Program. The program includes an Innovative Energy category which includes technically proven renewable energy systems that are not yet commercialized, like marine energy. The U.S. Department of Agriculture's Rural Energy for America program also provides loan financing and grant funding for purchasing and installing renewable energy systems, which include marine energy.

The students participating the 2023 Marine Energy Collegiate Competition and 2023 Hydropower Collegiate Competition gathered in Washington, DC for their competitions' finale alongside Waterpower Week. Source: National Renewable Energy Laboratory.

## RESEARCH & DEVELOPMENT

Universities, private companies, organizations, nonprofits, and six DOE national laboratories lead marine energy R&D in the United States. Additional U.S. R&D institutions work on marine energy, such as the U.S. Naval Research Laboratory, U.S. Navy Office of Naval Research, and the Marine Environmental Laboratories operated by NOAA. Coordination of marine energy R&D at U.S. universities is facilitated by the four National Marine Energy Centers and University Marine Energy Research Community.

Sandia National Laboratories, in partnership with Woods Hole Oceanographic Institution, is developing a WEC that can help power data-collecting sensors on the Pioneer Array, an ocean observing system that is part of the National Science Foundation-funded Ocean Observatories Initiative. In 2023 the project team determined design requirements and narrowed down a viable design to move forward with prototyping. In addition to projects pairing marine energy with ocean observing systems, other projects are assessing the feasibility of powering aquaculture and potential marine carbon dioxide removal activities with marine energy in the United States.

A study led by multiple DOE national laboratories and published in 2023 determined a more comprehensive method for theoretical wave energy resource assessment and updated the U.S. wave energy resource estimates using the new approach. Other projects led by national laboratories have been investigating novel energy harvesting technologies such as triboelectric nanogenerators and distributed embedded energy converters that can harness energy from a wider range of ocean movements.

Projects focused on the social science and community engagement aspects of marine energy have grown in the United States. In 2023, NOAA's Sea Grant and WPTO partnered to fund community engagement projects led by regional Sea Grant programs in Alaska, Guam, and Hawaii that will focus on efforts such as gathering community input, developing informational materials, and assessing workforce qualifications and training programs. Additional projects conducted by national laboratory and university researchers are focusing on social science data collection guidance, approaches to assess and bolster community readiness for marine energy deployment projects, and marine energy feasibility studies that incorporate community input.

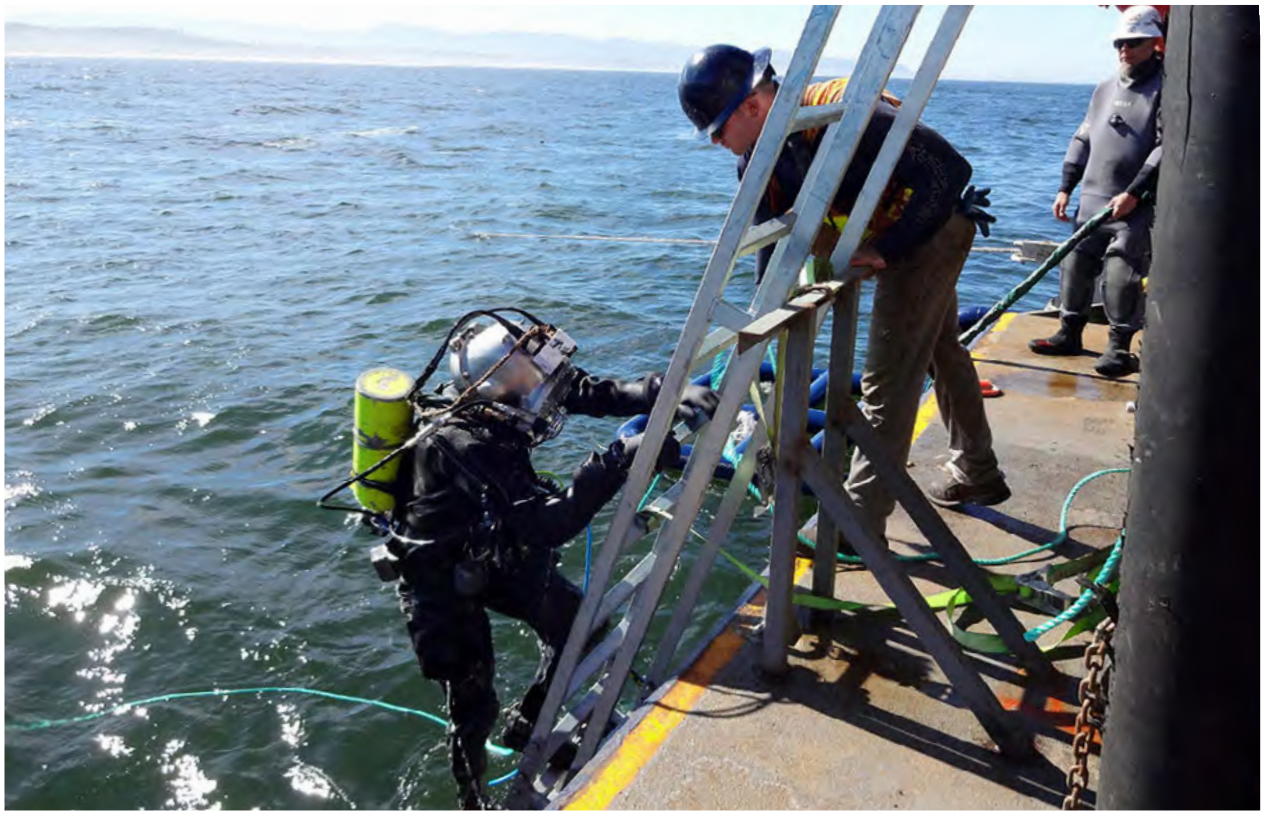
Several projects have been focusing on environmentally friendly approaches to coat and protect marine energy devices facing harsh ocean conditions. Pacific Northwest National Laboratory (PNNL) researchers are developing a method of using a laser to modify the surface of aluminum and steel to reduce corrosion and biofouling of marine energy devices. Another PNNL team has plans to validate their non-toxic, anti-biofouling superhydrophobic lubricant infused composite (SLIC) coating for marine energy applications. Researchers at Oak Ridge National Laboratory are also developing new lubricant additives that can protect tidal turbine gearboxes from wear and tear while having lower aquatic toxicity compared with traditional turbine lubricants.

DOE ARPA-E's Submarine Hydrokinetic and Riverine Kilo-megawatt Systems (SHARKS) program continues to support 11 projects initially funded in 2021, with the aim of developing new hydrokinetic turbine designs that reduce levelized cost of energy.

## TECHNOLOGY DEMONSTRATION

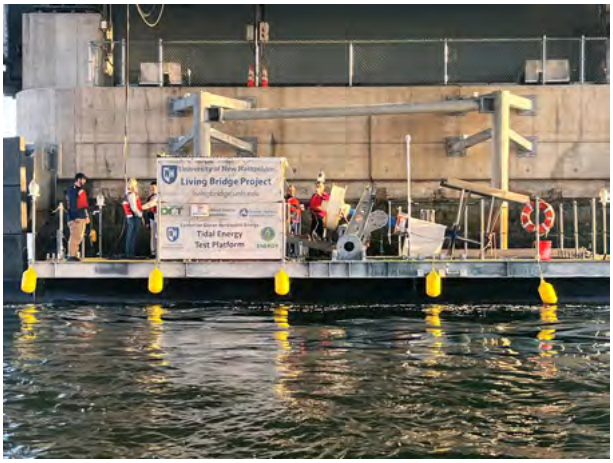
### Existing Open Water Test Sites

Existing open water test sites in the United States are spread geographically across the country's coasts and rivers. In Hawaii, the Wave Energy Test Site (WETS) offers an operational setting for testing pre-commercial WEC devices. WETS is a cooperative effort between DOE and the U.S. Navy with the support from Hawaii Natural Energy Institute and the Hawaii National Marine Renewable Energy Center. In Alaska, the Tanana River Test Site is a road accessible, fully permitted facility consisting of a mid-channel platform that can deploy devices and instruments. This site is run by the University of Alaska Fairbanks and is offered as an open water test site through the TEAMER program.



In summer 2023, divers prepared conduits for subsea cable installation planned for 2024 at the PacWave test facility off the coast of Oregon. Source: Oregon State University.

In Oregon, construction continued in 2023 on the PacWave South test site, a grid-connected and pre-permitted wave energy testing facility scheduled to be ready for testing selected projects in 2025. The Cabled Research Array for the Blue Economy and Energy (CRABEE) at the Pacific Northwest National Lab (PNNL) Sequim campus in Washington was also under construction on the West Coast in 2023. PNNL plans to deploy the cable and node in 2024, which will allow simultaneous testing of technologies such as tidal turbines, ocean observing instruments, autonomous vehicle chargers, and more, and can send power and data back to shore through a single connection. PNNL also has two pre-permitted marine test sites at Sequim Bay and Clallam Bay off the coast of Washington in the Strait of Juan de Fuca, between Cananda and the United States. These sites are also permitted for scientific research equipment, autonomous underwater vehicles, electromagnetic field studies, and acoustic devices.




The University of New Hampshire's tidal energy test platform is located under a bridge on the Piscataqua River and serves as a marine turbine test bed. Source: Sarah Loftus.

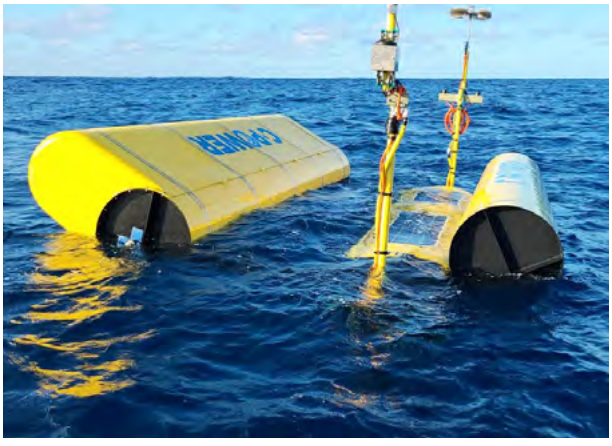
On the East Coast, the Coastal Studies Institute's Jennette's Pier in North Carolina offers a scaled test site for wave energy prototype testing. Farther north, the Marine Renewable Energy Collaborative operates the Bourne Tidal Test Site, a tidal energy testing platform in the Cape Cod Canal of Massachusetts. In New Hampshire, the University of New Hampshire, which leads the Atlantic Marine Energy Center, offers a tidal energy testing platform installed under a bridge on the Piscataqua River, where small prototype turbines can be installed.


Oscilla's Triton-C wave energy device is towed to the grid connection point at the Wave Energy Test Site in Hawaii. Source: Oscilla Power, Inc.

## Projects in the Water

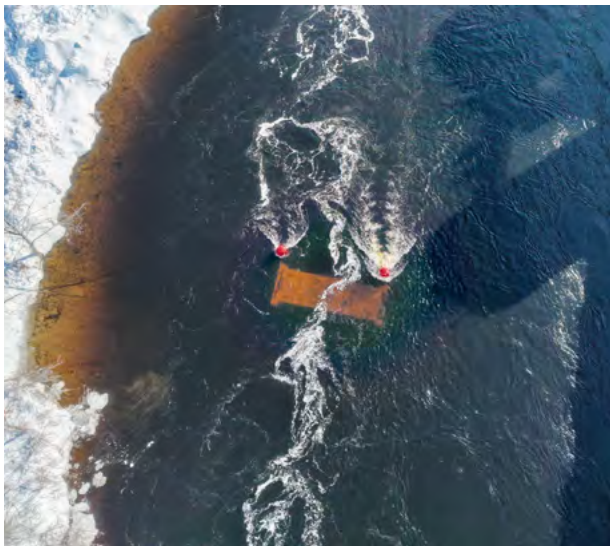
Wave energy developer Oscilla Power installed a 1/6-scale prototype of their 1 MW Triton WEC in the Castine Harbor of Maine in December 2023. In partnership with the University of Maine and Maine Maritime Academy, this deployment tested the WEC's submerging ability during extreme conditions and collected numerical model validations to advance the full-scale Triton design for future testing. In the Pacific, Oscilla also prepared to launch its Triton-C WEC by towing it from the harbor to the WETS grid connection point off the coast of Hawaii, where Oscilla is conducting in-water tests prior to demonstration. The Triton-C is a 100 kW community-scale device whereas the Triton WEC is Oscilla's utility-scale 1 MW device.

Also at WETS, in May 2023 C-Power completed an in-harbor test of their SeaRAY autonomous offshore power system (AOPS), which creates an autonomous, self-contained power and data mini-grid for applications such as environmental monitoring, intrusion detection, and oceanographic research. The SeaRAY AOPS was deployed in October 2023 for Phase 1 of the demonstration with Phase 2 scheduled for 2024.



C-Power's SeaRAY wave energy device deployed at the Wave Energy Test Site. Source: C-Power.

In January 2023 the developer Ocean Renewable Power Company (ORPC) deployed a Modular RivGen hydrokinetic device on the bottom of the Millinocket Stream for testing at an existing hydroelectric facility in Maine. A second Modular RivGen was deployed alongside the first device in May for array testing. ORPC received technical support from national laboratories to conduct hydrokinetic resource assessment for the stream and to perform computational fluid dynamics analyses, which helped the developer understand how the system would perform. Also in 2023, ORPC tested a single turbine version of its tidal energy converter, TidGen, in Maine's Cobscook Bay. The TidGen is similar to the RivGen device but, designed for tidal resources, is anchored differently and can be adjusted to a specific depth.



Ocean Renewable Power Company deployed the first of two modular RivGen devices on the bottom of the Millinocket Stream in January 2023. Source: DOE WPTO.

Farther south on the East Coast, Triton Systems deployed its WEC prototype, designed to power oceanographic and meteorological buoys, off the coast of Cape Cod, Massachusetts in August. The prototype continued operating even through unexpected eight-foot waves during a hurricane and was successfully retrieved. Also in Cape Cod, the developer Littoral Power tested a tidal energy device at the Bourne Tidal Test Site in April.

The University of Washington, which leads the Pacific Marine Energy Center, deployed their Turbine Lander system in October 2023 at the PNNL Sequim Bay testing site in Washington. The system includes a four-blade cross-flow turbine and is equipped with environmental monitoring instruments to assess marine animal collision risk and radiated noise.

Additionally, the developer BladeRunner Energy demonstrated their hydrokinetic device at the Tanana River Test Site in Alaska. The device consists of a turbine tethered to a floating platform with a generator and battery.

## Projects Planned for Deployment

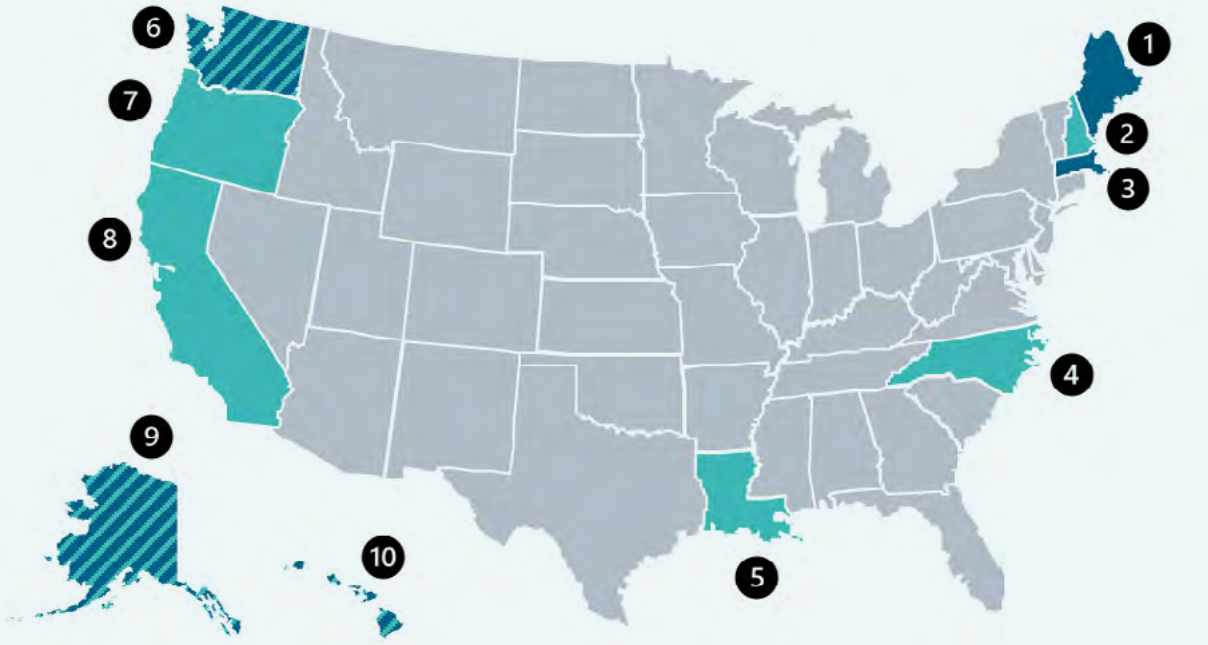
The University of New Hampshire and multiple national laboratories have been collaborating to design and fabricate a highly instrumented axial-flow marine turbine and plan to start short-term deployments in summer 2024 at the New Hampshire test site. This system will serve as a marine turbine test bed and will enable high resolution data collection for model verification and validation that will be made publicly available, along with the turbine design data, to further advance tidal energy development.

ORPC plans to deploy its full TidGen system in 2024/2025. This developer is also contracted to demonstrate two Modular RivGen devices in the Lower Mississippi River at a Shell Technology facility. The University of Washington in collaboration with PNNL plans to deploy its Turbine Lander again in the fall of 2024 in Sequim Bay.

Developers C-Power, CalWave, Oscilla, and Dehlsen Associates were selected by WPTO in 2022 for designing and testing the initial WEC devices to be deployed at PacWave, and they continue to optimize and prepare for future deployment. In Hawaii, Ocean Energy's OE35 buoy has completed repairs and is planning to deploy at WETS in 2024, in addition to C-Power and Oscilla.

In California, Eco Wave Power plans to deploy its wave energy technology at the campus of AltaSea at the Port of Los Angeles. Oneka Technologies, winner of the 2022 Waves to Water Prize, has partnered with the City of Fort Bragg, California to demonstrate its wave-powered desalination buoy off its coast. The device pressurizes water to send it through a reverse osmosis system, rather than converting wave energy to electricity.

## Recent Open Water Tests and Planned Deployments




**Key**
Open water test completed in 2023
Planned open water test

**1. Maine:** In 2023, ORPC deployed a river current device in the Millinocket Stream and a tidal energy device in Cobscook Bay, and Oscilla Power deployed a wave energy converter in the Castine Harbor.

**2. New Hampshire:** The University of New Hampshire will test a tidal turbine in summer 2024 in Portsmouth.

**3. Massachusetts:** Triton Systems deployed a wave energy converter and Littoral Power Systems deployed a tidal energy device, both off the coast of Cape Cod.

**4. North Carolina:** The National Renewable Energy Laboratory will redeploy its wave energy converter in Nags Head.

**5. Louisiana:** ORPC plans to demonstrate two Modular RivGen devices in the Lower Mississippi River at a Shell Technology facility.

**6. Washington:** The Pacific Marine Energy Center's tidal turbine lander was deployed at PNNL in Sequim and will re-deploy at the same site in 2024.

**7. Oregon:** C-Power, CalWave, Oscilla, and Dehlsen Associates will test their wave energy converters at PacWave South.

**8. California:** Eco Wave Power plans to install its wave energy system in Los Angeles. Oneka plans to install a wave-powered desalination plant in Fort Bragg.

**9. Alaska:** BladeRunner Energy demonstrated their hydrokinetic device at the Tanana River Test Site. ORPC river current systems were still in the water in Igiugig Village.

**10. Hawaii:** C-Power tested at the Navy's Wave Energy Test Site and plans to redeploy in 2024. Oscilla and Ocean Energy plan to test their wave energy systems at the same site in 2024.

## SPECIFIC INITIATIVES FOR INTERNATIONAL COOPERATION

International entities are often eligible to participate in U.S. opportunities. For example, non-U.S. institutions are eligible to participate in the Marine Energy Collegiate Competition (though must partner with a U.S. institution to be eligible for cash prizes) and non-U.S. developers can apply to TEAMER. 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 Community member portal, which can facilitate communication, collaboration, and coordination among those in the marine energy sector.

The International Electrotechnical Commission's Technical Committee (TC) 114 focuses on developing international standards for marine energy. U.S. DOE national laboratories continue to support and manage the U.S. Technical Advisory Group for IEC TC 114 and participate in the IECRE (IEC Renewable Energy Conformity Assessment System) with subject matter experts for testing and certification.

The Pacific Northwest National Laboratory is leading the OES-Environmental 2024 State of the Science report expected to publish in September 2024. This effort involves input and collaboration from OES-Environmental participating countries and will highlight the latest information regarding potential environmental effects of marine energy development around the world.

In 2023 OES published a second edition of the International Evaluation and Guidance Framework for Ocean Energy Technology, as well as Ocean Energy and Net Zero: an International Roadmap to Develop 300GW of Ocean Energy by 2050, both produced out of a collaboration between the European Commission, Wave Energy Scotland, WPTO, Edinburgh University, Tecnalia and other members of the OES Executive Committee. These frameworks provide funders and decision-makers with consistent information and policy guidance.

## RELEVANT NATIONAL EVENTS

Marine energy events in the United States in 2023:

- **May 8-10, 2023:** Water Power Week 2023 and WPTO's 2023 Marine Energy Collegiate Competition (MECC) Grand Finale; Washington, District of Columbia
- **June 21 – 23, 2023:** Ocean Renewable Energy Conference; Portland, Oregon
- **October 3-6, 2023:** University Marine Energy Research Community (UMERC) Summit and 2024 MECC Kick-off; Durham, New Hampshire

Events planned 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

Photo courtesy of LHD New Energy Corporation

# 05.
# APPENDICES

APPENDIX 1

# MEMBERSHIP OF THE EXECUTIVE COMMITTEE

## CABINET 2023

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**<br>University of Tasmania | **Professor Christophe Gaudin**<br>The University of Western Australia |
| **Belgium** | **Dr. Vicky Stratigaki**<br>Ghent University | **Mr. Jan Hensmans**<br>Federal Public Service Economy |
| **Canada** | **Dr. Jinxing Huang**<br>Natural Resources Canada | **Mrs. Elisa Obermann**<br>Marine Renewables Canada |
| **China** | **Mr. Peng Wei**<br>National Ocean Technology Center, SOA | **Mr. Wang Ji**<br>National Ocean Technology Center |

| | | |
|---|---|---|
| **Denmark** | **Mrs. Laerke Scov Hansen**<br>Danish Energy Agency | **Dr. Kim Nielsen**<br>Ramboll |
| **European Commission** | **Dr. Ir. Matthijs SOEDE**<br>EC DG Research & Innovation | **Ms Evdokia Tapoglou**<br>Joint Research Center |
| **France** | **Dr. Jean-François Filipot**<br>France Energies Marines | **Mr. Nicolas Ruiz**<br>France Energies Marines |
| **India** | **Dr. G A Ramadass**<br>National Institute of Ocean Technology | **Dr. Purnima Jalihal**<br>National Institute of Ocean Technology |
| **Ireland** | **Ms. Kerrie Sheehan**<br>Sustainable Energy Authority of Ireland | **Dr. Emer Dennehy**<br>Sustainable Energy Authority of Ireland |
| **Italy** | **Mr. Luca Benedetti**<br>Gestore dei Servizi Energetici (GSE) | |
| **Japan** | **Dr. Yasuyuki Ikegami**<br>Institute of Ocean Energy, Saga University | **Dr. Shuichi Nagata**<br>Institute of Ocean Energy, Saga University |
| **Korea** | **Ms. Jae-ok Roh**<br>Ministry of Oceans and Fisheries | **Dr. Jin-Hak Yi**<br>Korea Institute of Ocean Science & Technology |
| **Monaco** | **HE Bernard Fautrier**<br>Government of the Principality of Monaco | **Mr. Jérémie Carles**<br>Fondation Prince Albert II de Monaco |
| **Netherlands** | | **Mr. Sjoerd van Dijk**<br>Netherlands Entreprise Agency |
| **New Zealand** | **Mr. Martin Knoche**<br>AWATEA | **Mr. Vladislav Sorokin**<br>AWATEA |
| **Portugal** | **Prof. Luis Gato**<br>Instituto Superior Técnico (IST) | **Prof. António Falcão**<br>Instituto Superior Técnico (IST) |
| **Singapore** | **Prof. Subodh Mhaisalkar**<br>Energy Research Institute | **Dr Srikanth Narasimalu**<br>Energy Research Institute |
| **Spain** | **Mr. Yago Torre-Enciso**<br>BIMEP - Biscay Marine Energy Platform | **Ms. Dorleta Marina**<br>Simply Blue Energy Ltd |
| **Sweden** | **Mr Tobias Walla**<br>Swedish Energy Agency | **Mr. Lars Karlbom**<br>Swedish Energy Agency |
| **UK** | **Mr. Tim Warham**<br>Department for Business, Energy and Industrial Strategy (BEIS) | **Mr. Henry Jeffrey**<br>The University of Edinburgh |
| **USA** | **Mr. Tim Ramsey**<br>U.S. Department of Energy | **Ms Judith Elaine Buck**<br>US Department of Energy |

## 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 |

## 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**